2013 FRONTIERS IN EDUCATION CONFERENCE

OCTOBER 23 - 26, 2013 | OKLAHOMA CITY, OKLAHOMA, USA

Frontiers In Education FIE

ENERGIZING OUR FUTURE

PROCEEDINGS

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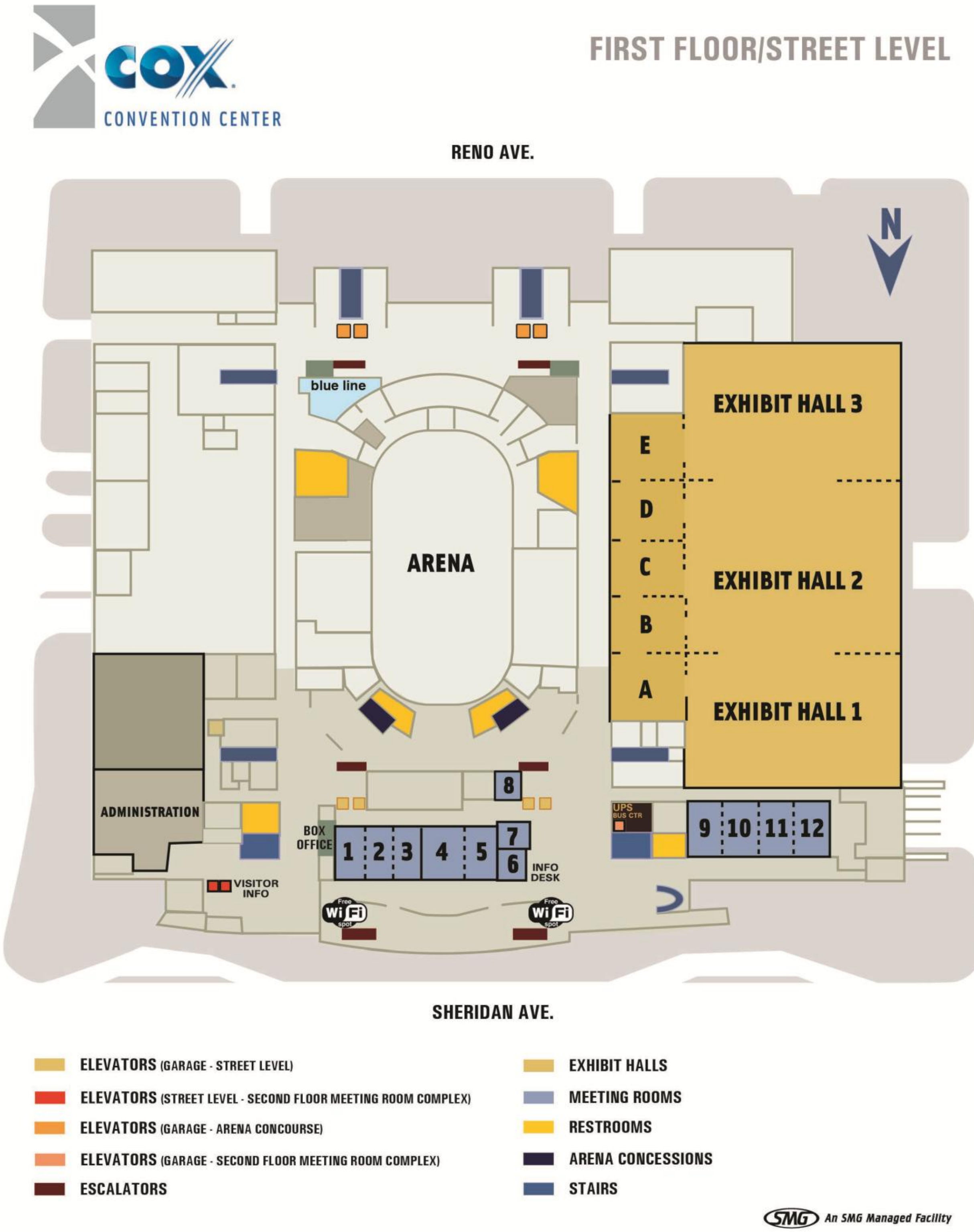

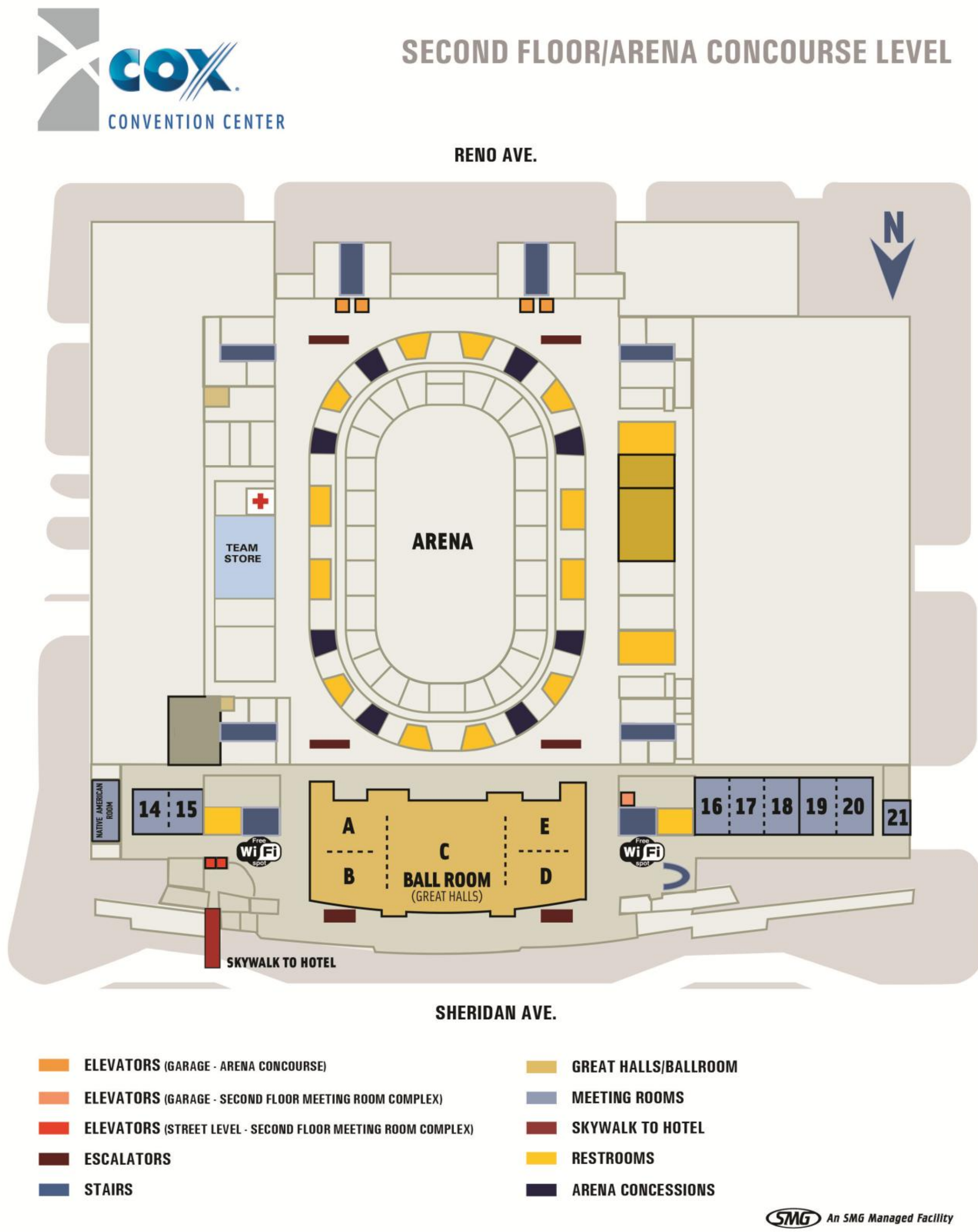
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CONFERENCE AT A GLANCE

Wednesday, October 23

11:00 am – 6:00 pm	Registration Second Floor Prefunction Area
1:30 pm – 6:00 pm	Exhibit Setup Great Hall D & E
1:30 pm – 4:30 pm	Pre-conference Workshops Session A
5:30 pm – 8:30 pm	Pre-conference Workshops Session B

Thursday, October 24

7:00 am – 5:00 pm	Registration Second Floor Prefunction Area
7:00 am – 8:00 am	Focus on First-Time Attendees Breakfast Buffet Great Hall C
8:00 am – 9:30 am	Plenary Session Katherine Banks, Vice Chancellor and Dean of Engineering, Texas A&M University Great Hall A & B
9:30 am – 5:00 pm	Exhibit Hall Open Great Hall D & E
9:30 am – 10:00 am	Exhibit Hall Break
10:00 am – 11:30 am	Technical Sessions (T1)
11:45 am – 1:15 pm	HP Terman and Rigas Awards Lunch Sponsored by the Hewlett-Packard Company Great Hall C
1:30 pm – 3:00 pm	Technical Sessions (T2)
3:00 pm – 4:00 pm	Exhibit Hall Break and
4:00 pm – 5:30 pm	Technical Session (T3)
6:00 pm – 9:30 pm	Transportation to and Reception at National Cowboy & Western Heritage Museum Bus loading zone: between the Renaissance hotel and the Cox Convention Center

Friday, October 25

7:00 am – 5:00 pm	Registration Open Second Floor Prefunction Area
7:00 am – 8:30 am	Breakfast & Plenary Session Mike McCracken, Director of Online Course Development and Innovation, College of Computing, Center for 21st Century Universities (C21U), Georgia Tech Great Hall C
8:30 am – 10:00 am	Technical Sessions (F1)
9:00 am – 4:30 pm	Exhibit Hall Open Great Hall D & E
10:00 am – 10:30 am	Exhibit Hall Break
10:30 am – Noon	Technical Sessions (F2)
Noon – 1:30 pm	Luncheon Great Hall C
1:30 pm – 3:00 pm	Technical Sessions (F3)
3:00 pm – 4:00 pm	Focus on Exhibits and New Faculty Fellows Great Hall D & E
4:00 pm – 5:30 pm	Technical Sessions (F4)
6:30 pm – 9:00 pm	Reception and Awards Banquet - Ticketed Event Great Hall C

Saturday, October 26

7:00 am – 2:00 pm	Registration Second Floor Prefunction Area
7:00 am – 8:00 am	Breakfast
8:00 am – 9:30 am	Technical Sessions (S1)
9:30 am – 10:00 am	Break - Second Floor Prefunction Area
10:00 am – 11:30 am	Technical Sessions (S2)
11:30 am – 1:00 pm	Lunch Great Hall C
1:00 pm – 2:30 pm	Technical Sessions (S3)
2:30 pm – 3:00 pm	Break - Second Floor Prefunction Area
3:00 pm – 4:30 pm	Technical Sessions (S4)

WELCOME FROM THE GENERAL CO-CHAIRS

Welcome to FIE 2013!

Oklahoma has long been known as an energy producing state, so we thought it appropriate to have "Energizing the Future" of engineering and computer science education as this year's theme. The name of our state, Oklahoma, is a Choctaw word that means "land of the red people". Oklahoma is home to 38 federally recognized Indian tribes and our history is enmeshed with stories of American Indian relocation and settlement, the Oklahoma land run, and the civil rights movement. So it is fitting that FIE highlight diversity and inclusion for our future. The conference also focuses on programs that bridge disciplines, such as the successful collaborations between engineering, computing and meteorology that can be seen during the evening tour of the National Weather Center, located in Norman Oklahoma. The traditional FIE topical themes of educational innovations and research in engineering and computing education are still front and center. We hope you find many opportunities to interact with your fellow conference attendees, including taking advantage of the "catalyzing conversations" sessions.

We look forward to meeting you Thursday evening at the welcoming reception, which is being held at a unique venue, the National Cowboy and Western Heritage Museum. There are many local attractions for you to enjoy during your stay, including the Oklahoma City National Memorial and Museum which memorializes the 1995 terrorist bombing of Alfred P. Murrah Federal Building; the Oklahoma City Museum of Art which is home to one of the largest collections of glass sculpture by noted artist Dale Chihuly; the Myriad Botanical Gardens featuring 17 acres of walking paths, splash fountains, and gardens, that feature plants from climates ranging from rain forests to desserts; and the Boathouse District which hosts a U.S. Olympic and Paralympic training site for rowing and canoe/kayaking and river sport adventures. All of these venues are within easy walking distance of the hotel. The Bricktown district is adjacent to the conference venue and offers a variety of restaurants and night clubs for your dining and entertainment pursuits.

The University of Oklahoma (OU) College of Engineering is pleased to host FIE 2013. We are grateful for the support of the OU administration as we prepared for the conference. We further express our sincere appreciation to our conference sponsors and exhibitors for their financial support.

We are very pleased you have joined us in Oklahoma City and wish you a hearty welcome!

Randa Shehab
Jim Sluss
Deborah Trytten

WELCOME FROM THE PROGRAM CO-CHAIRS

We are so glad you have joined us at FIE 2013! We hope that you will find your experience here enjoyable and valuable as you participate in the broad range of paper, panel, and special sessions, workshops, and social activities that have been scheduled.

This year's conference theme is *Energizing the Future*, and that is just what we hope happens for those who have chosen to join us. If you are new to the conference, you will find sessions on a wide variety of topics related to engineering and computing education. If you have been to FIE before, you will discover new opportunities, catalyzing conversations, as well as some of the tried and true favorites in the special sessions and traditional sessions. The technical program is complemented by the Conference's networking opportunities during breakfast and lunch with a big cowboy welcome at the reception – one you won't want to miss!

Our authors deserve the credit for the continuing quality of this conference – their innovative and compelling work and their promising works-in-progress seeking your input are once again outstanding. The reviewers who volunteered their time to provide quality, constructive feedback gain our thanks.

So, may your future be energized as you enjoy your time in Oklahoma City at FIE 2013!

IEEE/Computer Society Program Co-Chair
Mats Daniels
Uppsala University

ASEE/ERM Program Co-Chair
Teri Reed
Texas A&M University

IEEE/Education Society Program Co-Chair
Lynne Slivovsky
Cal Poly - San Luis Obispo

Workshops, Special Sessions & Panels Chair
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University of Oklahoma

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International Co-Chair, Asia
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Universidad Politecnica de Madrid

International Co-Chair, South America
Melany M. Ciampi
COPEC – Science and Education Research Council

MESSAGE FROM THE FIE STEERING COMMITTEE

Welcome to Oklahoma City and the 43rd annual Frontiers in Education Conference. FIE has an outstanding global reputation as a premier conference on engineering education. It is known for its collaborative author network and papers from its proceedings record are regularly cited in bibliographies.

This year the conference continues its long tradition of offering an outstanding technical program. I am confident you will find many sessions where speakers will challenge you to think differently about education and how we facilitate learning in our classrooms. The General Chair, Technical Program Chairs, paper reviewers, and session chairs all play important roles in guaranteeing that the technical program remains current and is of high quality. Please take a moment to thank these people for their professionalism and volunteer service to engineering education when you meet them during the conference.

This year, I want to focus my welcome message on the process of organizing a conference. FIE is a mid-sized conference event led by a nine member Steering Committee of appointed representatives from the three sponsoring professional societies. This Steering Committee sets mission and vision for the conference including desired size, technical program specifications, and registration fee structure. The Steering Committee regularly reviews the structure of FIE as it considers growth potential. ***Have you ever thought of hosting FIE*** in your city and wondered what the conference requires for facilities? Currently, the conference is designed to:

- use four conference days typically beginning on a Wednesday in October or November,
- host approximately 600 registered attendees,
- support a technical program of 400 paper and special session presentations,
- provide breakfast and lunch to its participants to foster collegiality and networking,
- provide a welcome reception and formal awards banquet,
- be in a conference hotel that can provide at least 300 rooms per night for FIE guests, and
- be in a conference hotel that has at least nine presentation rooms, two ballrooms, and exhibit hall space.

And, ***have you ever thought of hosting FIE*** in your city and wondered what the workload and leadership requirements are? Currently, the conference uses a structure that includes:

- one or two local General Chairs that are responsible for leading the planning team,
- three Technical Program Co-Chairs responsible for papers sessions,
- a Special Sessions Chair responsible for workshops, panels, and special sessions,
- a number of International Co-Chairs responsible for participation in FIE from other countries,
- an Awards Chair responsible for the conference awards program,
- a paid publications service provider contracted through a request-for-proposals (RFP) bid process,
- a paid logistics service provider contracted through an RFP bid process, and
- hundreds of volunteer peer reviewers and session chairs.

As General Chair, the responsibility of managing this planning team requires significant time. Much of the day-to-day work falls to other people on the planning committee, but the big decisions are ultimately the responsibility of the General Chair working in collaboration with the Steering Committee. Bids to host FIE begin by contacting the Steering Committee Chair four years before the conference date. After informal conversation with the Steering Committee Chair, a General Chair prepares a formal bid package that outlines the transportation, hotel, and tourism opportunities of their location. The Steering Committee expects that a proposed General Chair will attend every FIE conference before and through their own event if the bid package is selected. The workload for General Chairs is lighter during the first two years but ramps up significantly in the final year before the conference because of multiple logistical decisions and technical program deadlines.

The Steering Committee encourages you to think about hosting FIE.

The Steering Committee has set a goal to have FIE locations for the rest of this decade decided by June 2014. We are half way to meeting that goal! Now is the time to seriously consider volunteering as an FIE General Chair and work with us to host FIE in your city. Here is the current schedule showing set locations in **bold** as well as open years and suggested locations through the rest of the decade:

- **FIE 2014 : Madrid, Spain**
- **FIE 2015 : El Paso, Texas**
- **FIE 2016 : Erie, Pennsylvania**
- FIE 2017 : open (southeast U.S.)
- FIE 2018 : open (midwest U.S.)
- FIE 2019 : open (west coast U.S.)
- FIE 2020 : open (northeast U.S.)

Please note that the regional suggestions are just suggestions. The committee ***always*** entertains bids from prospective host sites in any location regardless of the proposed year. It should be noted, however, that current FIE policy requires FIE to be in the continental U.S. or Canada for at least five years before returning to any other international venue. If you are interested in hosting FIE as a General Chair, be sure to contact me soon so that we can have a frank conversation about requirements and the bid process.

The Steering Committee works for the Societies and the member communities. We encourage you to contact any one of us to discuss the FIE conference. We can be identified by Steering Committee ribbons on our conference badges.

ASEE Educational Research and Methods Division Representatives

- Beth Eschenbach, Humboldt State University, Elizabeth.Eschenbach@humboldt.edu
- Archie Holmes, University of Virginia, ah7sj@virginia.edu
- James Morgan, Texas A&M University, jmorgan@civil.tamu.edu

IEEE Computer Society Representatives

- Stephen Frezza, Gannon University, FREZZA001@gannon.edu
- Arnold Pears, Uppsala University, Arnold.Pears@it.uu.se
- Currently vacant pending appointment by the Computer Society

IEEE Education Society Representatives

- Russ Meier (Chair), Milwaukee School of Engineering, meier@msoe.edu
- James Sluss, University of Oklahoma, sluss@ou.edu
- Edmundo Tovar, Universidad Politecnica de Madrid, etovar@fi.upm.es

I hope you enjoy your conference and I look forward to meeting and talking with you in Oklahoma City!

Sincerely,

Russ Meier
Steering Committee Chair
Milwaukee School of Engineering
Milwaukee, WI, USA
meier@msoe.edu

FIE 2013 PLANNING COMMITTEE

General Co-Chair
James Sluss
University of Oklahoma

General Co-Chair
Randa Shehab
University of Oklahoma

General Co-Chair
Deborah Trytten
University of Oklahoma

Assistant to the General Chairs
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Edmundo Tovar Caro
Universidad Politecnica de Madrid

International Co-Chair, South America
Melany M. Ciampi
VP COPEC- Science and Education Research Council

Conference Historian
Ed Jones
Iowa State University

Awards Chair
Manuel Castro
Spanish National Distance University

FIE STEERING COMMITTEE

ASEE Educational Research and Methods Division Representatives
- Jim Morgan, Texas A&M University
(June 2011-June 2014)
- Archie Holmes, University of Virginia
(June 2012 - June 2015)
- Elizabeth A. Eschenbach, Humboldt State University
(June 2013 - June 2016)

IEEE Computer Society
- Stephen Frezza, Gannon University
(June 2011 - June 2014)
- Arnold Pears, Uppsala University
(June 2009 - June 2015)

IEEE Education Society
- Russ Meier, Milwaukee School of Engineering
IEEE Education Society VP Conferences, Steering Committee Chair
- Edmundo Tovar Caro, Universidad Politecnica de Madrid
(June 2008 - June 2014)
- James Sluss, University of Oklahoma
(June 2012 - June 2015)

FUTURE FIE CONFERENCES

FIE 2014 Madrid, Spain
FIE 2015 El Paso, Texas
FIE 2016 Eire, Pennsylvania

Are you interested in hosting a future FIE conference? Leave your business card at the registration desk, and an FIE steering committee member will contact you.

CONFERENCE SPONSORS

FIE 2013 is sponsored by:

American Society for Engineering Education (ASEE)
Educational Research Methods (ERM) Division

Institute of Electrical and Electronics Engineers (IEEE)
IEEE Computer Society
IEEE Education Society

FIE 2013 is hosted by:

The University of Oklahoma

The University of Oklahoma (OU) is a coeducational public research university located in Norman, Oklahoma. The university was founded in 1890 and existed for 17 years before Oklahoma became a state. OU enrolls more than 30,000 students, has more than 2,600 full-time faculty members, and has 21 colleges offering 163 majors at the baccalaureate level, 157 majors at the master's level, 81 majors at the doctoral level, 28 majors at the doctoral professional level, and 28 graduate certificates.

The school is ranked first per capita among public universities in enrollment of National Merit Scholars and among the top ten in the graduation of Rhodes Scholars. PC Magazine and the Princeton Review rated it one of the "20 Most Wired Colleges" in 2008.

The OU College of Engineering was formed in 1909 and recorded its first graduates in the spring of 1910. It is now the largest engineering program in Oklahoma, with 1,800 undergraduate students, 450 graduate students and a 115-member faculty.

OU is also well known for its athletic programs, winning seven NCAA Division I National Football Championships, playing in four BCS national championship games since the inception of the BCS system in 1998. Its baseball team has won 2 NCAA national championships, and the women's softball team won the national championship in 2000.

CORPORATE AFFILIATES AND SPONSORSHIPS

Corporate affiliates play an important role in supporting FIE conferences. This support subsidizes the cost of the award presentations and of meal functions. We appreciate these supporters and the part they play in making the 2013 FIE conference an outstanding event.

Thursday Activities

Hewlett-Packard — Frederick Emmons Terman and Harriet B. Rigas Award Luncheon

Friday Activities

NextThought — Morning Break in the Exhibit Hall

FIE 2013 EXHIBITORS

The FIE vendor and association exhibits are a popular and rewarding tradition for both attendees and exhibitors. Exhibits will include materials, equipment, textbooks, software, and state-of-the-art tools applicable to engineering education. We thank the vendors for their financial support and contributions to making FIE 2013 a meaningful experience.

Exhibit Hall Hours
The exhibits will be open in the Great Hall D&E from 9:00 a.m. to 5:00 p.m. Thursday and from 9:00 a.m. to 4:30 p.m. Friday. As of September 5, the following companies had committed to exhibiting at FIE 2013:

EXHIBITOR	WEBSITE
Digilent	www.digilentinc.com
EMA Design Automation	www.ema-eda.com
Emona Instruments	http://www.qpsk.com/
JMP statistical discovery software from SAS	http://www.jmp.com/
Purdue Engineering Education	engineering.purdue.edu/ENE
Stratasys	www.stratasys.com
Texas Instruments	http://education.ti.com/en/us/home
Utah State University Department of Engineering Education	www.eed.usu.edu/
Virginia Tech Engineering Education	http://www.enge.vt.edu/
Zyante	www.zyante.com

Focus on Exhibits and New Faculty Fellows Poster Presentation
Attendees and participants will be encouraged to visit the exhibit area throughout the conference. In order to provide full exposure for the exhibits, a special "Focus on Exhibits" session is planned for the afternoon of Friday, October 25th, during which time there will be no technical sessions scheduled. The New Faculty Fellows will also display their posters at this time. Door prizes contributed by some of the exhibitors will be awarded during the Focus on Exhibits. You must be present to win.

EXHIBITOR SHOWCASE PRESENTATIONS

Thursday, October 24

10:00 am – 11:30 am	**Texas Instruments**	**Meeting Room 3**

Thursday, October 24

1:30 pm – 3 pm	**Zyante**	**Meeting Room 3**

Topic: Animated Interactive Learning of Programming Languages
Speakers: Smita Bakshi and Frank Vahid
Description: Zyante develops web-based animated interactive learning material for lower division computer science and engineering. These offerings enable students to "learn by doing" as they engage with animations, interactive tools, embedded coding environments, games and self-assessment questions. Available for $35, students can also download them for later use. 4000+ students at over 40 universities are using Zyante's current offerings: C, C++, Java, Python, MATLAB, Embedded Systems, Data Structures & Discrete Math.

Join the founders, Smita Bakshi and Frank Vahid, at the Showcase to learn more about the material and the teaching tools. We'll provide you with a hands-on opportunity to evaluate the material and teaching tools, including the ability to view student activity data, and to rearrange and customize the material.

Friday, October 25

10:30 am – Noon	**ABET**	**Meeting Room 3**

Topic: Future Directions for the Computing Accreditation Criteria – A Discussion with the Computing Community
Speaker: Mark Stockman, University of Cincinnati
Description: The computing disciplines continue to undergo rapid change, as evidenced in part by the current cycle of model curricula efforts in the various disciplines. Driven by the same challenges, the ABET Computing Accreditation Commission (CAC) in cooperation with the ACM and IEEE Computer Society are currently considering revisions to the ABET Computing Accreditation Criteria. For ABET to be responsive to its constituencies, criteria changes must be driven by the community. As a result, CAC, ACM and the IEEE-CS are engaged in a variety of activities designed to obtain input from the community at large so as to effect appropriate evolution within the criteria. In this session, we present an update regarding some of the proposed changes to the Computing Criteria and provide an opportunity for review, comment and general input by the session participants. The results of this session will be used as an important input to the criteria change process.

1:30 pm – 3:00 pm	**NextThought**	**Meeting Room 3**

Topic: NextThought: Frontiers in Online Social Education
Speaker: Ken Parker
Description: NextThought is creating the future of online education today. Their unique software melds social media with content and course management to create active learning experiences that engage students. This session will provide a product demonstration by a faculty member using NextThought in the classroom and give attendees an opportunity to interact with the next big thing in higher education.

PLENARY SESSIONS

Thursday, October 24, 8:00 – 9:30 am
Great Hall A & B

Speaker: Katherine Banks, Vice Chancellor and Dean of Engineering, Texas A&M University

Introduction by Kyle Harper, Senior Vice Provost and Director of the Institute for the American Constitutional Heritage, the University of Oklahoma

Dr. M. Katherine Banks is vice chancellor for engineering for The Texas A&M University System and dean of the Dwight Look College of Engineering at Texas A&M University.

As vice chancellor, Banks oversees coordination and collaboration among the engineering, academic and research programs at universities throughout the A&M System, as well as three state agencies: the Texas A&M Engineering Experiment Station (TEES), the Texas A&M Engineering Extension Service (TEEX) and the Texas A&M Transportation Institute (TTI). Banks also is TEES director, overseeing research administration of more than 4,400 projects and $142.5 million in sponsored research awards. As dean of the Look College and holder of the Harold J. Haynes Dean's Chair in Engineering, Banks leads one of the largest engineering schools in the country, with more than 11,000 students and nearly 400 faculty.

Banks was previously the Bowen Engineering Head for the School of Civil Engineering at Purdue University and the Jack and Kay Hockema Professor at Purdue. She received her B.S.E. from the University of Florida, M.S.E. from the University of North Carolina, and Ph.D. in civil and environmental engineering from Duke University. For her research, Banks has received funding from the National Science Foundation, the U.S. Environmental Protection Agency, the U.S. Department of Defense, the U.S. Department of Energy and NASA, as well as industry and state government. She served as director of the EPA Hazardous Substance Research Center, associate director of the NASA Center for Advanced Life Support, and co-director of the 21st Century Center for Phytoremediation Research, all headquartered at Purdue.

Banks is a Fellow of the American Society of Civil Engineers (ASCE) and is a licensed professional civil engineer in Indiana and Kansas. She has received numerous awards including the ASCE Petersen Outstanding Woman of the Year Award, ASCE Rudolph Hering Medal, Purdue Faculty Scholar Award, Sloan Foundation Mentoring Fellowship and the American Association of University Women Fellowship. She is the author or co-author of more than 150 journal articles, proceedings papers and book chapters. Banks has served as editor-in-chief for the *ASCE Journal of Environmental Engineering* and associate editor of the *International Journal of Phytoremediation*.

Friday, October 25, 7:30 – 8:30 am
Great Hall C, immediately following breakfast
Boogies, Boojums and Snarks: There are MOOC's Under Your Bed and in Your Closet.

Speaker: Mike McCracken, Director of Online Course Development and Innovation, College of Computing, Center for 21st Century Universities (C21U), Georgia Tech

W. Michael McCracken is a Principal Research Scientist in the College of Computing at Georgia Tech. He is the Director of Online Course Development and Innovation for the Center for 21st Century Universities at Georgia Tech. In his position at C21U he is responsible for the overall development of the portfolio of Massive Open OnLine Courses (MOOCs) for Georgia Tech. Last year, Georgia Tech fielded 16 MOOCs and will field a minimum of 10 new MOOCs, repeat 11 of them, and extend 3 of them to full semester offerings. He is also a participant in the development of the newly announced OnLine Masters in Computer Science being developed jointly with Udacity. McCracken also teaches and conducts research in computer science and software engineering. Additionally, McCracken is on the editorial board of the *Journal of Computer Science Education*.

FIE 2013 WORKSHOPS

Wednesday, 1:30 – 8:30 pm (Pre-Registration is required.)

On Wednesday afternoon and evening, FIE features workshops—highly interactive sessions selected for their timeliness and value. Workshops offer a concentrated professional development experience. The wide range of workshop topics offers opportunities for everyone from new faculty members to the most experienced educators to expand their skills and knowledge.

Conference attendees must register separately for workshops. There is a $50 registration fee for each workshop. Complete abstracts for the workshops can be found in the Wednesday schedule of the program book.

GROUP MEETINGS

Wednesday, October 23

5:00 – 6:30 pm	FIE Steering Committee Meeting	Meeting Room 14

Thursday, October 24

10 am – Noon	IEEE EDUCON Steering Committee	Meeting Room 1
4:00 – 5:30 pm	ASEE ERM Division Business Meeting	Meeting Room 1

Friday, October 25

10 am – Noon	IEEE Education Society Board of Governors meeting	Meeting Room 1
4:00 – 5:30 pm	ASEE ERM Division Business Meeting	Meeting Room 1

This is an open meeting for all members of the community to participate in the strategic planning for ERM. We will build on the conversation begun at the ASEE meeting in June. Input from that previous meeting will be used to craft a set of goals to guide ERM activities going forward.

Saturday, October 26

8:00 – 9:30 am	FIE Steering Committee Meeting Executive Session	Meeting Room 1
1:00 – 3:00 pm	FIE 2014 Planning Committee Meeting	Meeting Room 1

NEW FACULTY FELLOW PROGRAM

Each year, FIE invites new engineering and computer science faculty to submit applications for possible selection as New Faculty Fellows. A review panel of engineering and computer science faculty from assistant, associate, and full professorship levels completes a rigorous peer review of each applicant's conference paper, nomination letters and professional résumé. The fellowship provides a $1,000 grant for conference travel expenses.

The purpose of the program is to promote the involvement of new faculty in the Frontiers in Education Conference so they will be exposed to the "latest and greatest" in engineering educational practices and will have the opportunity to exchange information with leaders in education innovations. This year, FIE 2013 will provide registration and travel grants for the awardee to attend the conference.

Focus on New Faculty Fellows

Each fellow will present a conference paper during FIE 2013. Join them in their session and share your thoughts and ideas about the future of engineering education. Also, during the Focus on Exhibits session Friday at 3 p.m., the Fellows will display posters describing their interests and activities and previewing the full papers that they will present as part of the FIE 2013 technical sessions.

2013 New Faculty Fellow:

Joseph Ranalli
Pennsylvania State University - Hazleton
Session T3G
Assessing the Impact of Video Game Based Design Projects in a First Year Engineering Design Course
Joseph Ranalli (Pennsylvania State University - Hazleton Campus); Jacqueline Ritzko (Pennsylvania State University- Hazleton Campus)

CONFERENCE AMENITIES

Breakfast

7:00 a.m.–8:00 a.m. Thursday Great Hall C

7:00 a.m.–8:00 a.m. Friday Great Hall C

7:00 a.m.–8:00 a.m. Saturday Great Hall C

Refreshment Breaks ●

Morning and afternoon breaks Thursday and Friday Exhibit Hall – Great Hall D & E
Morning and afternoon breaks Saturday Second Floor Prefunction East

Lunches

Frederick Emmons Terman and Harriet B. Rigas Awards Luncheon – Great Hall C
Sponsored by the Hewlett-Packard Company
11:45a.m. –1:15 p.m. Thursday
The Frederick Emmons Terman Award is presented annually to an outstanding young electrical engineering educator by the Electrical and Computer Engineering Division of the American Society for Engineering Education. The Harriet B. Rigas Award is presented annually to an outstanding woman engineering educator in recognition of her contributions to the profession.

Luncheon – Great Hall C
Noon – 1:30 p.m. Friday

Luncheon – Great Hall C
11:30 a.m. –1:00 p.m. Saturday

Reception
6:00 p.m.–9:30 p.m. Thursday
Join your colleagues as we board busses and take the short ride to the National Cowboy and Western Heritage Museum for a reception. We will have drinks, a western-themed dinner, and plenty of time to explore the exhibits. Be sure to bring the drink tickets you received when you checked in at registration. Buses will begin boarding at 6:00 pm between the Renaissance Hotel and the Cox Convention Center on Sheridan Avenue.

New Faculty Fellows ● Exhibit Hall – Great Hall D & E
3:00 p.m.–4:00 p.m. Friday
A special session focusing on the New Faculty Fellows will be held on Friday. This session will provide an opportunity to meet this year's New Faculty Fellows, a group of new CSET educators who were selected based on an application and a full paper being presented at this year's conference. There will also be an opportunity to view their poster presentations at this time.

Focus on Exhibits ● Exhibit Hall – Great Hall D & E
3:00 p.m.–4:00 p.m. Friday
Visit the FIE exhibits and check out the latest textbooks, computer software, lab equipment, and other innovations while enjoying refreshments provided by our sponsor.

Awards Banquet ● Great Hall C
6:30 p.m.–9:00 p.m. Friday
This year's awards banquet features fine food, drink, and camaraderie along with presentation of special awards from FIE, the IEEE Education Society, and the IEEE Computer Society. There is a separate charge for the banquet.

The National Weather Center Tour
6:00 p.m.–9:30 p.m. Friday
Visit the National Weather Center and the Lawrence G. Rawl Engineering Practice Facility on the University of Oklahoma campus. The bus boards at 6:00 pm between the Renaissance Hotel and the Cox Convention Center on Sheridan Avenue. There is a separate charge for the tour.

FIE Registration Conference Desk ● Second Floor Prefunction East
Registration will be open during these times:

Wednesday	11:00 a.m. – 6:00 p.m.
Thursday	7:00 a.m. – 5:00 p.m.
Friday	7:00 a.m. – 5:00 p.m.
Saturday	7:00 a.m. – 2:00 p.m.

Hospitality Table ● Near Conference Registration
If you are looking for a certain kind of a restaurant, shop, golf course, or health club, stop by the hospitality table close to the registration area. Maps and brochures of area attractions will be available.

FIE Message Center ● Near Conference Registration
The conference will maintain a message board by the registration area. Messages received for conferees will be posted there. In an emergency, we will make every effort to locate you.

Catalyzing Collaborative Conversations
Conference Registration and rooms assigned Please stop by the registration desk to reserve a room for collaborative conversations with your colleagues. Pick a time, get a room, name a topic, and we will announce it by the Message Center and via Twitter #fie2013.

Social Media. Twitter hashtag #fie2013
Are you in the TwitterSphere? Tweet your comments on the conference, thoughts on the speakers, a shout-out for work that inspires you, time and topic for a Collaborative Conversation - use #fie2013 to share your insights with your colleagues and the conference committee.

2013 FIE CONFERENCE AWARDS PRESENTATIONS

Thursday, October 24 .... Terman/Rigas Awards Luncheon
Noon - 1:30 p.m.

ASEE ECE Division Hewlett-Packard Frederick Emmons Terman Award
IEEE Education Society Hewlett-Packard/Harriet B. Rigas Award

Friday, October 25 .... Awards Banquet
6:00 p.m. - 8:30 p.m.

Frontiers in Education (FIE) Conference Awards

FIE 2012 Benjamin J. Dasher Best Paper Award
FIE 2012 Helen Plants Award
FIE Ronald J. Schmitz Award

IEEE Education Society

William E. Sayle Award for Achievement in Education
IEEE Transactions on Education Best Paper Award
Chapter Achievement Award
Distinguished Chapter Leadership Award
Distinguished Member Award
Edwin C. Jones, Jr. Meritorious Service Award
Mac Van Valkenburg Early Career Teaching Award
Student Leadership Award

AWARD SELECTION COMMITTEE CHAIRS

Frontiers in Education Conference

Benjamin J. Dasher Best Paper Award ....Jenefer Husman
Helen Plants Award ....Cordelia Brown
Ronald J. Schmitz Award ....Arnold Pears

ASEE Electrical and Computer Engineering Division

Hewlett-Packard Frederick Emmons Terman Award ....

IEEE Education Society

IEEE William E. Sayle Award for Achievement in Education ...Lyle D. Feisel
IEEE Transactions on Education Best Paper Award ....Jeff Froyd
Chapter Achievement Award ....Trond Clausen
Distinguished Chapter Leadership Award ....Edmundo Tovar
Distinguished Member Award...Ted Batchman
Edwin C. Jones, Jr. Meritorious Service Award ....Edwin C Jones Jr
Hewlett-Packard/Harriet B. Rigas Award ....Joanne Bechta Dugan
Mac Van Valkenburg Early Career Teaching Award ....S. Hossein Mousavinezhad
Student Leadership Award...Emmanuel A. Gonzalez

Mung Chiang
Princeton University

ASEE ECE Division Hewlett-Packard Frederick Emmons Terman Award

For an outstanding young electrical engineering educator in recognition of his contribution to the profession

Mung Chiang is the Arthur LeGrand Doty Professor of Electrical Engineering at Princeton University, and an affiliated faculty in the Program in Applied and Computational Mathematics and in Computer Science. His research on networking received the Alan T. Waterman Award (2013), the IEEE Kiyo Tomiyasu Award (2012), a U.S. Presidential Early Career Award for Scientists and Engineers (2008), several young investigator awards from National Science Foundation, Office of Naval Research, and Princeton, and a few paper awards including the IEEE SECON (2013) and INFOCOM Best Paper Awards (2012). A Technology Review TR35 Award recipient (2007), his inventions have resulted in a few commercial adoptions, and he serves on several networking companies' advisory board. Supported in part by many industry research awards, he founded the Princeton EDGE Lab in 2009, which has led to multiple technology transfers as well as startup companies. He was elected an IEEE Fellow in 2012.

In 2011, Chiang created an undergraduate course: "Networks: Friends, Money, and Bytes," which lead to an open online offering with 90,000 students during 2012-2013. The corresponding textbook, "Networked Life: 20 Questions and Answers," adopted the "just-in-time" approach and received the PROSE Award in Engineering and Technology (2012) from the Association of American Publishers. The second textbook "Networks Illustrated: 8 Principles without Calculus" was at the top of bestsellers in Networking on Kindle upon its release, and became a series of "micro-ebooks." In 2013 they became the first Integrated and Individualized Book-App (IIB) that adapted to individual readers. He chaired the Princeton University Committee on Classroom Design, and founded the non-profit online education platform "3 Nights and Done" (3ND).

Chiang also initiated a Network Optimization workshop series and the Smart Data-Pricing (SDP) industry forums, and co-chaired the US NITRD Workshop on Complex Engineered Networks. He has served as an associate editor of a few IEEE journals, an IEEE Communications Society Distinguished Lecturer, and Chairman of the founding steering committee of the new IEEE Transactions on Network Science and Engineering.

Past Recipients

'69 Michael Athans
'70 Andrew P. Sage
'71 Joseph W. Goodman
'72 Taylor L. Booth
'73 Sanjit Mitra
'74 Leon Ong Chua
'75 Michael L. Dertouzos
'76 Stephen W. Director
'77 J. Leon Shohet
'78 Ronald A. Rohrer
'79 Martha E. Sloan
'80 V. Thomas Rhyne
'81 Ben Garland Streetman
'82 Toby Berger
'83 Daniel P. Siewiorek
'84 Mathukumalli Vidyasagar
'85 Peter S. Maybeck
'86 Lance A. Glasser
'87 Kenneth L. Short
'88 Adel S. Sedra
'89 Frank L. Lewis
'90 Jerry D. Gibson
'91 Barry W. Johnson
'92 H. Vincent Poor
'93 Mark S. Lundstrom
'94 Supriyo Datta
'95 Perinkolam P. Vaidyanathan
'96 Prithviraj Banerjee
'97 Edward A. Lee
'98 Edwin K. P. Chong
'99 Randy H. Katz
'00 Sergio Verdu
'01 Zoya Popovic
'02 Theodore S. Rappaport
'03 Wayne Wolf
'04 Keshab K. Parhi
'05 Ali H. Sayed
'06 Vijay K. Madisetti
'07 Russel Jacob (Jake) Baker
'08 Keith M. Chugg
'09 David Tse
'10 Bhaskar Krishnamachari
'11 Tony Givargis
'12 Ali Niknejad

ASEE ECE Division Hewlett-Packard Frederick Emmons Terman Award (continued)

About the Terman Award

The Frederick Emmons Terman Award is presented annually to an outstanding young electrical engineering educator by the Electrical and Computer Engineering Division of the American Society for Engineering Education. The Terman Award, established in 1969 by the Hewlett-Packard Company, consists of $5,000, an engraved gold-plated medal, a bronze replica of the medal mounted on a walnut plaque, and a parchment certificate.

The recipient must be an electrical engineering educator who is less than 45 years old on June 1 of the year in which the award is presented and must be the principal author of an electrical engineering textbook published before June 1 of the year of his/her 40th birthday. The book must have been judged by his/her peers to be an outstanding original contribution to the field of electrical engineering. The recipient must also have displayed outstanding achievements in teaching, research, guidance of students, and other related activities.

About Frederick Emmons Terman

Frederick Emmons Terman received his A.B. degree in chemistry in 1920, the degree of engineer in electrical engineering in 1922 from Stanford University, and his Sc.D. degree in electrical engineering in 1924 from Massachusetts Institute of Technology. From 1925-1965, he served as instructor, then professor of electrical engineering, executive head of the Electrical Engineering Department, dean of the School of Engineering, provost, vice president, and finally, as acting president of Stanford University.

Among the many honors bestowed upon him were: the IEEE Medal of Honor; the first IEEE Education Medal; the ASEE's Lamme Medal; the 1970 Herbert Hoover Medal for Distinguished Service to Stanford University; an honorary doctor's degree by Harvard; a decoration by the British government; the Presidential Medal for merit as a result of his war work; and the 1976 National Medal of Science from President Ford at a White House ceremony.

Dr. Terman was a professor at Stanford University when William Hewlett and Dave Packard were engineering students there. It was under Dr. Terman's guidance in graduate work on radio engineering that Mr. Hewlett built the first tunable and automatically stabilized Weinbridge oscillator. Partially through Dr. Terman's urging, Hewlett and Packard set up their partnership in an old garage with $538 and the oscillator as their principal assets.

Dr. Terman died in December 1982. It is in appreciation of his accomplishments and guidance that Hewlett-Packard is proud to sponsor the Frederick Emmons Terman Award.

Nancy Amato
Texas A&M University

Past Recipients

’95 Denice D. Denton
’96 Karan L. Watson
’97 Patricia D. Daniels
’98 Delores M. Etter
’99 Sherra E. Kerns
’00 Leah Jamieson
’01 Valerie Taylor
’02 Nan Marie Jokers
’03 Joanne Bechta Dugan
’04 Jennifer L. Welch
’06 Eve A. Riskin
’07 Bonnie Heck Ferri
’08 Cheryl B. Schrader
’09 Cynthia Furse
’10 Mari Ostendorf
’11 Karen Panetta
’12 Tanja Karp

IEEE Education Society Hewlett-Packard Harriet B. Rigas Award

For increasing the participation of underrepresented members in the computing research community by promoting research experiences for undergraduates

Nancy M. Amato is Unocal Professor and Interim Department Head of the Department of Computer Science and Engineering at Texas A&M University where she co-directs the Parasol Lab. She received undergraduate degrees in Mathematical Sciences and Economics from Stanford University in 1986, and M.S. and Ph.D. degrees in Computer Science from UC Berkeley and the University of Illinois at Urbana-Champaign in 1988 and 1995, respectively. She was an AT&T Bell Laboratories PhD Scholar, received a CAREER Award from the National Science Foundation, is a Distinguished Speaker for the ACM Distinguished Speakers Program, was a Distinguished Lecturer for the IEEE Robotics and Automation Society, and is an IEEE Fellow.

She has served as an Associate Editor for the IEEE Transactions on Robotics and Automation and of the IEEE Transactions on Parallel and Distributed Computing.
She was co-Chair of the National Center for Women in Information Technology (NCWIT) Academic Alliance (2009-2011), is a member of the Computing Research Association's Committees on the Status of Women in Computing Research (CRA-W) and Education (CRA-E), and of the ACM, IEEE, and CRA sponsored Coalition to Diversity Computing (CDC). She has directed or co-directed the CRA-W/CDC Distributed Research Experiences for Undergraduates (DREU, formally known as the DMP) for more than 10 years. DREU is a national program that matches undergraduate women and students from underrepresented groups, including ethnic minorities and persons with disabilities, with a faculty mentor for a summer research experience at the faculty member's home institution. She received a University-level teaching award from the Texas A&M Association of Former Students and the Betty M. Unterberger Award for Outstanding Service to Honors Education at Texas A&M.

Her main areas of research focus are motion planning and robotics, computational biology and geometry, and parallel and distributed computing. She has graduated 13 PhD students, with most of them going on to careers in academia (7) and government or industry research labs (4), 15 master's students, and has worked with more than 100 Texas A&M undergraduate researchers and non-Texas A&M student interns, with the majority being students from groups underrepresented in computing.

She currently supervises 13 PhD students, 4 masters students, and more than 10 undergraduate and high school researchers.

IEEE Education Society Hewlett-Packard Harriet B. Rigas Award (continued)

About the Rigas Award

The Harriet B. Rigas Award is presented annually to recognize outstanding faculty women who have made significant contributions to electrical/computer engineering education. The award consists of an honorarium, plaque, certificate, and Frontiers in Education Conference registration.

The recipient must be a tenured or tenure track woman faculty member in an ABET-accredited engineering program in the United States, with teaching and/or research specialization in electrical/computer engineering.

About Harriett B. Rigas

Dr. Harriett B. Rigas (1934-1989), an IEEE Fellow, was an electrical engineer with an international reputation for her hybrid computer and computer simulation research. At Washington State University between 1966 and 1984, she was eventually both full professor and chair of Electrical and Computing Engineering School. Later she chaired larger departments at the Navy's Postgraduate School in Monterey and, at the time of her death, Michigan State University.

Her achievements in engineering research, administration, and service were widely recognized. In 1975-76, Harriett was a Program Director at the National Science Foundation and, over the years, a member of numerous panels and advisory committees at both the NSF and the national Academy of Sciences.

Professor Rigas' success was achieved within a profession and within university administrative structures where there were very few women. Her character and courage were both evident in her strong advocacy of advancement for women. She was involved both locally and nationally in the Society of Women Engineers.


Robin Adams
Purdue University


Alice Pawley
Purdue University


Brent Jesiek
Purdue University

Past Recipients

’73 Walter D. Story
’74 Richard Hooper
’75 John J. Alan III and
J.J. Lagowski
’76 John Hipwell and
David Blaume
’77 John W. Renner
’78 Albert J. Morris

Frontiers in Education Conference Benjamin J. Dasher Best Paper Award

Applying Philosophical Inquiry: Bringing Future Engineering Education Researchers into the Philosophy of Engineering Education **by Robin Adams, Alice Pawley and Brent Jesiek**
FIE 2012, T2B

Robin S. Adams is an Associate Professor in the School of Engineering Education at Purdue University. She was also a Senior Design Engineer in the semiconductor packaging industry, an Assistant Director for Research at the Center for Engineering Learning and Teaching, and the lead for the Institute for Scholarship on Engineering Education with the Center for the Advancement of Engineering Education. She received her PhD in Education, Leadership and Policy Studies and her MS in Materials Science and Engineering from the University of Washington, and a BS in Mechanical Engineering from California Polytechnic State University, San Luis Obispo. Her research seeks to empirically develop “languages for learning” in areas central to the practice of engineering – cross-disciplinarity and design – and to the practice of engineering education. A language of learning describes what it means to know, be able to do, or be as a professional and how this changes over time and through experience. It provides tools for learners to reflect upon and self-assess their own progress, teachers to design and assess learning experiences, and leaders to take action in shaping engineering education programs and policies. She conducts research in: (1) Cross-disciplinary ways of thinking, acting and being, (2) Engineering design learning trajectories and education for innovation, and (3) engineering education transformation. Dr. Adams is a recipient of a National Science Foundation CAREER award, teaching and leadership awards, best paper awards (*Journal of Engineering Education*, *Design Studies*), and publishes broadly. Her research group, XRoads, involves collaborators from a variety of disciplines to conduct research at the “crossroads” where different perspectives can connect, collide, and catalyze new ways of thinking. She also participates in many professional organizations including the American Society of Engineering Education (ASEE), American Educational Research Association (AERA), International Society of the Learning Sciences (ISLS), Design Research Society (DRS), Association for the Study of Higher Education (ASHE), and Association for Integrative Studies (AIS).

Alice L. Pawley earned her B. Eng (Chemical – Distinction) degree from McGill University in 2000, and a M.S. degree (2003) and Ph.D. degree (2007) in Industrial Engineering with a minor in women’s studies from the University of Wisconsin-Madison.

As a graduate student at UW-Madison, she worked with the Engineering Learning Center, the Wisconsin Engineering Education Laboratory, and the Center for the Integration of Research Teaching and Learning. She has served as an Assistant Professor in the School of Engineering Education and as an affiliate faculty member with the Women’s Studies Program and the Division of Environmental and Ecological Engineering at Purdue University in West Lafayette, IN from 2007 to 2012. In 2013, she was promoted to Associate Professor at Purdue. She serves on numerous advisory boards for federally funded projects across the nation, and reviews papers for the *Journal of Engineering Education*, the *International*

’79 Donald R. Woods, Cameron M. Crowe, Terrence W. Hoffman, and Joseph D. Wright
’80 Marilla D. Svinicki
’81 Martha Montgomery
’82 A.L. Riemenschneider and Lyle D. Feisel
’83 Davood Tashayyod, Banu Onaral, and James M. Trosino
’84 Bill V. Koen
’85 Bill V. Koen
’86 Richard S. Culver
’87 David A. Conner, David G. Green, Thomas C. Jannett, James R. Jones, M.G. Rekoff, Jr., Dennis G. Smith, and Gregg L. Vaughn
’88 Richard M. Felder
’89 Richard C. Compton and Robert York
’90 Cindy A. Greenwood
’91 Robert Whelchel
’92 William LeBold and Dan D. Budny
’93 Daniel M Hull and Arthur H. Guenther
’94 Burks Oakley II and Roy E. Roper
’95 Curtis A. Carver, Jr. and Richard A. Howard
’96 Val D. Hawks
’97 Edwin Kashy, Michael Thoennessen, Yihjia Tsai, Nancy E. Davis, and Sheryl L. Wolfe
’98 A.B. Carlson, W.C. Jennings, and P.M. Schoch
‘99 Wayne Burleson, Aura Ganz, and Ian Harris
’00 David W. Petr
’02 Zeynep Dilli, Neil Goldsman, Lee Harper, Steven I. Marcus, and Janet A. Schmidt
’03 Glenn W. Ellis, Gail E. Scordilis, and Carla M. Cook
’04 Matthew W. Ohland, Guili Zhang, Brian Thorndyke, and Timothy J. Anderson
’05 Gregory A. Moses and Michael Litzkow
’07 Donna Riley and Gina-Louise Sciarra
’08 Eric Hamilton and Andrew Hurford
‘09 Steve Krause, Robert Culbertson, Michael Oehrtman, Marilyn Carlson, Bill Leonard, C.V. Hollot, and William Gerace
’10 Glenda Stump, Jenefer Husman, Wen-Ting Chung and Aaron Done
’11 Jeffrey L. Newcomer
‘12 Kristi J. Shryock, Arun R. Srinivasa and Jeffrey E. Froyd

Journal of Engineering Education, the *European Journal of Engineering Education*, the *International Journal of Engineering, Social Justice and Peace*, *Science Education*, the *Journal of Higher Education*, *Advances in Engineering Education*, and *Engineering Studies,* and has reviewed for MIT Press.

Prof. Pawley is a member of the American Society for Engineering Education (ASEE), the National Women’s Studies Association (NWSA), the International Network for Engineering Studies (INES), the Society of Women Engineers (SWE), and the National Organization of Gay and Lesbian Scientists and Technical Professionals (NOGLSTP); she serves as faculty advisor to the Purdue chapters of ASEE and NOGLSTP. She received a NSF CAREER award in 2010 and a Presidential Early Career Award in Science and Engineering (PECASE) from President Obama in 2012.

Brent K. Jesiek earned his B.S. in Electrical Engineering (computer engineering option) from Michigan Technological University in 1998, and a M.S. degree (2003) and Ph.D. degree (2006) in Science and Technology Studies from Virginia Polytechnic Institute and State University. He is currently an Assistant Professor in the Schools of Engineering Education and Electrical and Computer Engineering at Purdue University, and is an Associate Director of Purdue’s Global Engineering Program. Dr. Jesiek draws expertise from engineering, computing, the social sciences, and humanities to investigate the geographic, disciplinary, and historical dimensions of engineering education and professional practice. He has a strong track record of grant-funded research, and in 2012 received an NSF CAREER award to study boundary-spanning roles and competencies among early career engineers. He leads the Global Engineering Education Collaboratory (GEEC), which serves as a hub for his research. An award-winning teacher, Dr. Jesiek regularly serves as instructor for courses in Purdue’s First-Year Engineering program and Engineering Education graduate program. His professional memberships include IEEE, International Network for Engineering Studies (INES), and American Society for Engineering Education (ASEE).

Frontiers in Education Conference Benjamin J. Dasher Best Paper Award (continued)

About the Dasher Award

The Benjamin Dasher Best Paper Award is given to the best paper presented at the annual Frontiers in Education Conference, as demonstrated by technical originality, technical importance and accuracy, quality of oral presentation, and quality of the written paper appearing in the Conference Proceedings. Papers are nominated for the award by reviewers.

A committee with representation from each of the organizing societies (ERM, IEEE Ed. Soc., IEEE Comp. Soc.) is formed to review nominated papers. During the FIE meeting, the committee attends presentations of the nominated papers. The committee then makes a final recommendation to the FIE Planning Committee for the Ben Dasher Award winner based on the overall quality of both the paper and the presentation.

About Benjamin J. Dasher

Benjamin J. Dasher was born December 27, 1912 in Macon, Ga. He earned his bachelor's and master's degrees in electrical engineering in 1935 and 1945, respectively, and graduated with a doctorate in electrical engineering in 1952 from the Massachusetts Institute of Technology. At MIT, Dr. Dasher worked on the electronics of instrumentation of electromechanical transducers and analog-to-digital converters. He was the author of "Dasher's method" for synthesis of resistance-capacitance two-port networks, which is found in standard textbook treatments.

While at Georgia Tech, Dr. Dasher served as a graduate assistant in 1936, then as an instructor in 1940, and became an assistant professor in 1945. While earning his PhD at MIT, he was an instructor from 1948-51. Before finishing with his PhD, he became an associate professor at Georgia Tech in 1951, was promoted to professor in 1952, and became director of the School of Electrical Engineering in 1954, where he served in that capacity until 1969. In 1968, Dr. Dasher was appointed associate dean in the College of Engineering. At Georgia Tech, Dr. Dasher served as director of network synthesis projects and transistor oscillator projects. His fields of interest included advanced network theory, electronic theory, electronic circuits, electrical engineering education, machine translation, speech analysis, and pattern recognition. He was credited for bringing undergraduate engineering education to the forefront at Georgia Tech and for increasing interactions between undergraduates and industry.

Dr. Dasher was a member of Phi Kappa Phi, ASEE, Sigma Xi, and the American Association of University Professors; he was a Fellow of both the IEEE and the Institute of Radio Engineers. He served as a regional director for IEEE and as the chair for the Atlanta section of IEEE; he was on numerous committees for IRE, AIEE, and IEEE. He served as President of the IEEE Education Group in 1970-71.

Ben Dasher organized the first Frontiers in Education Conference; it was held in Atlanta in 1971, and attracted 100 participants. There were 34 papers in six technical sessions.

Dr. Dasher died of congestive heart failure on December 13, 1971 in Houston, Texas.

Lynn Andrea Stein
Franklin W. Olin
College of Engineering

Caitrin Lynch
Franklin W. Olin
College of Engineering

Past Recipients

'80 Helen Plants
'81 Jim Russell and John C. Lindenlaub
'82 Karl A. Smith and Harold Goldstein
'83 E. Dendy Sloan and Charles F. Yokomoto
'84 David W. Johnson and Karl A. Smith
'85 Billy V. Koen
'86 Martha A. Nord and Patricia H. Whiting
'87 John C. Lindenlaub
'89 Karl A. Smith
'91 Troy E. Kostek
'92 Barbara M. Olds and Ronald L. Miller
'93 John C. Lindenlaub and Alisha A. Waller
'94 Billy V. Koen

Frontiers in Education Conference Helen Plants Award Best Nontraditional Session at FIE 2012

Special Session: Connecting with Community: Empathy, Experience, and Engineering with Elders, FIE 2012, Session S1A

Lynn Andrea Stein is a founding faculty member of the Franklin W. Olin College of Engineering, where she is Professor of Computer and Cognitive Science and Associate Dean for External Engagement and Initiatives. Stein's research, at Olin and over a decade on the faculty of MIT, spans the fields of artificial intelligence, programming languages, and human-computer interaction. She is a co-author of the foundational documents of the semantic web and the "mother" of a humanoid robot and an intelligent room. Stein is also active in the engineering and computer science education communities, a member of curricular advisory boards, and a frequent speaker at educational conferences on work including pioneering curricular applications of inexpensive robotics, an innovative curriculum for introductory computer science, and curricular change processes with academia. In 2009, Stein was named the founding director of Olin's Initiative for Innovation in Engineering Education.

Caitrin Lynch is a cultural anthropologist with cross-cultural expertise in labor, gender, and aging. An Associate Professor of Anthropology at Olin College of Engineering, she is also a Visiting Research Associate in the Department of Anthropology at Brandeis University. She is the author of two books, *Juki Girls, Good Girls: Gender and Cultural Politics in Sri Lanka's Global Garment Industry* (Cornell, 2007) and *Retirement on the Line: Age, Work, and Value in an American Factory* (Cornell, 2012). She is editor, with Jason Danely, of a collection of essays on aging and the life course: *Transitions and Transformations: Cultural Perspectives on Aging and the Life Course* (Berghahn, 2013). Lynch also is the producer of a documentary film "My Name is Julius" (directed by Titi Yu); see www.juliusfilm.com. Lynch strives to expose engineering students to critical analysis and identification of the burgeoning needs and opportunities in our aging world. One outlet for these efforts is in her interdisciplinary service-learning course (co-taught with faculty in engineering and design and created with Lynn Andrea Stein) "Engineering For Humanity: Helping Elders Age in Place through Partnerships for Healthy Living" (http://e4h.olin.edu/).

Helen Plants Award Past Recipients, Continued

‘95 Burks Oakley II and Mark Yoder
’96 Alisha A. Waller, Edward R. Doering, and Mark A. Yoder
’97 Karl A. Smith, James D. Jones and Elizabeth Eschenbach
’98 Alice Agogino
’99 Melinda Piket-May and Julie L. Chang
’03 William C. Oakes
’04 Susan M. Lord, Elizabeth A. Eschenbach, Alisha A. Waller, Eileen M. Cashman, and Monica J. Bruning
‘05 Ruth A. Streveler
‘06 Ruth A. Streveler, Karl A. Smith, and Ronald L. Miller
’08 Maura Borrego, Lynita Newswander, and Lisa McNair
’09 Lisa C. Benson, Sherrill B. Biggers, William F. Moss, Matthew Ohland, Marisa K. Orr, and Scott D. Schiff
’10 Russell Korte and Karl A. Smith
’11 Mark Somerville, Dave Goldberg, Sherra E. Kerns, and Russell Korte
’12 Şenay Purzer and Jonathan C. Hilpert

About the Plants Award

The Helen Plants Award is given for the best special (non-traditional) session at the FIE conference, as demonstrated by originality, session content and presentation including the use of written materials and visual aids, and participation of session attendees.

About Helen Margaret Lester Plants

Helen Margaret Lester was born in Desloge, Missouri, in March 1925, the only child of Rollo Bertell and Margaret Stephens Lester.

She entered the University of Missouri as a journalism major, but soon switched to Civil Engineering. She received her BSCE in 1945. She joined West Virginia University in 1947 as a graduate student and Instructor in Mechanics, and received her MS in Civil Engineering in 1953. She was a Professor of Theoretical and Applied Mechanics and of Curriculum and Instruction in the Division of Education at WVU. She became Professor Emeritus, Mechanical and Aerospace Engineering in 1983. From 1985 to 1990 she served as Chair of Civil Engineering Technology at Indiana University-Purdue University - Fort Wayne.

Her husband Ken Plants had been a "bureaucrat" with the US Bureau of Mines in Morgantown - a chemical engineer with great expertise in cost estimation. Some of their "courting" evenings were spent manually checking the design calculations on the Star City, WV Bridge, designed by the Dean and State Bridge Engineer. While in Morgantown, Helen was active in Trinity Episcopal Church where she served as a Vestryman and Bishop's Man. For many years she was a Girl Scout leader. Helen died in Tulsa, Oklahoma in September 1999.

From the beginning of her academic career, she was a gifted teacher and a role model for the few women students at West Virginia University at that time. Later, she became an advocate of programmed and individualized instruction. She and Wally Venable wrote series of papers on these topics and several texts: *Introduction to Statics, a Programmed Text*, (1975), *A Programmed Introduction to Dynamics* (1967), and *Mechanics of Materials, A Programmed Textbook* (1974). She established the first doctoral program in Engineering Education at West Virginia University.

In 1975, the University of Missouri at Columbia recognized her with the Missouri Honor Award for Distinguished Service in Engineering. She became an ASEE Fellow in 1983 as a member of the first class of Fellows. She also received Distinguished Service Award, Western Electric Fund Award, and was an ASEE Vice-President (1974 – 1976).

Jennifer Karlin
South Dakota School of Mines and Technology

Frontiers in Education Conference
Ronald J. Schmitz Award

For outstanding contributions to the conference series though her steering committee activities and especially her organization, coordination and management of the 2011 FIE conference in Rapid City, South Dakota

Dr. Jennifer Karlin received her undergraduate degree from Washington University in St. Louis and her Ph.D. in industrial and operations engineering from the University of Michigan, specializing in engineering management. As far as her committee could determine, she was the first person in the Industrial and Operational Engineering department to successfully defend a solely qualitative methodology dissertation. While a graduate student at the University of Michigan, she taught a senior elective and worked for the Center for Research on Learning and Teaching. Dr. Karlin is now an associate professor of industrial engineering at the South Dakota School of Mines and Technology. She teaches courses in engineering management, quality, strategy, and operational excellence in both the industrial engineering and engineering management undergraduate and technology management graduate programs. She is also the Coordinator of Faculty Development for the university.

These days, the majority of Dr. Karlin's research is in learning organizations, holistic learner development, and impact of engineering education on economic development. In 2006, Jennifer received a National Science Foundation CAREER award to continue her study of organizational and student learning, determining the relative organizational health of colleges and departments of engineering and correlating this to changes in student intellectual development. Her work has been funded by the National Science Foundation, the United States Air Force (through a congressional earmark), and the Material Handling Industry of America (MHIA).

Dr. Karlin has been active in FIE serving as conference general co-chair for the 2011 conference and an ERM representative on the FIE steering committee. She has also served as an ERM Board Member. She received the ASEE ERM Division Distinguished Service award in 2011.

Past Recipients

'84 Carol Schmitz
'85 Lawrence P. Grayson
'86 John C. Lindenlaub
'87 George Burnett
'88 James R. Rowland
'89 Lyle D. Feisel
'90 Edwin C. Jones, Jr.
'92 Karl A. Smith
'92 Victor K. Schutz
'93 Bruce A. Einstein
'94 David V. Kerns, Jr.
'95 David R. Voltmer
'96 William E. Sayle II
'97 Richard S. Culver
'98 Dan Budny
'99 Robert J. Herrick
'00 Larry J. Shuman
'01 David L. Soldan
'02 Goranka Bjedov
'03 Larry G. Richards
'04 James A. Roberts
'05 Robert J. Hofinger
'06 Jane Chu Prey
'07 Joseph L. A. Hughes
'08 Ted E. Batchman
'09 Russ Meier
'10 Dan Moore
'11 Susan M. Lord
'12 Arnold Pears

Frontiers in Education Conference Ronald J. Schmitz Award (continued)

About the Schmitz Award

The Ronald Schmitz Award is given to recognize outstanding and continued service to engineering education through contributions to the Frontiers in Education Conference.

About Ronald J. Schmitz

Ronald J. Schmitz was born near Ionia, Iowa on April 25, 1934. He attended a one-room country school through the eighth grade and then, as was not uncommon at the time, decided to forgo high school and work on his father's farm. At age 18, he joined the United States Navy. He served as an Electricians Mate, spending much of his enlistment at sea and made a round-the-world cruise aboard the USS Saipan.

In the Navy, Ron found an interest in and an aptitude for technology and recognized the need for further education. He completed a GED program in the Navy and, when he was discharged, enrolled in electrical engineering at Iowa State University. He received all his degrees there, finishing his doctorate in 1967.

In the fall of 1967, he accepted appointment as Assistant Professor in the Department of Electrical Engineering at the South Dakota School of Mines and Technology in Rapid City. He was involved in various research activities and directed both masters and doctoral students, but his strongest interest was always in teaching. Ron was a consummate teacher, patient with students who were having difficulty but intolerant of sloth. He received the School of Mines Teaching Award in 1975 and the Western Electric Fund Award for Excellence in Teaching in 1981.

Dr. Schmitz was very active in the IEEE, especially the Education Society, and served as Secretary Treasurer of the Society. He was also active in ERM and attended, and contributed to, many Frontiers in Education Conferences. He served as general chair of FIE 1981 in Rapid City.

Ron was an avid hunter and fisherman, a devoted husband and father and a faithful friend. He served his church as Lector and Lay Minister and was active as a Boy Scout leader.

Ron contracted cancer in 1983 and died on July 19, 1984.

Karen Panetta
Tufts University

Past Recipients

'79 Lawrence P. Grayson
'80 Demetrius T. Paris
'81 Lindon E. Saline
'82 Anthony B. Giordana
'83 Joseph Bordogna
'84 John C. Lindenlaub
'85 John D. Ryder
'86 James R. Rowland
'87 Bruce Eisenstein
'88 Mac Van Valkenburg
'89 Edward W. Ernst
'90 Ernst Weber
'91 J. David Irwin
'92 Jerrier A. Haddad
'93 Chalmers F. Sechrist
'94 Eric A. Walker
'95 Stephen W. Director
'96 William H. Hayt, Jr.
'97 Jerry R. Yeargan
'98 Ted E. Batchman
'99 Lyle D. Feisel
'00 Irene C. Peden
'01 Donald E. Kirk and Eli Fromm
'02 Burks Oakley II
'03 Frank Barnes and Delores Etter
'04 William E. Sayle II
'05 H. Vincent Poor
'06 George D. Peterson
'07 Sarah A. Rajala and Marwan A. Simaan
'08 James A. Roberts
'09 Jose B. Cruz, Jr.
'10 Rob Reilly
'11 Susan E. Conry
'12 Theodore Rappaport

IEEE Education Society William E. Sayle II Award for Achievement in Education

Presented by name

For innovative approaches to engineering education and inspiring young people to pursue a career in engineering

Dr. Karen Panetta is a Fellow of the IEEE. Dr. Panetta received the B.S. in Computer Engineering from Boston University, and the M.S. and Ph.D. in Electrical Engineering from Northeastern University. She is the 2013 Vice-President of Communications and Public Relations for IEEE-USA. She is the Editor-in-Chief of the award winning IEEE Women in Engineering Magazine and Editor of the IEEE Boston "Reflector" Newspaper. She served as the 2011 Chair of the IEEE Boston Section. During 2009-2007, she served as the Chair for the IEEE Women in Engineering, overseeing the world's largest professional organization supporting women in engineering and science.

She is the Associate Dean for Graduate Education and a Professor of Electrical and Computer Engineering at Tufts University. She is the Director of the Simulation Research Laboratory. Her research focuses on developing efficient algorithms for simulation, modeling, signal and image processing for security and biomedical applications.

Before joining the faculty at Tufts, Dr. Panetta was employed as a computer engineer at Digital Equipment Corporation. Her research in Simulation and Modeling has won her research team five awards from NASA for "Outstanding Contributions to NASA Research" and "Excellence in Research". She is a NASA Langley Research Scientist "JOVE" Fellow, is a recipient of the NSF Career Award and won the 2003 Madeline and Henry Fischer Best Engineering Teacher Award. Dr. Panetta was also awarded a Mass High Tech All-Star by Mass High Tech Magazine. She is the recipient of the 2006 Boston University Outstanding Alumni Award and was a recipient of the "Be The Change" award from the Massachusetts Conference for Women. She is the 2009 Norm Augustine Award recipient from the National Academies of Engineering and Science, American Association of Engineering Societies. In 2010, the IEEE recognized Dr. Panetta by awarding her the IEEE Educational Activities Board, Major Educational Innovation Award. In 2011, she was awarded the "Women of Vision" award from the Anita Borg Institute and the IEEE Education Society Harriet B. Rigas Award for Outstanding Engineering Educator. In 2011, U.S. President Obama presented Karen with the NSF Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring. In 2013, she was awarded the E-Week New England Leadership award and the IEEE Award for Ethical Practices.

Dr. Panetta serves on the Boston University Engineering Alumni Board and is a board member for the Center for Balance by Design. She is also a member of the ACM, AAAS, AWIS, SWE, SPHE, Tau Beta Pi, ASEE and the Society for Computer Simulation. She is the faculty advisor to both the Tufts SWE and IEEE student chapters.

Believing that real world experience is critical for engineering education, Dr. Panetta maintains consulting positions in industry and brings her experience back to the classroom. She is a Design Consultant for Tycoelectronics, M/A-Com Inc. and consults for school systems and Science Museums across the United States to inspire engineering and technology education.

Dr. Panetta is dedicated to promoting women in engineering and created the nationally acclaimed "Nerd Girls" program, where undergraduate engineers use their engineering skills to solve real world problems and serve as role models for younger students. By showing youth how engineering helps society and can improve the quality of life for humans and wildlife, Karen Panetta has connected young students with the motivation for pursuing engineering careers.

The IEEE.tv video, "Nerd Girls", which demonstrates Karen's most successful mentoring and recruiting philosophy, shows that female engineers are smart, well-rounded, talented girls. The video has won an APEX GRAND award and an Aegis Award for Best Educational Outreach video. The IEEE.tv video, "Ship the Chip" documented Karen personally mentoring 100 female students from a diversity of ethnic and socio-economic backgrounds. The participants included both physically challenged girls and girls with learning disabilities, all exploring the excitement of engineering as a team.

About the Sayle Award and William E. Sayle II

The William E. Sayle II Award is presented to recognize a member of the IEEE Education Society who has made significant contributions over a period of years in a field of interest of the IEEE Education Society. The award consists of a plaque, a certificate, and paid registration to the Frontiers in Education Conference.

Dr. William (Bill) E. Sayle received his BSEE and MSEE degrees from the University of Texas at Austin and his Ph.D. from the University of Washington. He joined the faculty in electrical engineering at Georgia Institute of Technology in 1970, just as Georgia Tech was beginning the transition from an undergraduate institution to a research university. He was the ECE associate chair for undergraduate affairs from 1988-2003 and, following retirement in 2003, served as director of undergraduate programs at Georgia Tech-Lorraine in France until 2007. Bill was a tireless advocate for students, putting in countless late night and weekend hours in addressing student issues, assigning teaching assistants, and meeting with prospective students and parents.

Throughout his career, Bill touched the lives of many people in the worldwide academic community. He was a leader and a pioneer in many areas. In the 1970s, he was a founding member of the IEEE Power Electronics Society, where he served in many leadership roles over the years. He was a champion of diversity and in recruiting underrepresented minorities and women to engineering and science, long before it became a national issue. He visited many high schools on behalf of the Southeastern Consortium for Minorities in Engineering, a role where he made many friends for Georgia Tech among high school administrators and students in the southern part of Georgia.

In his 30-year career at Georgia Tech, Bill received the ECE outstanding teacher award twice, as well as the Georgia Tech outstanding teacher award and outstanding service award. Bill lent his voice and efforts to Georgia Tech faculty governance throughout his career, serving as an elected member of Institute-level committees, the Academic Senate, and the Executive Board.

Bill was a long-time member and active volunteer in the IEEE Education Society and the Electrical and Computer Engineering Division of ASEE. He was a Fellow of both IEEE and ASEE. He was the recipient of the Education Society's 2001 Meritorious Service Award and 2004 Achievement Award and of the ECE Division's 2001 Meritorious Service Award and 2006 ECE Distinguished Educator Award. Bill was the General Chair of the 1995 Frontiers in Education (FIE) Conference, which is still remembered for its all-vegetarian menu, and received the 1996 Ronald J. Schmitz Award for outstanding service to FIE.

Much of Bill's professional career was devoted to engineering accreditation, serving at various times as member and chair of the IEEE Committee on Engineering Accreditation Activities and the IEEE Accreditation Policy Council. He participated in more than 20 visits as a program evaluator, in addition to serving as a team chair and member of the Engineering Accreditation Commission of ABET for more than five years. Bill received the IEEE Educational Activities Board Meritorious Achievement Award in Accreditation Activities in 2004.

Dr. Sayle passed away on February 2, 2008.

IEEE *Transactions on Education* Best Paper Award

***Factors That Influence Dissemination in Engineering Education*, Benjamin T. Hazen, Yun Wu and Chetan S. Sankar, IEEE Transactions on Education, Vol. 55, Issue 3, pp. 384-383, August of 2012.**

Benjamin Hazen
U.S. Air Force

Yun Wu
Auburn University

Chetan Sankar
Auburn University

Benjamin T. Hazen received the B.S. degree in Business Administration from Colorado Christian University, in 2004. He received the M.A. degree in Organizational Leadership from Gonzaga University, in 2006, the M.B.A. degree from California State University, Dominguez Hills, in 2007, and the Ph.D. degree in Management from Auburn University, in 2012.

He is a United States Air Force maintenance officer and has served on active duty continuously since 1999. From 1999 to 2002, he served as a Satellite and Wideband Communications Journeyman at Tinker Air Force Base, Oklahoma. He then managed the Engineering Laboratory in the Department of Astronautics at the United States Air Force Academy, Colorado, from 2002 to 2006. From 2006 to 2009, he served in a variety of aircraft maintenance positions at Travis Air Force Base, California. From 2009 to 2012, he participated in an advanced degree program and worked as a Doctoral Candidate in the Department of Aviation and Supply Chain Management at Auburn University. Currently, he serves as the Maintenance Operations Officer for the 916th Maintenance Squadron at Seymour Johnson Air Force Base, North Carolina. His primary research interest is in the area of innovation diffusion.

Yun Wu received the B.S. degree in Management Information Systems from Beijing University of Post and Telecommunications, China, in 2005. She received the M.S. degree in Management Engineering from Politechnico di Milano, Italy, in 2007.

She is currently a Doctoral student in the Department of Aviation and Supply Chain Management at Auburn University. Her research interests include IT innovation diffusion, cloud computing, healthcare information systems and pedagogy dissemination.

Chetan S. Sankar (M ’81-SM ‘88) received the B.S. degree in Mechanical Engineering from Regional Engineering College, Trichy, India, in 1971, and the M.B.A. degree from Indian Institute of Management Calcutta, India, in 1973. He received the Ph.D. degree in Decision Sciences from the Wharton School, University of Pennsylvania, in 1981.

From 1973 to 1974, he worked as an inventory control manager at Balmer Lawrie & Co., Ltd. He was a Research Fellow at the Indian Institute of Management, Calcutta, from 1974 to 1977. He served as an Assistant Professor at Temple University, from 1981 to 1985. He then worked as a project manager at AT&T Bell Laboratories, from 1985 to 1989. In 1989, he joined the faculty at Auburn University, where he is currently the College of Business Advisory Council Professor of Information Systems, and the Director of the Geospatial Research and Applications Center at Auburn University. He has received more than three million dollars from grants sponsored by the National Science Foundation and Economic Development Administration to develop exceptional instructional

Past Recipients

’99 J.A. Buck, H. Owen, J.P. Uyemura, C.M. Verber, and D.J. Blumenthal
’00 David J. Russomanno and Ronald D. Bonnell
’01 Christopher W. Trueman
’02 Mohan Krishnan and Mark J. Paulik

’03 Tyson S. Hall,
James O. Hamblen, and
Kimberly E. Newman
’04 M. Brian Blake
’04 Russell L. Pimmel
’05 Antonio J. Lopez-Martin
’06 Euan Lindsay and
Malcolm C. Good
’07 Jason A. Day and
James D. Foley
’08 France Bélanger,
Tracy L. Lewis,
George M. Kasper,
Wanda J. Smith and
K. Vernard Harrington
’09 Kenneth Ricks,
Jeff Jackson, and
William A. Stapleton
’10 Keith Holbert and
George G. Karady
’11 Julie A. Rursch,
Andy Luse, and
Doug Jacobson
’12 Susan Lord,
Richard Layton, and
Matthew Ohland

materials that bring real-world issues into classrooms and to help communities recover from disasters effectively. He serves as the Editor-in-Chief of the Decision Sciences Journal of Innovative Education and the Managing Editor of the Journal of STEM Education: Innovations and Research. His research interests include improving instructional and pedagogy methodologies and innovative uses of information technologies to benefit the public.

Dr. Sankar has won awards for research and teaching excellence from the Society for Information Management, NEEDS, Decision Sciences Institute, American Society for Engineering Education, American Society for Mechanical Engineering, International Network for Engineering Education & Research, and the Project Management Institute.

IEEE India Council

Deepak Garg
Chair

Raghu Raman
Past Chair

Prashant R. Nair
Vice Chair

IEEE Education Society Chapter Achievement Award

For exemplary technical activities, membership services, societal activities to its members, and for outstanding leadership by Chapter officers

Dr Deepak Garg is currently faculty in Computer Science and Engineering Department of Thapar University, Patiala. He holds a PhD in Efficient Algorithm Design for Pattern Discovery. He has more than 100 publications to his credit. He is the Chair of Steering Committee of IEEE International Advanced Computing (IACC) Series of Annual Conference. He is also the chair of Steering Committee of IEEE International Conference in MOOC, Innovation and Technology in Education.

He is currently the Chair of IEEE Computer Society, India Council and the Chair of IEEE Education Society, India Council. He is the Chair of ACM SIGACT North India Chapter. He is teaching UG and PG courses and guiding PhD students in different areas of algorithms. He has executed few projects with funding from Indian Govt. His workshops on Advanced Algorithms and data structures are very popular. Currently his research areas are advanced algorithms, Theoretical Computer Science and Bioinformatics.

Prof. Raghu Raman currently heads the Center for Research in Advanced Technologies for Education (CREATE) at Amrita University, India. As Principal Investigator for multiple research projects totaling over $2.3m, Raghu's main research focus is in the area of computational intelligence for Intelligent and Adaptive Learning Systems, Virtual Interactive learning environments, and Diffusion of ICT Innovations.

Prior to joining Amrita, Raghu worked at NEC Research Labs, USA on the Intelligent Video surveillance technology using neural networks that was ultimately spun out into a new venture. Formerly, Raghu was the Executive Director of Product Development at IBM, where he provided product leadership and direction for engineering groups with full responsibility for operations and budget control of an annual budget of over $8m. Raghu holds an MBA from Haas School of Business, UC Berkeley and is the recipient of President's gold medal. He serves on the board of directors for Amrita Technology Business Incubator; as Member, Standing Committee, National Mission on Education through ICT (NME ICT) and is the past chair of IEEE Education Society Chapter, IEEE India Council.

Mr. Prashant R. Nair is the Vice-Chairman - Information Technology at Amrita School of Engineering, Amrita University, Coimbatore in South India. Since 2000, he has been on the faculty of Amrita University, where he also teaches at the Business School and Centre of Excellence in Cyber Security. Since 2008, he has been holding the administrative responsibility of Vice-Chairman for Accreditation & Quality Assurance for Amrita University. He has taught at academic programs in USA and Europe at University of California, San Diego and Sofia University, Bulgaria as an Erasmus Mundus fellow. His research interests include Application of ICT tools for Supply Chain Management & Education, Cyber Security and Internet Technology. He completed his B.E from Bharathiar University and MBA from Amrita School of Business, Coimbatore, which is ranked among the top 25 B-schools in India.

Om Vikas
Chair, Policy and Planning

Past Recipients
’06 Nordic Chapter
’07 Spanish Chapter
’08 Gulf Chapter
’09 Santa Clara Valley Chapter and Portugal Chapter
’10 Austria Chapter
’11 Spain Chapter
’12 Hong Kong Chapter

He has served on the program committee of over 60 international conferences including the IEEE International Conference on Technology Enhanced Education (ICTEE) 2012, IADIS WWW/Internet conference, and editorial board of 3 international journals including Computer Society of India (CSI)Transactions on ICT, a Springer Journal. He is presently holding several leadership roles in professional bodies like Student Activity Chair (SAC) of IEEE Computer Society, India Council; Executive Committee member of IEEE Madras Section and Member of National Student Committee of CSI. He is the Associate Site Director for ACM International Collegiate Programming Contest (ICPC), which is considered as the world championship of programming. Various Awards won include ASDF Award for Best Academic Administrator (2012) and CSI Academic Excellence award (2011).

Dr. Om Vikas possesses B Tech(EE), M Tech(EE), Ph.D.(CSE) all from IIT, Kanpur. Formerly Director/VC, ABVIIITM (Indian Institute of Information Technology & Management) Gwalior, Senior Director in the Department of Electronics & Information Technology (DE&IT, Govt of India), and Counselor (Science & Technology) in Indian Embassy, Tokyo, Japan. In DE&IT, he headed Technology Development for Indian Languages Mission and Computer Manpower Development Division. He served in TCS as System Engineer. He was visiting professor at IIT/K, adjunct professor at IIT/D & NSIT; Professor in charge CLASS project at NCERT, Director, IP Engineering College, Advisor to C-DAC, and on Academic Councils of various universities / Institutions. Currently he is Professor-Emeritus at Mahamaya Technical University.

He has vast experience of designing curricula 1-to-12 school level (Vocational & Academic) for CBSE, and UG & PG curricula – Computer Applications, Knowledge Engineering, Industrial Informatics, Engineering Education, etc. He is invited as Expert Assessor of NBA/AICTE and NAAC/UGC for assessment & accreditation of technical programmes / institutions. He is member of Organizing Committee of World Summit on Accreditation WOSA -2014. Dr. Vikas received several awards for his outstanding contribution towards IT for masses.

Alfonso Perez Gama
Foundation of Higher Education, San Jose

Past Recipients

’06 Michael E. Auer and Manuel Castro
’07 Carlos Rueda Artunduaga and Oliver K. Ban
’08 Bakr Hassan and Edmundo Tovar
’09 Emmanuel A. Gonzalez
’10 Martín Llamas-Nistal
’11 Russ Meier
’12 German Cabuya

IEEE Education Society
Distinguished Chapter Leadership Award

For his efforts to make Colombia the 2nd largest chapter in our Society, sponsoring many activities, and being directly involved in the development of the chapter, providing meaningful service in Colombia

Jesus Alfonso Perez Gama was a tenured professor and university master fellow at the National University of Colombia, as well as director of the Master and Systems Engineering Undergraduate Program and University Superior Council Teacher representative. Currently Alfonso is the faculty engineering dean at the Foundation of Higher Education, San Jose and is also director of the International Research Group, San Jose EIDOS. He has conducted several research projects dealing with social and economic problems for tertiary education, using mathematical and computational models and artificial intelligence, which were sponsored by Colciencias, CYTED-D (Spain - V Centenary) and the Ministry of National Education and FODESEP.

Alfonso is a graduate of the Mayor San Bartolome. He also studied Electronic Engineering at the U City University of Bogota and received a Master of Science from the University of Essex, UK and a Systems Engineering Magister from the National University and Economics Graduate Program at Universidad de los Andes, Bogota. He is IEEE Senior Life Member and a member of the New York Academy of Sciences, the International Council on Systems Engineering, the International Input Output Association, the International Institute of Software Architects, Systems Engineering Colombia Association, and the Colombia Informatics Association, which he chairs.

He has received the James Rooke Honorary Scholarship, granted by British Council; the 2012 Roberto Valenzuela IEEE Life and Achievement Award; and the City University Francisco Jose de Caldas IEEE Student Branch 50 Years with Professional Excellence recognition. Alfonso was also recognized for his *A Successful Case in Superior Education: Mathematical and Computer Model for Engineering Using Propaedeutic Cycles*, which was included in the Bank of Significant Experiences in Higher Education 2010 by Ministry of National Education of Colombia.

Victor Nelson
Auburn University

IEEE Education Society Distinguished Member Award

For leadership and service on the Board of Governors; as chair of the Constitution and By-Laws Committee; and related professional contributions through publications, accreditation activities, and as an associate editor

Victor P. Nelson is a Professor and Assistant Chair of Electrical and Computer Engineering at Auburn University, where he has been on the faculty since 1978. His primary research interests include embedded systems and computer-aided design and testing of digital systems and application-specific integrated circuits (ASICs). He is co-author of the textbook *Digital Logic Circuit Analysis and Design* and IEEE tutorial book *Fault-Tolerant Computing*. He is past chair of the ECE Curriculum Committee and coordinator of the ECE Graduate Program, and served one year as Associate Dean for Assessment in the College of Engineering. He was a co-winner of the 2005 "Wireless Educator of the Year" award from the Global Wireless Education Consortium for his role as one of the developers of the Bachelor of Wireless Engineering program at Auburn University, which is the first of its kind in the U.S., and currently serves as the director of that program. He received the Birdsong Merit Teaching Award in 2000 and the Walker Merit Teaching Award in 2002 from the College of Engineering, and was named outstanding member of the Graduate Faculty in 2004.

He is a member of the IEEE Education Society, in which he has served as a member of the Board of Governors, chair of the Constitution and Bylaws committee, and previously as an associate editor of the *IEEE Transactions on Education*. He was a member of the IEEE Computer Society/ACM Task Force that developed the *Computer Engineering 2004* report on model computer engineering curricula. He is active in accreditation activities, having served as an ABET program evaluator and a current member of the ABET Engineering Accreditation Commission, and previously as a member and mentor coordinator of the IEEE Committee on Engineering Accreditation Activities (CEAA). He is also a member of ASEE, and previously served as chair of the ASEE ECE Division.

Past Recipients

'05 Marion O. Hagler and Burks Oakley II
'06 Ted Batchman and David A. Conner
'08 David L. Soldan
'10 Manuel Castro
'11 Susan M. Lord
'12 Matthew Ohland

Charles Fleddermann
University of
New Mexico

Past Recipients

’78 Warren B. Boast
’79 Joseph M. Biedenbach
’80 Edwin C. Jones, Jr.
’81 Lyle D. Feisel
’82 Roy H. Mattson
’83 Robert F. Fontana
’84 Gerald R. Peterson
’85 Luke H. Noggle
’86 James A. Mulligan
Sidney S. Shamis
’87 Thomas K. Gaylord
’88 Robert F. Cotellessa
’89 E. Ben Peterson
’90 Darrell L. Vines
‘91 Victor K. Schutz
’92 William K. LeBold
’93 Frank S. Barnes
’94 Patricia D. Daniels
’95 Robert W. Ritchie
’96 Marion O. Hagler
Donald E. Kirk
’97 Robert Sullivan
’98 Burks Oakley II
’99 Gerald L. Engel
’00 Ted E. Batchman
’01 William E. Sayle II
’02 James Rowland
’03 David A. Conner
’04 Trond Clausen
’05 J. David Irwin
Rodney J. Soukup
’06 Robert A. Reilly
’07 David V. Kerns, Jr.
’08 James J. Sluss, Jr.
’09 Manuel Castro
’10 Michael E. Auer
’11 Russ Meier
’11 Claudio da Rocha Brito
and Melany M. Ciampi
’12 Susan Lord

IEEE Education Society Edwin C. Jones, Jr. Meritorious Service Award

For his outstanding contributions and service as the Editor in Chief of the IEEE Transactions on Education

Charles Fleddermann is a Professor of Electrical and Computer Engineering and Associate Dean of the School of Engineering at the University of New Mexico (UNM) where he has been on the faculty for over 27 years. He also has served as Dean of Graduate Studies at UNM. Prof. Fleddermann earned his Ph.D. and M.S. degrees in electrical engineering from the University of Illinois at Urbana-Champaign, and a B.S. degree, also in electrical engineering, from the University of Notre Dame.

Dr. Fleddermann is a senior member of the IEEE, and is also a member of the ASEE. He has served as the Editor in Chief of IEEE Transactions on Education (ToE); previous to that he was an Associate Editor for the journal. He serves as an electrical engineering program evaluator for the Accreditation Board for Engineering and Technology (ABET).

His research interests are in engineering education, photovoltaics, plasma processing of electronic materials, optical diagnostics of plasma systems, and engineering ethics. He has taught a variety of courses at both the undergraduate and graduate levels, including on-line courses. He has developed and taught a course on professional ethics for engineers, and has been involved in research projects in the area of ethical issues in nanotechnology. He has also taught professional development seminars on ethics for engineers in New Mexico and elsewhere in the U.S. over the past few years. He is the author of two textbooks: the 4th edition of *Engineering Ethics,* was released in 2011; and he co-authored *Introduction to Electrical and Computer Engineering*, intended to help first-year students develop knowledge and strategies for success in the profession.

About the Edwin C. Jones Award

The Edwin C. Jones Meritorious Service Award is presented to recognize a member of the IEEE Education Society who has made pioneering contributions to the administrative efforts of the IEEE Education Society over a period of years. The award consists of a plaque, a certificate, and registration to the Frontiers in Education Conference.

About Edwin C. Jones

Professor Jones served as a Society officer from 1970 through 1976; this service included two years as president. He served as Editor-in-Chief of the *IEEE Transactions on Education* from 1982-84. Since he first became involved in the Society in the late 1960s, he has held virtually every office in the Education Society. He is still actively involved with the Education Society. Professor Jones also serves the IEEE as a member of the IEEE Committee on Engineering Accreditation Activities. Dr. Jones is University Professor and Associate Chair, emeritus, Department of Electrical and Computer Engineering, Iowa State University. Prior to joining Iowa State in 1966, he was an Assistant Professor at the University of Illinois from 1962-66. He received his PhD in 1962 from the University of Illinois; the DIC in 1956 from Imperial College of Science and Technology, University of London; and the BSEE in 1955 from West Virginia University. Dr. Jones' honors and awards include: Fellow, Institute of Electrical and Electronics Engineers; Fellow, American Society for Engineering Education; Fellow, American Association for Advancement of Science; Fellow, Accreditation Board for Engineering and Technology; IEEE Centennial Medal, 1984; ASEE Centennial Medal, 1993.

Muhammad Zaman
Boston University

Past Recipients

’04 Parham Aarabi
’05 John R. Buck
’06 Lisa G. Huettel
’07 Susan C. Hagness
’08 Kathleen E. Wage
’09 Min Wu
’10 Craig Ziles
’11 Jonathan Makela
’12 Babak Ayazifar

IEEE Education Society Mac Van Valkenburg Early Career Teaching Award

For his innovative teaching approach, simultaneous emphasis on disciplinary rigor and on the societal implications of engineering in his classes, and his deep commitment to inspiring engineering students to address high-value global development problems in resource limited settings

Muhammad H. Zaman is Associate Professor of Biomedical Engineering at Boston University. He also holds appointments in the Department of Medicine and the Department of International Health at Boston University School of Medicine. Prof. Zaman is also Associate Chair of Biomedical Engineering and Associate Director of Kilachand Honors College at Boston University. Prof. Zaman got his PhD in Physical Chemistry from the University of Chicago in 2003, where he was a Burroughs-Wellcome Graduate Fellow in Interdisciplinary Sciences. After his Ph.D. he was a Herman and Margaret Post-Doctoral Fellow at MIT from 2003-2006. He was Assistant Professor of Biomedical Engineering at UT Austin from 2006-2009 and moved to BU in Fall 2009. His lab focuses on developing new experimental and computational technologies for high value healthcare problems in both the developing and developed world.

Prof. Zaman is actively involved in two areas of research. The first is developing new tools and quantitative understanding of tumor formation and tumor metastasis. The second is developing robust and affordable diagnostic technologies for the developing world. He is working on capacity building and engineering education in these countries as well. Technologies developed by Prof. Zaman and his team are in various stages of implementation in multiple African countries.

Additionally, Prof. Zaman is actively involved in bringing high quality engineering education to developing countries. He is currently involved in setting up the first biomedical engineering departments at various African Universities in Kenya, Zambia, Uganda and Ethiopia. He is also a member of the technical committee of the UN Economic Council on Africa (UNECA) and co-Director of the UNECA biomedical innovation program in Africa. He contributes regularly on issues in engineering and development as a regular op-ed columnist to various newspapers and magazines including the Huffington Post and Express Tribune (one of the leading English daily newspaper in Pakistan).

Prof. Zaman’s emphasis on excellence in teaching has been a major part of his academic career. His contribution to engineering education has been highlighted by the New York Times, NPR and a number of other organizations. Prof. Zaman has won numerous awards for his research and teaching, including BU College of Engineering Early Career Research Excellence Award, Saving Lives at Birth Innovator Award, Tewkesbury Fellowship, American Society for Engineering Education Outstanding Assistant Professor Award, BME outstanding teacher award at UT Austin, College of Engineering Outstanding Teaching by an Assistant Professor Award at UT Austin and the highest award for teaching in the entire UT System, the UT System Regents Outstanding Teaching Award. He has been invited by the National Academies of Engineering to participate in both frontiers of engineering and frontiers of engineering education as well as Japan-US Frontiers of Engineering.

Subhamoy Mandal
TU München and
Helmholtz Zentrum
München

Past Recipients

‘09 Seiji Isotani
‘10 Emmanuel Gonzalez and Kai-Pan Mark
’11 Dario Schor
’12 Elio San Cristobal Ruiz and Sergio Martin

IEEE Education Society Student Leadership Award

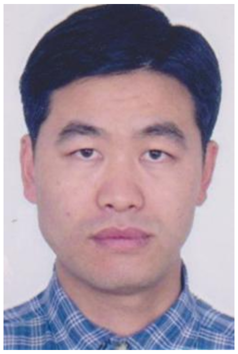
For exemplary leadership in the execution of programs and continuous improvements of the IEEE Education Society Student Activities Committee (SAC) and excellent performance in the upgrading of the IEEE Technology in Engineering Education (formerly IEEE Multidisciplinary Engineering Education Magazine)

Subhamoy Mandal (StM’04, GSM’08) is currently a DAAD PhD Scholar with the Institute of Biological and Medical Imaging at TU München and Helmholtz Zentrum München. He received his MS (by research) from the Indian Institute of Technology Kharagpur, and B.E. in Biomedical Engineering from Manipal University, Karnataka, India. Subhamoy’s areas of interest are Medical Signal & Image Processing, Medical Imaging and DSP/GPU based algorithm design. His current research pertains to visual quality enhancement and development of novel methods for optoacoustic (photoacoustic) imaging.

Subhamoy is an active Member of IEEE, and is the Student Rep and AdCom member of its Engineering in Medicine and Biology (EMB) Society, and the 2010-13 Chair, IEEE Education Society Student Activity Committee (IEEE EduSocSAC). As the Chair of the EdSocSAC he was instrumental in designing and implementing the IEEE TechSym, a unique student only conference which is archived in IEEE Xplore DL. Further, he initiated the IEEE Direct to Student (D2S) and One World- One Education (1WoE), which has achieved notable initial success. Subhamoy was the Founding Chair, IEEE EMB Student Club of IIT Kharagpur, which was awarded the Best New Student Club/Chapter Award 2010 by IEEE EMBS Student and Member Activity Committee. He has been a Member of IEEE Ad-hoc Committee on Social Media Policy reporting directly to the IEEE Board of Directors, founding Chair of the IIT Kharagpur GOLD Affinity, and also actively volunteered with the IEEE Student Branches at IIT Kharagpur(Treasurer 2009-10) and MIT Manipal (2005-07).

Subhamoy has been closely associated with several corporate organizations including Philips, GE and Microsoft. During his internships with Philips and the master’s thesis, he has focused on developing low cost point of care technologies to address healthcare challenges of emerging economies. At GE Global Research his primary area of focus has been Magnetic Resonance Imaging (MRI) and its application in Brain Iron Quantification, leading to early diagnosis of Alzheimer's and other neuro-degenerative diseases.

Subhamoy’s goal is to achieve success in innovating point-of-care healthcare solutions using expertise of biomedical engineering and domain knowledge of medical sciences by synchronized efforts in a collective venture. He aims to leverage the acumen and experiences gained through his own training to encourage growth of better educational and technical training facilities in emerging economies, including the Indian Subcontinent.



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Xinyou Zhao was born in Biyang Village, Henan Province, China in 1976. He received the B.S. degree in computer education from Xinyang Normal University, China, in 2000 and obtained the M.S. degree in Computer Science from Guilin University of Electronic Technology, China, in 2003. He was awarded a Ph.D. degree in Engineering at Graduate School of Information Systems, The University of Electro-Communications, Tokyo, Japan, in 2010.

From 2003 to 2007, he worked as a lecturer at Guilin University of Electronic Technology, Guilin, China. During May 2005 to April 2006, he was also a visiting scholar in Matsumoto Research Lab., GITI, Waseda University, Tokyo, Japan. Now he is working at ACARIC Co. Ltd as a system engineer, Tokyo, Japan. He is also a guest researcher in Advanced Research Center for Human Sciences, Waseda University, Tokorozawa, Japan. He has published more than 30 papers in national and international journals and conferences and numerous technical reports. His research interests include mobile learning, data mining with big data, intelligent tutoring system and multimedia technology.

Dr. Zhao was a recipient of the Best Ph.D. Student Award of 11th International Conference on Computers and Advanced Technology in Education (CATE 2008), Conference Presentation Grant of C&C NEC Foundation, 2008, Conference Presentation Grant of The Hara Research Foundation, 2010 and Doctoral Fellowship of Japanese Ministry of Education, Culture, Sports, Science and Technology, 2008 - 2010.

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This year, FIE 2013 had over 600 papers and presentations submitted for consideration. The FIE2013 Program Committee wishes to thank the following individuals for acting as abstract and paper reviewers. The program committee asked these individuals to help control the quality of the presentations at this year's conference by reviewing the submissions for FIE2013. Their outstanding effort has helped maintain the high standard that has become the reputation of each FIE conference.

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Llanos Tobarra	Spanish University for Distance Education - UNED
Edmundo Tovar	Universidad Politécnica de Madrid
Joseph Tranquillo	Bucknell University
Kathryn Trenshaw	University of Illinois at Urbana-Champaign
James Trevelyan	University of Western Australia
Micaela Troglia Gamba	Istituto Superiore Mario Boella
Deborah Trytten	University of Oklahoma
Janet Tsai	University of Colorado Boulder
Stephen Turner	University of Michigan-Flint
Luther Tychonievich	University of Virginia
Suleyman Uludag	The University of Michigan - Flint
Mark Urban-Lurain	Michigan State University
Leo Ureel	Michigan Technological University
Tristan Utschig	Georgia Institute of Technology
James Vallino	Rochester Institute of Technology
Francisco Herbert Vasconcelos	Federal University of Ceará
Rosa Vasconcelos	Minho University
Carlos Vaz de Carvalho	Instituto Superior de Engenharia do Porto
Srinivasa Vemuru	Ohio Northern University
Elena Verdú Pérez	Universidad de Valladolid
María Jesús Verdú Pérez	Universidad de Valladolid
Claudia Vergara	Michigan State University

Name	Institution
Camilo Vieira	Purdue University
Arto Vihavainen	University of Helsinki
Vimal Viswanathan	Georgia Institute of Technology
Susan Walden	University of Oklahoma
Charles Wallace	Michigan Technological University
Alisha Waller	Georgia Institute of Technology
René Wamkeue	Université du Québec en Abitibi-Témiscamingue
Andrew Wandel	University of Southern Queensland
Guoping Wang	Purdue University
Xiaofang Wang	Villanova University
Cindy Waters	NCA&T State University
Christopher Watson	Durham University
Heather Watson	James Madison University
Lemuel Watson	University of South Carolina
Craig Watterson	Victoria University of Wellington
Alfred Weaver	University of Virginia
Russ Weeks	Logan High School
Jacob Wheadon	Purdue University
Patricia Widder	Washington University in St. Louis
Timothy Wilson	Embry-Riddle Aeronautical University
Marco Winzker	Bonn-Rhine-Sieg University
Wanda Worley	IUPUI
Li Yang	University of Tennessee at Chattanooga
Kumar Yelamarthi	Central Michigan University
Wook-Sung Yoo	Fairfield University
James Young	Rice University
Xiaohong Yuan	North Carolina A & T State University
Rachad Zaki	Khalifa University of Science, Technology and Research
Justyna Zander	MathWorks
Luis Felipe Zapata Rivera	EAFIT University
Sarah Zappe	Pennsylvania State University
Yevgeniya Zastavker	F. W. Olin College of Engineering
Amir Zeid	American University of Kuwait
Seyed (Reza) Zekavat	Michigan Technological University
Ming Zhang	Peking University
Tao Zhang	Hitachi China Research & Development Corporation
Ya Zhou	Beijing Institute of Technology
Quanyan Zhu	University of Illinois at Urbana Champaign
Rebecca Ziino	Worcester Polytechnic Institute
Ben Zoghi	Texas A&M University
Carla Zoltowski	Purdue University
Sergio Zorzo	Federal University of Sao Carlos
Danilo Zutin	Carinthia University of Applied Sciences

SESSION CHAIRS

The conference committee would like to thank the people that have agreed to act as session chairs at the 2013 Frontiers in Education Conference. Session chairs play an important role in ensuring the conference runs smoothly and that the technical presentations are a valuable experience for both speakers and attendees. Session chairs also have served a critical role in helping with the Ben Dasher Award process.

The primary responsibilities of session chairs are to:

- Read the session's papers in advance and recommend papers for the Ben Dasher Best Paper committee.
- Contact the authors in the session and become familiar with the authors who are presenting.
- Introduce the session and make any FIE announcements that are needed.
- Briefly introduce each speaker and paper.
- Manage audience questions, and ensure that presentations begin and end within their time slots.

The program committee would like to thank the following individuals for their efforts to help make FIE2013 both informative and successful:

Session	**Time**	**Room**	**Session chairs**	**Affiliation**
T1C: Approaches to Student-Centered Learning I	10:00 AM	Room 16	Irene Rothe	Bonn-Rhine-Sieg University
T1D: Student Beliefs, Motivation & Persistence I	10:00 AM	Room 17	Lisa Benson	Clemson University
T1E: Software Engineering, Computing & Informatics Education I	10:00 AM	Room 18	Walter Schilling	Milwaukee School of Engineering
T1F: Innovation and Entrepreneurship I	10:00 AM	Room 19	Gurdip Singh	Kanas State University
T1G: First and Second Year Programs I	10:00 AM	Room 20	Kurt Thoroughman	Washington University in St. Louis
T1H: Assessment I	10:00 AM	Room 2	Ashutosh Marathe	University of Pune
T1I: Mobile and Online Learning I	10:00 AM	Room 4	Khallai Taylor	Triton College
T2C: Approaches to Student-Centered Learning II	1:30 PM	Room 16	Melany Ciampi	Safety, Health and Environment Research Organization
T2D: Teaming and Engagement	1:30 PM	Room 17	Dietrich Romberg	Anhalt University of Applied Sciences
T2E: Computing I	1:30 PM	Room 18	Rajendra Raj	Rochester Institute of Technology
T2F: ECE I	1:30 PM	Room 19	Firas Hassan	Ohio Northern University
T2G: First and Second Year Programs II	1:30 PM	Room 20	Susan Donohue	University of Virginia
T2H: Experiential Learning I	1:30 PM	Room 2	Abhijit Nagchaudhuri	University of Maryland Eastern Shore
T2I: Mobile and Online Learning II	1:30 PM	Room 4	Jacob Bishop	Utah State University
T3C: Innovative Computing Practice I	4:00 PM	Room 16	Claudio Brito	Science and Education Research Council
T3D: Real World Influences in Experiential Learning	4:00 PM	Room 17	Elif Miskioglu	The Ohio State University

Session	Time	Room	Session chairs	Affiliation
T3E: Energy Engineering Education I	4:00 PM	Room 18	Madhumi Mitra	University of Maryland Eastern Shore
T3F: Experiential Learning II	4:00 PM	Room 19	Wookwon Lee	Gannon University
T3G: Game-Based Learning I	4:00 PM	Room 20	Amir Zeid	American University of Kuwait
T3H: Open Educational Resources and Practices I	4:00 PM	Room 2	Velvet Fitzpatrick	Purdue University
T3I: Inclusivity and Diversity I	4:00 PM	Room 4	Catherine Samuelson	University of Washington
F1C: Faculty Development I	8:30 AM	Room 16	Rachel Kajfez	Virginia Tech
F1D: Teams, Communication & Profession	8:30 AM	Room 17	Kelly Cross	Virginia Polytechnic Institute and State University
F1E: Philosophy of Engineering and Engineering Education I	8:30 AM	Room 18	Eric Pappas	James Madison University
F1F: ECE II	8:30 AM	Room 19	Dale Carnegie	Victoria University of Wellington
F1G: Game-Based Learning II	8:30 AM	Room 20	Srividya Bansal	Arizona State University - Poly Campus
F1H: Learning Theories	8:30 AM	Room 2	Dazhi Yang	Boise State
F1I: Approaches to Student-Centered Learning IV	8:30 AM	Room 4	Dejang Liu	College of DuPage
F2C: Online Learning I	10:30 AM	Room 16	Theodore Manikas	Southern Methodist University
F2D: Open Educational Resources and Practices II	10:30 AM	Room 17	John Skardon	California State University-Monterey Bay
F2E: Philosophy of Engineering and Engineering Education II	10:30 AM	Room 18	Dorothy Jones-Davis	National Science Foundation
F2F: ECE III	10:30 AM	Room 19	Aurenice Oliveira	Michigan Technological University
F2G: Faculty Development II	10:30 AM	Room 20	Geoffrey Herman	University of Illinois
F2H: Design and Assessment	10:30 AM	Room 2	Deborah Munro	University of Portland
F2I: pK-12 STEM I	1:30 PM	Room 4	Anthony Joseph	Pace University
F3C: Approaches to Student-Centered Learning III	1:30 PM	Room 16	Asad Azemi	Pennsylvania State University
F3D: Student as Learner	1:30 PM	Room 17	Mauricio Dziedzic	Universidade Positivo
F3E: Assessment Strategies	1:30 PM	Room 18	Manuel Castro	Spanish University for Distance Education - UNED
F3F: Learning Approaches in ECE	1:30 PM	Room 19	O'Connell Robert	University of Missouri-Columbia
F3G: Mobile and Online Learning III	1:30 PM	Room 20	Mahesh Banavar	Arizona State University
F3H: ECE IV	1:30 PM	Room 2	Vignesh Subbian	University of Cincinnati
F3I: Integrating Design Throughout the Curriculum	1:30 PM	Room 4	Aurenice Oliveira	Michigan Technological University
F4C: Student Beliefs, Motivation & Persistence II	4:00 PM	Room 16	Jia-Ling Lin	University of Minnesota Twin Cities
F4D: Innovative Computing Practice II	4:00 PM	Room 17	Irene Rothe	Bonn-Rhine-Sieg University
F4E: Cognitive and Affective Domains of Learning	4:00 PM	Room 18	Stephen Frezza	Gannon University

Session	Time	Room	Session chairs	Affiliation
F4F: Pathways to Engineering Degrees	4:00 PM	Room 19	Dorothy Jones-Davis	National Science Foundation
F4G: Inclusivity and Diversity II	4:00 PM	Room 20	Deborah Munro	University of Portland
F4H: ECE V	4:00 PM	Room 2	Joseph Hoffbeck	University of Portland
F4I: pK-12 STEM II	4:00 PM	Room 4	Mindy Hart	Purdue University
S1C: pK-12 STEM III	8:00 AM	Room 16	Andres Navarro	Universidad Icesi
S1D: Innovative Computing Practice III	8:00 AM	Room 17	Daniel Krutz	Rochester Institute Of Technology
S1E: Distance Education I	8:00 AM	Room 18	James Rowland	University of Kansas
S1F: Innovation and Entrepreneurship II	8:00 AM	Room 19	Anthony Joseph	Pace University
S1G: First and Second Year Programs III	8:00 AM	Room 20	Leen-Kiat Soh	University of Nebraska-Lincoln
S1H: ECE VI	8:00 AM	Room 2	Abdel-Hameed Badawy	Arkansas Tech University
S1I: Online Learning II	8:00 AM	Room 4	Dorothy Jones-Davis	National Science Foundation
S2C: Teaming I	10:00 AM	Room 16	Amy Javernick-Will	University of Colorado at Boulder
S2D: Experiential Learning III	10:00 AM	Room 17	James Rowland	University of Kansas
S2E: Industry Partnerships	10:00 AM	Room 18	Xiaosong Li	Unitec Institute of Technology
S2F: Ethics and Moral Reasoning	10:00 AM	Room 19	Melany Ciampi	Safety, Health and Environment Research Organization
S2G: First and Second Year Programs IV	10:00 AM	Room 20	Aleardo Manacero	São Paulo State University - UNESP
S2H: pK-12 STEM IV	10:00 AM	Room 2	Charles Wallace	Michigan Technological University
S2I: Interdisciplinary Programs I	10:00 AM	Room 4	Rose Gamble	University of Tulsa
S3C: Student Beliefs, Motivation & Persistence III	1:00 PM	Room 16	Leen-Kiat Soh	University of Nebraska-Lincoln
S3D: Computing Pedagogy Research	1:00 PM	Room 17	Xiaosong Li	Unitec Institute of Technology
S3E: Engineering in International Contexts I	1:00 PM	Room 18	Velvet Fitzpatrick	Purdue University
S3F: Assessment II	1:00 PM	Room 19	James Rowland	University of Kansas
S3G: Energy Engineering Education II	1:00 PM	Room 20	Je-Hyeong Bahk	Purdue University
S3H: pK-12 STEM V	1:00 PM	Room 2	Julie Rursch	Iowa State University
S3I: Software Engineering, Computing & Informatics Education II	1:00 PM	Room 4	Aleardo Manacero	São Paulo State University - UNESP
S4C: Student Beliefs, Motivation & Persistence IV	3:00 PM	Room 16	Rose Gamble	University of Tulsa
S4D: Computing II	3:00 PM	Room 17	Charles Wallace	Michigan Technological University
S4E: Engineering in International Contexts II	3:00 PM	Room 18	Luis Amaral	University of Minho
S4F: Assessment III	3:00 PM	Room 19	Asako Ohno	Osaka Sangyo University

Session	Time	Room	Session chairs	Affiliation
S4G: Distance Education II	3:00 PM	Room 20	Dorothy Jones-Davis	National Science Foundation
S4H: pK-12 STEM VI	3:00 PM	Room 2	Min-Chi Kao	National Taichung University of Education
S4I: Interdisciplinary Programs II	3:00 PM	Room 4	Mahesh Banavar	Arizona State University

SESSION GRID – WEDNESDAY, OCTOBER 23RD

	Room: 16	Room: 17	Room: 18	Room: 19	Room: 20
1:30 PM	W1A: Pre-Conference Workshop: Computer Engineering Curriculum Guidelines (FREE workshop - costs covered by NSF grant)	W1B: Pre-Conference Workshop: Modeling Software the Alloy Way	W1C: Pre-Conference Workshop: Programming Board Game Strategies in CS2	W1D: Pre-Conference Workshop: Why are continuous-time signals and systems courses so difficult? How can we make them more accessible?	W1E: Pre-Conference Workshop: Using Problets for Problem-Solving Exercises in Introductory C++/Java/C# Courses
5:30 PM	W2E: Pre-Conference Workshop: Refining a Taxonomy for Engineering Education Research (FREE workshop - costs covered by NSF grant)	W2D: Pre-Conference Workshop: Teaching Service-Oriented Programming to CS and SE Undergraduate Students (FREE workshop - costs covered by NSF grant)	W2C: Pre-Conference Workshop: An Online Revolution in Learning and Teaching: from e-books to MOOCs	W2B: Pre-Conference Workshop: The Erlang Approach to Concurrent System Development	W2A: Pre-Conference Workshop: Inspiring Inventive Genius in Middle and High School Students with Chain-Reaction STEAM Machines™

SESSION GRID - THURSDAY, OCTOBER 24TH

	Room: 14	Room: 15	Room: 16	Room: 17	Room: 18	Room: 19	Room: 20	Room: 2	Room: 4
7:00 am – 5:00 pm	Registration Location: Second Floor Prefunction Area								
7:00 am - 8:00 am	Focus on First-Time Attendees Breakfast Buffet Location: Great Hall C								
8:00 am - 9:30 am	Plenary Session Location: Great Hall A & B Keynote: Katherine Banks, Vice Chancellor and Dean of Engineering, Texas A&M University								
9:30 am – 5:00 pm	Exhibit Hall Open Great Hall D & E								
10:00 am - 11:30 am	**T1A: Mini-Workshop: Exploring Boyer's Scholarship of Application for Submissions to the IEEE Transactions on Education**	**T1B: Special Session: Assessing Lifelong Learning: The Role of Information Gathering and Application Skills**	**T1C: Approaches to Student-Centered Learning I**	**T1D: Student Beliefs, Motivation & Persistence I**	**T1E: Software Engineering, Computing & Informatics Education I**	**T1F: Innovation and Entrepreneurship I**	**T1G: First and Second Year Programs I**	**T1H: Assessment I**	**T1I: Mobile and Online Learning I**
11:45 am - 1:15 pm	HP Terman and Rigas Awards Lunch Location: Great Hall C Sponsored by the Hewlet-Packard Company								
1:30 pm - 3:00 pm	**T2A: Mini-Workshop: New National Science Foundation Opportunities for Improving Undergraduate Engineering Education**	**T2B: Panel: Model Collaboration for Advancing Student-Centered Engineering Education**	**T2C: Approaches to Student-Centered Learning II**	**T2D: Teaming and Engagement**	**T2E: Computing I**	**T2F: ECE I**	**T2G: First and Second Year Programs II**	**T2H: Experiential Learning I**	**T2I: Mobile and Online Learning II**
4:00 pm - 5:30 pm	**T3A: Mini-Workshop: Catching the Wave: Big Data in the Classroom**	**T3B: Special Session: DiSrUpTiOn**	**T3C: Innovative Computing Practice I**	**T3D: Real World Influences in Experiential Learning**	**T3E: Energy Engineering Education I**	**T3F: Experiential Learning II**	**T3G: Game-Based Learning I**	**T3H: Open Educational Resources and Practices I**	**T3I: Inclusivity and Diversity I**
6:00 pm - 10:00 pm	Transportation to and Reception at Western Museum Bus Loading Zone: Between the Renaissance Hotel and the Cox Convention Center								

SESSION GRID - FRIDAY, OCTOBER 25TH

	Room: 14	Room: 15	Room: 16	Room: 17	Room: 18	Room: 19	Room: 20	Room: 2	Room: 4
7:00 am – 5:00 pm	Registration Location: Second Floor Prefunction Area								
7:00 am - 8:30 am	Breakfast and Plenary Session Location: Great Hall C Keynote: Mike McCracken, Director of Online Course Development and Innovation, College of Computing, Center for 21st Century Universities (C2IU), Georgia Tech								
8:30 am - 10:00 am	**F1A: Mini-Workshop: Tools to Facilitate Development of Conceptual Understanding in the First and Second Year of Engineering**	**F1B: Panel: Building an Inclusive REU Program: A Model for Engineering Education**	**F1C: Faculty Development I**	**F1D: Teams, Communication & Profession**	**F1E: Philosophy of Engineering and Engineering Education I**	**F1F: ECE II**	**F1G: Game-Based Learning II**	**F1H: Learning Theories**	**F1I: Approaches to Student-Centered Learning IV**
9:00 am - 4:30 pm	Exhibit Hall Open Location: Great Hall D & E								
10:30 am - Noon	**F2A: Mini-Workshop: Why are continuous-time signals and systems courses so difficult? How can we make them more accessible?**	**F2B: Special Session: True Grit: Toward a Culture of Psychological Preparedness in Engineering Education**	**F2C: Online Learning I**	**F2D: Open Educational Resources and Practices II**	**F2E: Philosophy of Engineering and Engineering Education II**	**F2F: ECE III**	**F2G: Faculty Development II**	**F2H: Design and Assessment**	**F2I: pK-12 STEM I**
Noon - 1:30 pm	Luncheon Location: Great Hall C								
1:30 pm - 3:00 pm	**F3A: Special Session: What is the Role of MOOCs in Engineering Education?**	**F3B: Special Session: Defining and Assessing Engineering Ethics**	**F3C: Approaches to Student-Centered Learning III**	**F3D: Student as Learner**	**F3E: Assessment Strategies**	**F3F: Learning Approaches in ECE**	**F3G: Mobile and Online Learning III**	**F3H: ECE IV**	**F3I: Integrating Design Throughout the Curriculum**
3:00 pm - 4:00 pm	Focus on Exhibits and New Faculty Fellows								
4:00 pm - 5:30 pm	**F4A: Mini-Workshop: Hands-On Activities with Portable Electronics to Engage Students in Analog Electronics Education (lab-in-a-box)**	**F4B: Panel: Effective Recruiting for Diversity**	**F4C: Student Beliefs, Motivation & Persistence II**	**F4D: Innovative Computing Practice II**	**F4E: Cognitive and Affective Domains of Learning**	**F4F: Pathways to Engineering Degrees**	**F4G: Inclusivity and Diversity II**	**F4H: ECE V**	**F4I: pK-12 STEM II**
6:30 pm - 9:00 pm	Reception and Awards Banquet – Ticketed Event Location: Great Hall C								

SESSION GRID - SATURDAY, OCTOBER 26TH

	Room: 14	Room: 15	Room: 16	Room: 17	Room: 18	Room: 19	Room: 20	Room: 2	Room: 4
7:00 am - 2:00 pm	Registration Location: Second Floor Prefunction Area								
7:00 am - 8:00 am	Breakfast Location: Great Hall C								
8:00 am - 9:30 am	**S1A: Special Session: The CS 2013 Computer Science Curricula Guidelines Project**	**S1B: Panel: Engineering Education in Countries of Portuguese Language**	**S1C: pK-12 STEM III**	**S1D: Innovative Computing Practice III**	**S1E: Distance Education I**	**S1F: Innovation and Entrepreneurship II**	**S1G: First and Second Year Programs III**	**S1H: ECE VI**	**S1I: Online Learning II**
10:00 am - 11:30 am	**S2A: Special Session: The Lord of PhD: Fellowship of the Dissertation; A guide to the Engineering PhD**	**S2B: Mini-Workshop: Integrate by Design: Bringing Science, Math, and Technology Together Through the Engineering Design Process**	**S2C: Teaming I**	**S2D: Experiential Learning III**	**S2E: Industry Partnerships**	**S2F: Ethics and Moral Reasoning**	**S2G: First and Second Year Programs IV**	**S2H: p K-12 STEM IV**	**S2I: Interdisciplinary Programs I**
11:30 am - 1:00 pm	Lunch Location: Great Hall C								
1:00 pm - 2:30 pm	**S3A: Mini-Workshop: Integrating International Students' Contests with Software Engineering Courses: Lessons Learned and Best Practices**		**S3C: Student Beliefs, Motivation & Persistence III**	**S3D: Computing Pedagogy Research**	**S3E: Engineering in International Contexts I**	**S3F: Assessment II**	**S3G: Energy Engineering Education II**	**S3H: pK-12 STEM V**	**S3I: Software Engineering, Computing & Informatics Education II**
3:00 pm - 4:30 pm			**S4C: Student Beliefs, Motivation & Persistence IV**	**S4D: Computing II**	**S4E: Engineering in International Contexts II**	**S4F: Assessment III**	**S4G: Distance Education II**	**S4H: pK-12 STEM VI**	**S4I: Interdisciplinary Programs II**

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W2B: Pre-Conference Workshop: The Erlang Approach to Concurrent System Development
5:30 - 8:30 pm
Room: 19

W2C: Pre-Conference Workshop: An Online Revolution in Learning and Teaching: from e-books to MOOCs
5:30 - 8:30 pm
Room: 18

W2D: Pre-Conference Workshop: Teaching Service-Oriented Programming to CS and SE Undergraduate Students (FREE workshop - costs covered by NSF grant)
5:30 - 8:30 pm
Room: 17

W2E: Pre-Conference Workshop: Refining a Taxonomy for Engineering Education Research (FREE workshop - costs covered by NSF grant)
5:30 - 8:30 pm
Room: 16

SESSIONS - Thursday, October 24th

T1A: Mini-Workshop: Exploring Boyer's Scholarship of Application for Submissions to the IEEE Transactions on Education
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T1B: Special Session: Assessing Lifelong Learning: The Role of Information Gathering and Application Skills
10:00 - 11:30 am
Room: 15

Session T1C: Approaches to Student-Centered Learning I
Chair: Irene Rothe
10:00 - 11:30 am
Room: 16

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Chair: Dietrich Romberg
1:30 - 3:00 pm
Room: 17

Session T2E: Computing I
Chair: Rajendra Raj
1:30 - 3:00 pm
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Session T2H: Experiential Learning I
Chair: Abhijit Nagchaudhuri
1:30 - 3:00 pm
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Session T2I: Mobile and Online Learning II
Chair: Jacob Bishop
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T3A: Mini-Workshop: Catching the Wave: Big Data in the Classroom
4:00 - 5:30 pm
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T3B: Special Session: DiSrUpTiOn
4:00 - 5:30 pm
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Session T3C: Innovative Computing Practice I
Chair: Claudio Brito
4:00 – 5:30 pm
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Session T3D: Real World Influences in Experiential Learning
Chair: Elif Miskioglu
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Session T3E: Energy Engineering Education I
Chair: Madhumi Mitra
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Chair: Wookwon Lee
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F1B: Panel: Building an Inclusive REU Program: A Model for Engineering Education
8:30 - 10:00 am
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Session F1C: Faculty Development I
Chair: Rachel Kajfez
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Room: 16

Session F1D: Teams, Communication & Profession
Chair: Kelly Cross
8:30 - 10:00 Am
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Session F1E: Philosophy of Engineering and Engineering Education I
Chair: Eric Pappas
8:30 – 10:00 am
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Session F1F: ECE II
Chair: Dale Carnegie
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Session F1G: Game-Based Learning II
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Chair: Mauricio Dziedzic
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Chair: Manuel Castro
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Session F3F: Learning Approaches in ECE
Chair: Robert O'Connell
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Session F3I: Integrating Design Throughout the Curriculum
Chair: Aurenice Oliveira
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Session F4D: Innovative Computing Practice II
Chair: Irene Rothe
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Room: 17

Session F4E: Cognitive and Affective Domains of Learning
Chair: Stephen Frezza
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Session F4H: ECE V
Chair: Joseph Hoffbeck
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Session F4I: pK-12 STEM II
Chair: Mindy Hart
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SESSIONS - Saturday, October 26th

S1A: Special Session: The CS 2013 Computer Science Curricula Guidelines Project
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S1B: Panel: Engineering Education in Countries of Portuguese Language
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Room: 14

Session S1C: pK-12 STEM III
Chair: Andres Navarro
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Chair: Daniel Krutz
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Session S1E: Distance Education I
Chair: James Rowland
8:00 - 9:30 am
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Session S1F: Innovation and Entrepreneurship II
Chair: Anthony Joseph
8:00 - 9:30 am
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Session S1G: First and Second Year Programs III
Chair: Leen-Kiat Soh
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Room: 20

Session S1H: ECE VI
Chair: Abdel-Hameed Badawy
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Room: 2

S2B: Mini-Workshop: Integrate by Design: Bringing Science, Math, and Technology Together Through the Engineering Design Process
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Session S2C: Teaming I
Chair: Amy Javernick-Will
10:00 - 11:30 am
Room: 16

Session S2D: Experiential Learning III
Chair: James Rowland
10:00 - 11:30 am
Room: 17

Session S2E: Industry Partnerships
Chair: Xiaosong Li
10:00 - 11:30 am
Room: 18

Session S2F: Ethics and Moral Reasoning
Chair: Melany Ciampi
10:00 - 11:30 am
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S3A: Mini-Workshop: Integrating International Students' Contests with Software Engineering Courses: Lessons Learned and Best Practices
1:00 - 2:30 pm
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Session S3C: Student Beliefs, Motivation & Persistence III
Chair: Leen-Kiat Soh
1:00 - 2:30 pm
Room: 16

Session S3D: Computing Pedagogy Research
Chair: Xiaosong Li
1:00 - 2:30 pm
Room: 17

Session S3E: Engineering in International Contexts I
Chair: Velvet Fitzpatrick
1:00 - 2:30 pm
Room: 18

Session S3G: Energy Engineering Education II
Chair: Je-Hyeong Bahk
1:00 - 2:30 pm
Room: 20

Session S3H: pK-12 STEM V
Chair: Julie Rursch
1:00 - 2:30 pm
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Session S4F: Assessment III
Chair: Asako Ohno
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Room: 19

Session S4G: Distance Education II
Chair: Dorothy Jones-Davis
3:00 - 4:30 pm
Room: 20

Session S4H: pK-12 STEM VI
Chair: Min-Chi Kao
3:00 - 4:30 pm
Room: 2

Session S4I: Interdisciplinary Programs II
Chair: Mahesh Banavar
3:00 - 4:30 pm
Room: 4

Computer Engineering Curriculum Guidelines

Eric Durant (Moderator)
Electrical Engineering and Computer Science Department
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***Abstract*— Participants of this pre-conference workshop will learn about the development of computer engineering curricula reports. They will also learn about the revision process and will have the opportunity to provide comment and opinion on drafting an update of the joint ACM and IEEE Computer Society document from 2004 titled, "Curriculum Guidelines for Undergraduate Degree Programs in Computer Engineering" known also as CE2004. The authors of this workshop welcome all participation including overall comments and targeted editing assistance from the computer engineering education community. This activity will ensure that an updated document is a forward-looking summary of state-of-the-art educational practices in the computer engineering field.**

Keywords—Computer engineering; curriculum guidelines; CE2004; ACM; IEEE Computer Society

I. Background

In early 2011, the ACM and the IEEE Computer Society created the CE2004 Review Task Force (RTF) and charged it with reviewing and determining the extent to which the document titled, "Curriculum Guidelines for Undergraduate Degree Programs in Computer Engineering" (CE2004) [1] required revision. The RTF developed and issued survey invitations to over twenty thousand industry and academic constituents in the computer engineering field. It also contacted some ABET industry program evaluators to solicit their input. Although the survey default was anonymity, over sixty respondents provided contact information indicating they were interested in further participation in the revision process.

The RTF reported on its survey of academic and industry constituents in July of 2011. Part of the report included some new or expanded technical skill areas such as system on a chip (SoC) technologies, networking, software engineering agile methods and tools, embedded system design, parallel programming, and hardware/software co-design. It also recommended specific contemporary topics to be strengthened or added while de-emphasizing other topics that appeared to be waning from the mainstream of computer engineering topics.

The RTF found that the majority of what the constituencies believe is important is already covered rather well in CE2004. However, the RTF did identify significant deviations that could guide the revision process toward a document that is appropriately forward looking given the continuing changes in the computer engineering landscape. Thus, this preconference workshop is an effort to engage the computer engineering education community in evaluating the current draft for recommended changes and in planning further revisions to the guidelines with the hope of issuing a preliminary report in 2014 or in 2015.

Additionally, the RTF recommended that the two societies form a joint committee to update and edit the earlier document and to seek input and review from the computer engineering industrial and academic communities through workshops co-located at major conferences [2,3]. At an RTF meeting in Raleigh, North Carolina, the RTF recommended that a team of volunteers lead the revision effort with interim updates as necessary. This new team or special committee would consist of at least sixteen representatives divided equally between ACM and the IEEE Computer Society. At the same meeting the RTF indicated the importance of having international representation. It also recommended that this special

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committee should include representatives from academia, industry, government, and community college groups.

The RTF largely affirmed the contents of the CE2004 report compiled nearly a decade ago. However, the RTF recognized that several significant advances in computer engineering have occurred since that time. The special committee should make key drafts of their revisions available to a wide constituency, including all respondents to the survey who expressed interest in having further input. The special committee should make efforts to include a presence at key conferences both within and outside of the United States.

II. WORKSHOP FORMAT

Discussions and questions will be encouraged throughout this interactive workshop session. The major topics to be covered are:

- Background, goals, and timeline of the revisions effort
- Curriculum types targeted with brainstorming (*e.g.*, Should other degree types be targeted? Should the document address master's degree programs?)
- Body of Knowledge (BoK) structure, changes, size, required and elective topics, with brainstorming regarding the utility of the structure
- Seven key BoK revision areas with brainstorming in areas of participant interest
- Overview of non-technical areas addressed in the document based on the 2011 survey and the FIE'12 special session
- Small group discussions: key technical and non-technical skills needed for computer engineers graduating over the next several years. Groups will share results and the RTF will collect notes from all groups that wish to share them.
- Additional discussion of items of audience interest to include: plans for publishing the next draft, ways to involve more people, access to drafts, opportunities to provide feedback, and opportunities to lead revisions of specific sections.

III. WORKSHOP PRESENTERS

Eric Durant (Milwaukee School of Engineering) is the lead IEEE-CS member of the team and the de facto leader of the RTF. In addition to conducting the workshop, Eric will summarize the activities of the group and key changes contemplated in the current draft of the CE2004 revisions.

John Impagliazzo (Hofstra University) is the lead ACM member of the RTF team and was a member and principal co-author of CE2004 committee. In addition to participating in the workshop, John will present a brief overview of the CE2004 document, describe the evolution and components of the 2004 report, and focus on its body of knowledge.

Susan Conry (Clarkson University) is a RTF member and is the past chair of the Engineering Accreditation Commission (EAC) of ABET. In addition to participating in the workshop, Susan will discuss ways in which the computer engineering curriculum complements the current ABET criteria. She will highlight the essential elements of the criteria and show how the new curriculum satisfies those criteria.

Andrew McGettrick (University of Strathclyde) is the Chair of the ACM Education Board and the ACM Education Council. Andrew is an RTF member and was a member of the CE2004 committee. He will summarize the specific BoK changes in the current draft.

Mitch Thornton (Southern Methodist University) is a RTF member and he is a member, past chair, and past vice chair of the EPE subcommittee working group for the National Council of Examiners for Engineering and Surveying. Mitch is also the vice chair, past chair, and a member of the IEEE-USA Committee on Licensure and Registration. He will focus on the results of the surveys and contrast the suggestions received from industry with those received from academia.

Timothy Wilson (Embry-Riddle Aeronautical University) is the Past Chair of ASEE's Electrical Engineering division for the Southeast region. Timothy is a RTF member and will discuss the revisions timeline.

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Modeling Software the Alloy Way

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***Abstract*—Until recently, those who taught mathematical modeling (or "formal methods") faced daunting challenges. First, most modeling tools used seemingly esoteric notations that were hurdles for many students. Even if the notation could be tamed, the tools themselves were rarely more than syntax checkers, possibly with support for simple expression evaluation. Venturing beyond this requires understanding of proof theories and strategies well beyond that typical of other engineering disciplines. What is more, the tools worked at a much lower level than that of the domain itself; it was easy for students to miss the forest for the trees.**

The development and release of the Alloy from MIT has improved the situation dramatically. With Alloy, instructors now have a tool that supports formal structural and behavioral modeling (using C-like syntax), along with state space exploration and property verification using relational logic, predicates, and assertions The tradeoff involved - only first order systems over finite domains can be analyzed - is not problematic in practice.

The workshop will introduce Alloy - both the language and support tool - to faculty interested in formal methods and mathematical modeling. After a brief introduction to Alloy concepts, the tool and language will be explored by interactively developing a simple software system model. This approach mirrors the way Alloy is taught and used within RIT's undergraduate software engineering program.

***Keywords*—formal methods; mathematical modeling; software engineering education.**

I. Workshop Organizer

Professor Lutz has almost 40-years of academic experience in computer science and software engineering. In the 1990s he instigated and led the effort to establish the nation's first B.S. in Software Engineering at RIT. He has extensive industrial and consulting experience, which he has brought into the courses he teaches.

Professor Lutz has taught courses in formal methods and modeling for over 20 years, first in RIT's computer science program, and for the past 15 years in the software engineering program. He has used Alloy[1,2] for over a decade, and has reported on his experiences at ACM[3] and ASEE[4] conferences..

II. Topic Outline

The Context: Alloy vs. Other Formal Methods

During this time participants will install Alloy on their notebooks.

What Alloy's Analyzer Can (and Cannot) Guarantee.

Alloy Foundations: Signatures, Atoms, Sets, Relations.

Specifying constraints: Facts and Predicates.

Exploring the state space: The Run command.

Relational navigation: Joins and Transitive Closures,

Verifying properties: Assertions.

Questions and Discussions.

III. Audience (20 max)

The workshop is primarily for computer science, software engineering and computer engineering faculty using discrete mathematics to describe and analyze software system structures. Participants should bring a notebook computer (Mac / Linux / Windows) with a USB port for installation of the software.

IV. Logistics

Computer video projector system (screen or large monitor).

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Programming Board Game Strategies in CS2*

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***Abstract*—This workshop presents freshman-level projects based on designing and programming player strategies for well-established board games. Unlike modern computerized games, board games are typically discrete, where the game state can be stored in basic data structures, and a variety of search techniques can be used to evaluate possible player moves. Such board games provide a natural context for many introductory Computer Science topics. The strategy component makes the project open-ended, motivating the students to keep improving their code. After appropriate background information is presented, to better understand how the project works from the students' perspective, participants will act as students, brainstorm through a variety of data structures, and develop a small part of a player module.**

Keywords—data structures; software design; algorithms; introductory computer science curriculum

I. Introduction

Well-established board games such as Quoridor [3], The aMAZEing Labyrinth [2], and San Francisco Cable Cars [1] provide excellent opportunities to teach data structure and algorithm design to students in computer science. Because of the discrete turn-taking nature of the games and the simple organizations of the game board environments, a variety of search techniques can be used to evaluate possible player moves. We have developed game engines that graphically display the current game state as they cyclically call the individual player modules to make their moves. Every student team designs and implements its own player strategy in one of these player modules. Our latest engine, for the Quoridor game, runs remotely via a web service, which has given us the opportunity to provide client-side support code for player modules written in multiple languages, currently Java and Python. We provide, in each language, a player module template into which the students put their strategy implementation.

We tested the framework at the Rochester Institute of Technology as part of the Computer Science 2 course taken by over 400 students from a variety of majors.

The participants at the workshop will gain practice developing a simple path-determining algorithm for the Quoridor game. They will also experience testing a student code in the environment of a real game engine.

The participants will receive the supporting project documentation and all necessary code modules so that they will be able to utilize the games in their own classes.

Work supported by the NSF via the TUES grant program, award 1044721

II. The True Term Project

A. Design

Through a small package on the student's computer, the student's code accesses a web-based "engine" service that displays the current state of the game back inside the student's web browser. It cyclically calls functions in the student's player module code. The student implements three functions: one that is called by the engine at the beginning of the game to initialize the player module's data structures; one that is called by the engine whenever it is that module's turn to move and that returns the chosen move of their player; and one that is called after every move, informing the module of the move so that it can update its data structures accordingly.

B. Assignment Logistics

The project is split into four separate parts to guide the students in implementing their strategies. In the first part, the students implement a function useful to the game, for example searching for the shortest path through a maze. In the second part, their software needs to be able to play as a single player in the game, computing moves that follow the rules of the game and updating data structures accordingly. The third part has them play against other players – without the need to win. The fourth part consists of designing and experimenting with a player strategy, requiring minimally that the students consistently beat an unsophisticated or random player. Many students go well beyond this base line and develop very clever strategies. At the end of the term, the students' players compete in a not-for-credit tournament.

At RIT there are problem-solving sessions scheduled at the time each new part of the project is assigned. The instructions for these sessions are part of the workshop's documentation package. Instructors use these sessions in their classes to stimulate discussions about the project among small groups of students. The groups develop rough designs on paper before they proceed to their implementations. In other courses it may be more appropriate to dictate, or at least strongly suggest, specific approaches instead. It could also be an option whether students develop and submit their coded solutions individually or in teams.

In our experience many students go well beyond what is required to pass the course. They seek out advanced computing concepts or come up with advanced approaches on their own in order to give their players an edge over other players.

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III. WORKSHOP SCHEDULE

The goal of the workshop is to offer the project materials to the attending educators for use in their own courses. One of the best ways to assess the applicability of the materials to their own classes is to get faculty to go beyond just learning about the project by experiencing the work for themselves.

In brief, the workshop will introduce the projects and discuss their relevance to typical CS2 topics, demonstrate the "engine" software and the functions the students are asked to implement, describe the four project parts in detail for the Quoridor game, present several student-implemented strategies competing against each other, and finally give the participants a chance to develop their own strategies for the chosen game. A more detailed schedule follows in **Error! Reference source not found.**. The total time for this workshop is **3 hours**.

After the workshop the participants will be familiar with the described CS2-level project, which is open-ended enough to accommodate the beginning programmer with the achievable goal of beating a random player. They should also have a fair idea of what it takes to build an engine for new games, including ones that are simpler or more advanced than the ones shown.

IV. MATERIALS PROVIDED

Participants will be provided with both the software and documentation for the project. The software includes access to a web-based engine that runs games for students, and personal copies of client support software that is easily adapted to many languages. (Currently we support Java and Python versions.) Participants also get the full set of materials for the project, including individual project part descriptions and the related "problem solving" documents. The problem solving documents are to be used in a course to stimulate discussions about the project among small groups of students. The rough designs so generated are used as starting points for the lab work.

The participants will bring home hard copies of the documents and will be given a URL where the documents, supporting software libraries, and the game engine service will be made available.

TABLE I. WORKSHOP SCHEDULE

Topic	**Time Needed (min.)**
Introduction	5
Objectives and rationale for the board game projects	20
Brief description of individual board games used in our projects, and a short discussion of the underlying data structures and algorithms	15
Detailed description of the rules of one board game	10
Demonstration of the corresponding engine	10
Description of the individual project parts	10
Demonstration of student-implemented strategies	5
Break	15
Hands-on session: participants act as students	75
Discussion	15

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Why are continuous-time signals and systems courses so difficult? How can we make them more accessible?

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***Abstract*— The introductory continuous-time signals and systems (CTSS) course is widely considered one of the most difficult courses in electrical and computer engineering (ECE) curricula. This workshop is an interactive discussion about sources of difficulty and what can be done to help improve student learning and understanding. In the first part of the workshop, discussion will be sparked and encouraged through presentation of historical data and directed questions. The goal will be to advance a continually developing understanding of the problem. In the second part of the workshop, attendees will learn about hands-on activities that are being done at Bucknell and Rose-Hulman to help address what the authors think some of the issues are. Attendees will have an opportunity to attempt some of these activities, use the technology to develop their own activity, and review the activities with regard to the previous discussion about learning difficulties. Each attendee is highly encouraged to bring a laptop and will receive a USB memory stick with the software, lesson plans, materials, and background literature that support this workshop.**

Keywords—signals and systems; continuous-time; active learning; hands-on activities

GOALS OF THE WORKSHOP

The introductory CTSS course is one of the most difficult courses that students encounter in an electrical and computer engineering (ECE) curriculum. This is evidenced at Rose-Hulman over the last 10 years by drop/failure rates that are at least two times greater than any other course except electromagnetics. We have received NSF funding to explore why students find these courses so difficult and to determine effective methods for helping students grasp the concepts. This workshop offers engineering and science faculty an engaging opportunity to explore how to improve learning in introductory continuous-time signals and systems (CTSS) courses [1]. The two primary goals of the workshop are to provide:

- an interactive discussion that will try to provide as broad a perspective as possible to the question "Why is signals and systems difficult?" and,
- a hands-on experience with laboratories that developed and used at Rose-Hulman Institute of Technology and Bucknell University over the past 4 years to improve learning in CTSS courses

CONTENT OF THE WORKSHOP

While many people are developing supplemental materials for CTSS courses, very little exploration of the sources of difficulty from the student's perspective has been done[2][3]. There are many opinions and ideas with regards to these sources, but we would like to take a scientific approach to arrive at more definitive answers. Once more of these sources are identified, we can tailor the supplemental materials to be more effective. We are analyzing historical data and developing new studies to try to identify more of these issues. In addition to those studies we want to gather input from the community at large to try to get as broad an understanding of the problem as possible. The first part of the workshop will be an interactive discussion with the purpose of gathering such input. Discussion will be sparked by presenting data, current ideas, and directed questions. The results of this discussion will be used to guide the remainder of the workshop.

We have been trying to address issues that are related to lack of motivation and learning by creating application-oriented hands-on active-learning opportunities for students[4][5]. There are many examples of such opportunities described in the literature, but most of these activities make use of MATLABP®, LabVIEWP®, or DSP hardware [6]. The exercises described in this workshop are based on analog circuits and real-world applications of continuous-time signal processing and system modeling. There are certainly advantages to using software simulation tools for laboratory exercises because they are relatively inexpensive and students can perform many "experiments" relatively quickly. In fact, many of the exercises described in this workshop could be simulated entirely using such software tools. We are not advocating the elimination of these simulators, and in many cases use them for both prelab exercises and/or analysis of results. However, there is one key advantage to using hardware-based hands-on activities and real-world applications that simply cannot be obtained with software-only based activities. Practicing engineers use the theoretical and mathematical concepts from CTSS courses to model real-world

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physical phenomena. The overwhelming majority of students have never had an opportunity to connect those theoretical concepts with the physical phenomena that they are trying to model[2]. So it's possible that a lack of motivation could be due to a lack of understanding of what use the concepts have. While software tools can help students visualize the concepts, they are in-themselves also modeling tools. An important way for students to gain an experience of the phenomena that they are trying to model is to actually experiment with them[7]. Using a real system with real-world applications creates a degree of credibility and relevance that is not possible with software simulations. When students manipulate these systems, there is an understanding that they are changing something physical rather than simply adjusting a number.

In order to facilitate application-oriented hands-on activities, we have developed a number of laboratory lesson plans and an analog printed circuit board, the signals and systems exploration platform (SSEP)[8]. The SSEP can be configured easily to sum, multiply, filter, and sample continuous-time signals. With an onboard microphone, ECG/instrumentation amplifier, and generic signal input, a wide variety of signals can be studied and manipulated. During the workshop, attendees will be able to load the software onto their own laptop from a USB memory stick and work individually with an SSEP.

This workshop will provide a detailed introduction to the SSEP and some of the lesson plans that were developed both with and without the SSEP in mind. The attendees will then have an opportunity to run through some of the lesson plans. Time will also be given for attendees to play with the equipment and develop a mini-lesson plan of their own. Finally, in order to close the loop, attendees will then be able to provide feedback relating the activities to the previous discussion about sources of difficulty in CTSS courses.

INTENDED AUDIENCE AND NUMBER OF ATTENDEES

We expect this workshop to be primarily of interest to undergraduate electrical engineering faculty who are involved in signal processing education. We will also make the activities accessible to pre-college educators who are attending the conference. In fact, the instrumentation used in this workshop is currently being used in high-school physics courses. The examples and materials presented would also be of interest to those teaching Fourier theory in other disciplines such as physics, mathematics, and other types of engineering. We would expect to have approximately 10-15 attendees.

WORKSHOP AGENDA

I. Introduction to the workshop. **(10 minutes)**
II. Participant discussion of the initial question: Why is CTSS such a difficult subject for students? **(30 minutes)**
III. Introduction to hands-on activities being done at Rose-Hulman and Bucknell **(15 minutes)**
IV. Overview of the SSEP **(15 minutes)**
V. Supervised activities using the SSEP **(60 minutes)**
VI. Free time with the SSEP and exploration of other ideas. **(30 minutes)**
VII. Review of hands-on activities with regard to the initial question. **(15 minutes)**
VIII. Assessment of this workshop **(5 minutes)**

TAKE AWAY SKILLS

We are expecting attendees to leave the workshop with a greater appreciation for the sources of difficulty in CTSS courses and some ideas of simple hands-on activities that can be used to help make the material more approachable to the students. They will have some personal experience with these activities and knowledge about how to use the SSEP and acquire the hardware. They will be given a memory stick containing all lesson plans and software so that they could begin using these activities at their own institution. They will also be invited to attend a more in-depth summer workshop at Rose-Hulman during the summer of 2014 and to participate in an ongoing discussion of the issues.

QUALIFICATIONS OF THE PRESENTERS

Mario Simoni is an Associate Professor of Electrical and Computer Engineering at Rose-Hulman Institute of Technology. He has been teaching for 12 years including the introductory CTSS course and analog circuits. He has been teaching for 12 years including the introductory CTSS course and analog circuits. He developed the SSEP and associate hands-on activities with input from Maurice Aburdene. He has been using these activities for the past three years.

Maurice Aburdene is a Professor of Electrical Engineering at Bucknell University. He has been teaching for over 30 years, including courses on linear systems and signal processing.

Farrah Fayyaz is a doctoral student in the School of Engineering Education at Purdue University. She holds Bachelors and Masters degrees in electrical engineering from the University of Engineering and Technology, Lahore, Pakistan and taught signals and systems, digital signal processing, analog circuits and microelectronics in Pakistan for more than eight years. Her Masters research focused on identifying student difficulties in learning signal analysis. She will continue investigating students' understanding of various concepts in signals and systems for her PhD dissertation.

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Using Problets for Problem-Solving Exercises in Introductory C++/Java/C# Courses

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***Abstract*—This workshop will help participants introduce problem-solving exercises into their introductory C++/Java/C# programming courses. The purpose of problem-solving exercises is two-fold: they supplement classroom instruction and complement the programming projects traditionally assigned in the course. The benefits of problem-solving exercises are many: they improve students' comprehension of programming constructs, their self-confidence, especially that of female students, and their coding skills. In this workshop, problets (www.problets.org) will be introduced as a tool for problem-solving exercises. They parameterize problems to deter plagiarism; provide step-by-step explanation of the correct solution to each problem, which helps students learn; and adapt to the learner's needs. They are a web-based service freely available for educational use. Problets have been rigorously evaluated, and have been adopted and used by dozens of instructors every semester since 2004. The workshop is appropriate for instructors of introductory C++/Java/C# programming courses in Computer Science or engineering. Participants are asked to bring a WiFi-enabled laptop to the workshop for hands-on experience.**

Keywords—introductory programming, problem-solving, software tutors, C++, Java, C#

I. Goals of the Workshop

Solving problems is an integral part of STEM learning. The goal of this workshop is to help participants introduce problem-solving exercises into their introductory C++/Java/C# programming courses using problets (www.problets.org), a web-based service freely available for educational use. Evaluations have shown that problets improve students' knowledge of programming constructs [1], their self-confidence in the material [2] and their ability to write code [3]. The exercises presented by problets are meant to supplement classroom instruction and complement programming projects traditionally assigned in the course.

II. Description of the Content

The workshop will be an introduction to using problets to incorporate problem-solving exercises into introductory C++/Java/C# programming courses. Topics will include a description of the software service, its history, its problem-generation, feedback and adaptation features, the introductory programming topics and learning objectives that it covers, the types of problems it presents, the benefits of using it in the introductory course, the ways in which it can be used in a course, the support provided to faculty adopters, the process for adopting and using problets in a course, and the opportunities for using problets in one's own research on teaching and learning of introductory programming. In addition, participants will get to try out problets hands-on, on different topics and types of problems, and have the opportunity to resolve technological and pedagogical issues in incorporating problets into their own course(s) at their institution.

III. Qualifications of the Presenter

The presenter is the developer of problets. Funded by grants from the National Science Foundation, he has worked on the development of problets for over a dozen years, and has been using them in his own courses all those years. He has been disseminating problets through conference presentations and NSF showcases. Finally, he has been supporting the use of problets by dozens of faculty adopters each semester since 2004, setting up the service for them, configuring problets for their needs and generating reports of student use for them.

IV. Workshop Agenda

1. Introduction, history, topics, problem types: (30 minutes)
2. Problem generation features: (5 minutes)
    - Hands-on activity – Arithmetic Expressions: (15 minutes)
3. Feedback features – Delayed, Error-flagged: (10 minutes)
    - Hands-on activity – Selection and code-tracing (15 minutes)
    - Hands-on activity - Debugging functions (15 minutes)
4. Learning objectives and adaptation feature: (15 minutes)
    - Hands-on activity – Student setup of arrays [15 minutes]

5. Benefits of using problets for students, Ways to use problets in a course – (15 minutes)
6. Adopting problets, support provided to adopters (15 minutes]
    - Demonstration – Problem and learning objective reports
7. Teaching and learning research with problets (15 minutes)
8. Questions and answers, Wrap-up (15 minutes)
9. Optional demonstrations (time permitting): Classes, Bit-wise expressions, Assignment expressions

V. Audience

This workshop would be of interest to instructors of introductory C++, Java or C# programming courses, who would like to incorporate more problem-solving, active-learning, and blended-learning activities into their courses. The material is appropriate for introductory programming courses taught in Computer Science, engineering or business schools, baccalaureate or associate's degree-granting institutions as well as high schools.

VI. Expected Outcomes

Attendees will learn how they can use problets to incorporate problem-solving and active-learning exercises into their introductory C++/Java/C# programming courses. They will get hands-on experience using problets and get the opportunity to explore pedagogical and technological issues in incorporating problets into their own courses. Evaluations have shown that problets help improve students' knowledge of programming constructs, improve their self-confidence (especially that of female students [4]), and their ability to write code in the course.

VII. Additional Information

The web site www.problets.org contains demonstration versions of various tutors, listing of the learning objectives covered by each problet, publications covering the results of evaluating problets, student testimonials, and a sample of the report provided to adopters.

Acknowledgment

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Inspiring Inventive Genius in Middle and High School Students with Chain-Reaction *STEAM Machines*™

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***Abstract*—In this hands-on pre-conference workshop, participants will learn about the STEAM Machines™ program, which teaches middle and high school students the engineering design process in the context of designing and building Rube Goldberg®-style chain reaction machines.**

Keywords—design; K-12; outreach; creativity; project

I. Description

A *STEAM Machine*™ (http://steamlabs.asu.edu) is a Rube Goldberg®-style chain reaction contraption that completes a simple task in an overly complex way. This hands-on workshop introduces participants to the project-based *STEAM Machines*™ program, where middle or high school students brainstorm ideas, design, and build creative inventions that solve everyday problems - like sending a text message - using chain-reaction machines. Students are challenged with learning and applying the Boston Museum of Science Engineering is Elementary® engineering design process and integrating science, technology, engineering, arts, and math concepts together in the design and construction of their machines. In addition, the program embeds students in local or geographically-distributed teams to expose them to other cultures, improve the quality and quantity of their design communication, and simulate a trans-national engineering and manufacturing environment by having students swap designs with peers. Machines designed by geographically-distributed teams have the added constraint that their parts must connect together across camp sites using communication technology, resulting in machines that start at one site, progress through a number of challenging intermediate steps, and culminate by completing the simple task such as popping a balloon at the final site. This hands-on workshop will begin with a description of the *STEAM Machines*™ program, and a video of a chain-reaction machine from a recent camp offering. Examples of how science, technology, engineering, arts, and math learning objectives are addressed by the curriculum (including 21st century skills) will be presented, along with the pedagogical techniques employed. Opportunities for assessment of knowledge, skills, and attitudes of students will be discussed. Then, results of current design-based research on the *STEAM Machines*™ program will be presented including a discussion of its effectiveness and impact. Workshop participants will have the opportunity to engage in a hands-on *STEAM Machine*™ design activity, followed by discussion and reflection on how the program could be adapted for implementation at other sites. Student pathways for participation in other engineering outreach programs will be presented, including the Rube Goldberg Machine Contest® (http://www.rubegoldberg.com). Finally, participants will receive sample curriculum resources for use in their programs.

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The Erlang Approach to Concurrent System Development

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***Abstract*— The prevalence of multi-core processors means application developers can no longer ignore concurrency and its attendant problems of data races, deadlock, safety, and liveness. Imperative languages such as Java and C, based on shared, mutable state, have added locks, semaphores and condition variables to address these problems; unfortunately, these locking approaches are notoriously error-prone.**

Functional ("single assignment") languages with immutable state have been promoted as tools to mitigate these problems. In particular, Erlang, a functional language with roots in Prolog, has been used by Erickson, Ltd., to develop robust, concurrent, fault-tolerant, communications switches (31ms downtime per year). This workshop will introduce Erlang to educators interested in the language *per se* as well as those focusing on concurrent system development. The goal is to encourage the use of both imperative and functional languages in teaching about concurrency.

Participants will install the Erlang system on their notebooks so as to engage in activities along with the organizer. Both sequential and concurrent systems - small but complete - will be developed in conjunction with the presentations. Time is allocated at the end of the workshop to discuss the pedagogical issues involved in adopting Erlang or similar technology.

Keywords—functional vs. imperative languages, concurrent and distributed systems, software engineering education.

I. Workshop Description

Until quite recently, dealing with concurrency was the domain of specialists in operating systems and transaction processing. Today, the prevalence of multi-core processers means these issues can no longer be ignored by application developers. What is more, concurrency highlights the problems of extending imperative, mutable state languages such as Java and C into this arena: synchronization and controlled access to shared, mutable state via locks and condition variables are notoriously error-prone.

Functional languages (for example, Haskell [1], Clojure [2] and Scala [3]) have been proposed as tools to mitigate some of these problems. A key characteristic of these languages is the elimination of or severe restriction on mutable state. The program effects are not caused by changing values in memory cells, but rather by sophisticated composition of pure mathematical functions. Of course any implementation on a traditional instruction set will manipulate memory, but the data structures and algorithms need only be created once; the bulk of the software is written functionally.

Erlang [4-5], a functional language with roots in Prolog, has been used by Erickson, Ltd., to develop robust, fault-tolerant, distributed communications switches. These switches exhibit “nine nines availability” (less than 32 ms of downtime per year). More recently, Erlang has incorporated symmetric multiprocessing support, allowing Erlang processes to execute with real as well as virtual concurrency. Commercially, Erlang is a key component in well-known applications such as GitHub [6] and Twitter [7], and is the language to develop the CouchDB [8] database system.

The goal of the workshop is to expose computing educators to Erlang as a vehicle for concurrent software design and implementation. With the workshop experience in hand, attendees will have the basic knowledge needed to assess the appropriateness of Erlang (and similar languages) in the context of their institution.

II. Workshop Organizer

Professor Lutz has almost 40-years of academic experience in computer science and software engineering. In the 1990s he instigated and led the effort to establish the nation’s first B.S. in Software Engineering at RIT. He has extensive industrial and consulting experience with the design and implementation of concurrent systems, which he has brought into the courses he teaches.

Most recently he has worked on Erlang-based projects with several independent study students. As part of RIT's transition from quarters to semesters, he is incorporating Erlang as part of a concurrent and distributed systems course now focused solely on Java and and its mutable state concurrency.

III. Topic Outline

Issues in concurrency: race conditions, deadlocks, livelocks.

Problems with mutable state approaches.

Functional programming concepts and their applicability to concurrency.

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Erlang the Language

Erlang shell

Expressions; variables & single assignment.

Atoms, numbers, tuples, lists.

Assignment as pattern matching.

Modules and functions; pattern matched arguments.

Clauses; selection via case statement.

Recursive definitions; tail-recursive functions.

Process spawning; sending and receiving messages.

Concurrent System Development with Erlang

Processes, actors, and controlled state mutation.

Erlang: concurrency problem mitigation, not cure.

Process design heuristics and patterns.

Fault-tolerance and "fail fast".

Monitors and fault recovery.

Teaching courses with Erlang.

Projects based on Erlang.

Open discussion.

IV. AUDIENCE (20 MAX)

Computer science, software engineering and computer engineering faculty interested in functional languages and their application to concurrency. Participants should bring a notebook computer (Mac / Linux / Windows) with a USB port for installation of the software.

At the end of the workshop, participants will have:

1. Installed versions of the Erlang system and accompanying documentation,
2. Basic knowledge of Erlang syntax and semantics,
3. An overview of Erlang's approach to classic concurrency issues, with a focus on how it differs from that of imperative languages,
4. Used Erlang to create a simple client/server system,
5. Discussed the advantages and disadvantages of using Erlang in the classroom.

V. LOGISTICS

Computer projector with screen.

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An Online Revolution in Learning and Teaching

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***Abstract*— College-level online learning took off in a big way in 2012, and is likely to impact every department and teacher in some manner. This workshop will highlight major developments in online education technology in engineering and computer science. The workshop will highlight recent online trends like flipped classrooms and MOOCs, will survey various authoring and delivery platforms like EdX and Zyante, summarize some research on online/flipped teaching, discuss methods for instructors to collaborate on delivering instructional experiences, and highlight experiences by teachers of online and hybrid courses.**

Keywords—Online education, MOOCs, hybrid classrooms, flipped classrooms, inverted classrooms, group teaching.

I. Overview

This workshop will highlight major developments in online education technology in engineering and computer science. The workshop components include:

- Overview of latest developments, including MOOCS, flipped classrooms, web-native learning material, and the growth in online courses.
- Summarizing of various authoring and delivery platforms, such as those from EdX (edx.org), Inkling (inkling.com), Zyante (zyante.com), along with other collaborative teacher and student technologies.
- Highlighting some studies of the flipped classroom model, utilizing MOOCs in traditional classes, and utilizing interactive learning material.
- Discussion of teaching roles and skills and how to effectively execute community teaching.
- Sharing of some online teaching experiences.
- Discussion on directions of the field, and ideas for teachers on adapting to the online trend.

II. Presenters

Diane Rover is a Professor of Electrical and Computer Engineering at Iowa State University. She serves as the director for two large-scale NSF-funded education related programs: IINspire LSAMP is an alliance of sixteen institutions to broaden participation in STEM; and SP@ISU is a campus-wide program to support the broader impacts work of faculty. She is also the principal investigator on NSF STEP and S-STEM grants at Iowa State that have focused on the recruitment, retention and success of engineering students. She received her B.S. in Computer Science and M.S./Ph.D in Computer Engineering from Iowa State Univ. She was formerly on the faculty of Michigan State Univ.

Yacob Astatke is Associate Chair of Electrical and Computer Engineering at Morgan State Univ. He has over 15 years experience in the design/delivery of web-based course supplements for electrical engineering courses. He directs "Foundations of Mathematics", a free online math course, offered to all pre-freshman engineering students. He also teaches the "Electric Circuits" and "Introduction to Electrical Laboratory" courses completely online using innovative pedagogy and interactive Mobile StudioTM technology. He is recipient of the 2012-2013ASEE Mid-Atlantic Distinguished Teacher Award. He received his B.S. in Electrical Engineering and Doctor of Engineering degrees from Morgan State Univ, and his M.S. in Electrical Engineering from Johns Hopkins Univ.

Smita Bakshi is CEO of Zyante, a Silicon Valley startup company developing a framework to create online interactive animated learning material, and building a community of content contributors especially for core computing and engineering topics. The web-based offerings are being used by over 2000 students at dozens of leading universities including UT Austin, UC Davis, UC Riverside, Univ of Arizona and others. She was formerly on the faculty of Univ. of California, Davis in Electrical and Computer Engineering. She received her Bachelor of Engineering from the Delhi Instit. of Technology, and her M.S./Ph.D. in Computer Science from the Univ. of California, Irvine. She also received her M.B.A from Harvard Univ. She has been a software developer and product manager at several companies including Synplicity, Intuit, Symantec, and Veritas.

Frank Vahid is a Professor of Computer Science and Engineering at the Univ. of California, Riverside. He has co-authored several college textbooks with various publishers using different publishing formats. He created the first online courses at UC Riverside, all on computer science topics, and assists with the course offerings. He is part of the Univ. of California's Online Education 10-campus pilot project. His recent focus is on creating a framework to help instructors develop interactive animated online content, and creating interactive web-native lower-division computing, engineering, and math content. He has been principal investigator on several education-focused NSF grants. He has a B.S. in Computer Engineering from Univ. of Illinois, Urbana/Champaign, and M.S./Ph.D. in Computer Science from Univ. of California, Irvine.

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Teaching Service-Oriented Programming to CS and SE Undergraduate Students

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***Abstract*—Service-Oriented Programming (SOP) is a relatively new programming paradigm that supports the development of new software applications using existing services as building blocks. SOP has gained significant popularity in industry as it increases software reuse and productivity. As the SOP paradigm can improve modern software development, the presenters have created a course-module based approach for incorporating SOP into Computer Science (CS) and Software Engineering (SE) curricula; a course module is a distinct curricular unit such as a lab or teaching component that an instructor may incorporate into an existing course typically without requiring formal curricular approval. SOP course modules have been developed for inclusion in standard courses in many CS and SE programs; for example, an introductory SOP course module in a CS2 course while advanced modules for courses such as Programming Language Concepts, Software Engineering, or Web Services. This workshop will present basic concepts and techniques of SOP and describe how the course-module approach toward SOP can be adapted for the participants' own teaching. The typical participant would be a faculty member with some background in programming, and is interested in learning more about SOP but does need not to have prior web service programming experience.**

Keywords—service-oriented programming; service-oriented architecture; web services; computer science; software engineering

I. MOTIVATION

This workshop presents Service-Oriented Programming (SOP), which is a new programming methodology that permits the development of software applications by connecting and composing existing services [1], thus facilitating software reuse. SOP builds on object-oriented programming (OOP), as services are developed in an object-oriented (OO) fashion and then wrapped as Web services. OOP provides the basis to model and implement software components as objects, while SOP permits modeling and implementing software systems as web-accessible services, and has attracted attention from the industry as it substantially improves software reuse. SOP leverages the web's communication infrastructure to provide easier access to existing software components. Consequently, more and more companies have begun to offer their business functionalities via web services. Some search engines have been developed specifically for finding existing web services. For example, www.programmableweb.com indexes over 5814 web services and 6610 mashups (which are applications, built on web services). Other search engines, such as www.webservicelist.com and www.biocatalogue.org, list web services by application domains.

This workshop is broadly divided into two major parts. In the first part, the presenters will describe the problem areas and motivation underlying the SOP paradigm, the techniques of designing and implementing services, and the techniques for developing applications using services. Topics covered include service-oriented architecture, web services, service description and discovery, service invocation, service composition architecture, and core SOP protocols, e.g., Web Services Description Language (WSDL), Universal Description Discovery and Integration (UDDI), Simple Object Access Protocol (SOAP), and Representational State Transfer (REST). Participants will also be provided guidance to develop and deploy web services in a stepwise fashion, and be split into small groups for an activity, e.g., to compare OOP and SOP. In the second part, participants will be introduced to the developed teaching materials, including a demo of the SOP framework that exemplifies SOP techniques. Participants will again work in groups and discuss issues about how to incorporate SOP course modules into their existing courses.

This workshop is in line with the goals of FIE because it aims to introduce new software development methodology into existing STEM curricula.

II. WORKSHOP DESCRIPTION

As stated, this workshop will introduce the major concepts and technologies of SOP, and demonstrate the development of web services and SOP applications. The presenters will also share their curricula materials and experiences in teaching SOP in programming courses for undergraduate students.

Table I outlines the tentative agenda for the workshop.

TABLE I. WORKSHOP AGENDA

Event	Duration
1. Presenter and participant introductions	10 min
2. SOP fundamentals 2.1 The evolution of programming abstractions 2.2 Motivation for SOP 2.3 Service-oriented Architecture 2.4 Examples of web services 2.5 Team activity: Each group will do an exercise, for example, given a problem, provide and compare corresponding OOP and SOP solutions.	40 min
3. SOP Standards 3.1 WSDL 3.2 SOAP & REST 3.3 UDDI	30 min
4. SOP Development Environment 4.1 .NET Framework for Windows Communication Foundation (WCF) services 4.2 Netbeans + GlassFish for Java-based services 4.3 Hands-on exercises of SOP.	30 min
5. SOP teaching materials 5.1 SOP framework demo 5.2 Course module for CS2 5.3 Course module for Programming Language Concepts 5.4 Course module for Software Engineering 5.5 Team activity: Each group will do another exercise, for example, discuss how to effectively and smoothly incorporate the course modules to the targeted course.	50 min
6. SOP: Reflection & Conclusion	20 min

III. WORKSHOP LEARNING OUTCOMES

The workshop's learning outcomes are as follows:

- Attendees will explain the main issues and concepts in SOP.
- Attendees will solve a problem using SOP techniques.
- Attendees will have in-depth experience with SOP.
- Attendees will explain and apply SOP teaching materials, including the SOP framework and course modules, developed by the presenters.

Among other outcomes, the presenters will make their SOP curricular materials available to the participants.

IV. QUALIFICATIONS OF THE PRESENTERS

Of the five authors, the three who will be presenting this workshop are Rajendra K. Raj, Tom Reichlmayr and Alex Pantaleev. Professors Raj and Reichlmayr are faculty members at Rochester Institute of Technology and Dr. Pantaleev is a faculty member at SUNY at Oswego.

Rajendra K. Raj is a professor in RIT's Computer Science department, and his current research interests currently include in large-scale data management, distributed/mobile computing, security, and critical infrastructure protection. He is also interested in computing education methodologies, and is involved in program assessment, evaluation and accreditation. Dr. Raj teaches courses in database systems, cloud and large-scale data management, distributed systems, and security. Prior to RIT, he was a software designer, developer, architect and manager in the Information Technology Division at Morgan Stanley & Co., where he architected, built and managed globally distributed database infrastructures for financial applications handling big data. He received his PhD in Computer Science from the University of Washington, Seattle.

Tom Reichlmayr is an associate professor in RIT's Software Engineering department. He has extensive experience in curriculum development and cooperative learning. He has developed and coordinated an introductory software engineering course as well as advanced courses in software engineering design and process. He has actively converted software engineering courses from traditional lecture/lab format to studio classroom delivery.

Alex Pantaleev is an assistant professor in SUNY Oswego's Computer Science department that offers degrees in Computer Science, Information Systems and Software Engineering. His current research interests include service-oriented architecture, computer science education, and distributed computing, especially as it applies to computer game development. Dr. Pantaleev's work has appeared in conferences such as ASEE and ITiCSE. He has developed two new courses and redesigned several others at SUNY Oswego including CS2 and web services. He is the major creator of a new concentration in the Computer Science major at Oswego.

All presenters are experienced teachers who use active learning techniques extensively and teach in multiple settings including traditional classroom or blended settings.

ACKNOWLEDGMENTS

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Refining a Taxonomy for Engineering Education Research*

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***Abstract*—Engineering education research is a diverse, rapidly-evolving, international field in which scholars apply the methods of educational research to address a variety of issues pertaining to teaching and learning in engineering. As the field has grown, so has the need for a standardized terminology and an updated taxonomy to map and communicate research initiatives. Refining a U.S-centric taxonomy is the focus of this workshop. Participants will engage in activities to reflect on a draft taxonomy and offer suggestions to refine it. Participants are encouraged to bring a computer, and interested participants at any experience level are encouraged to join this dialogue.**

Keywords— outline; taxonomy

I. Goals

The goals of this workshop are to:

- Apply the taxonomy to a series of related abstracts
- Engage the community in refining the taxonomy

II. Description of the Workshop

The workshop will involve opportunities for participants to use the taxonomy (through a computerized interface) to identify keywords for a series of related abstracts as well as to work with others in refining the taxonomy. The workshop will be interactive.

III. Workshop Agenda

15 minutes: Welcome and overview
60 minutes: Using taxonomy
90 minutes: Revising the taxonomy
15 minutes: Next steps and wrap up

IV. Presenter Qualifications

The author has engaged in a project to develop a U.S. centric taxonomy for the field of engineering education research. This workshop is one of multiple opportunities for community engagement.

V. Intended Audience

Interested participants at any experience level are encouraged to join this dialogue. There is no limit on number of attendees.

VI. Take Away Materials for Attendees

Participants will contribute to a dialogue to create a U.S.-centric taxonomy for the field of engineering education research.

VII. A/V Needs

The presenter requires an LCD projector and a power adaptor. She will provide her own laptop computer and all workshop materials.

VIII. Participant Fees

This project is funded by National Science Foundation, grant #1240797, and there is no cost for participants.

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Exploring Boyer's Scholarship of Application for Submissions to the IEEE Transactions on Education

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***Abstract*—A substantial percentage of the manuscripts submitted to the IEEE Transactions on Education as well as a substantial percentage of the papers that have been published fall within the scholarship of application as described by Boyer. The scholarship of application in electrical and computer engineering education might be briefly described as the scholarship of teaching practice in these disciplines. While this is a critical arena for electrical and computer engineering education, standards and criteria across the scholarly community for this area of scholarship have not been well established. Thus, this workshop at FIE 2013 offers opportunities for dialog about these issues. A starting point for the conversation will be the new review criteria that the Transactions has established for the scholarship of application. The intent of the workshop is to explore how authors interpret the new criteria, how authors might address the new criteria, and how support for authors can be fostered. Small groups will explore in greater depth the meaning of review criteria for the scholarship of application for education in electrical and computer engineering. Then, small groups with share their results with the large group for broader conversations.**

Keywords—Boyer's model of scholarship; electrical and computer engineering; engineering education; publishing

I. Introduction

As Boyer pointed out in his exploration of the meaning of scholarship [1], restricting description of scholarly contributions only in terms of new knowledge contributed, i.e., scholarship of discovery, ignores varieties of necessary intellectual contributions. He went on to describe at least two more areas of scholarship, i.e., application and discovery; however, describing the nature of contributions in these two areas upon which further intellectual contributions can be built has not received the attention needed to elaborate expectations so that scholars can frame their work. Thus, this workshop at FIE 2013 provides an excellent opportunity to engage an important segment of the community of potential scholars in constructive conversations about appropriate review criteria and how authors can address these criteria within this area that sees hundreds of potential annual contributions. At the end of the workshop, participants should be able to:

- Describe Boyer's three areas of scholarship and distinguish the scholarship of application from the other two areas
- Describe their ideas about criteria appropriate for the scholarship of application
- Provide ideas on how to write a manuscript that contributes to the scholarship of application

II. Criteria: Scholarship of Application

Words related to application, e.g., practice, design, create, innovate, invent, etc., might be the basis for a set of criteria. The following are the criteria for the scholarship of application in the IEEE Transactions on Education as of June 2013.

(i) Relevance/Importance/Need/Opportunity: How relevant are issues, practices and applications described in the manuscript to education in electrical engineering, computer engineering, and related fields? Are significant issues in education for electrical engineering, computer engineering, or related fields clearly articulated? Has a need for potential contributions been established? How widespread among engineering educators is interest in the issues, practices, and applications presented in this manuscript?

(ii) Intended outcomes: What were the outcomes that the authors were seeking? To what extent were the outcomes explicit and clearly stated? Did the authors just mention the course or topic or did they articulate clear intentions for instructional practices described in the manuscript? To what extent have the authors articulated intended contributions in education in electrical engineering, computer engineering, or related fields? If the authors present approaches to instruction, how well have authors articulated intended learning outcomes or objectives?

(iii) Context: Have the authors analyzed prior research related to their intended contribution? Have they identified the appropriate references? Have they situated their work within the context of prior research?

(iv) Application Design: In the scholarship of application, a key focus is on decisions that authors made as they applied existing knowledge and research. This criterion focuses on these decisions. What were key decisions that needed to be made in the process of designing approaches, strategies, tactics, activities, behaviors, and structures to achieve the outcomes? Have the authors identified and explained the key decisions that were needed for their approach? For each decision, what are alternatives drawn from the literature that were, or should

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have been, considered? To what extent have the authors considered possible alternatives, including alternatives described in prior research? For each decision, what were the criteria used to guide prioritization among the alternatives? To what extent have the criteria that the authors use in making their decisions been clearly and adequately explained? How did the authors prioritize their alternatives, based on their criteria? Did they describe how they arrived at their decisions? Were the descriptions clear and the reasoning solid?

(v) Findings: Once the choices were made and implemented, to what extent did the activity achieve intended outcomes? Is evidence presented by the authors sufficient to support the findings? Has the evidence been analyzed and interpreted according to accepted practices?

(vi) Conclusions: What is the significance of the conclusions? Are opportunities for further innovations in practice identified? Are potential research questions identified? Are implications for broader acceptance of the applications considered?

III. Workshop Overview

Interactive activities have been designed to catalyze conversations that will advance scholarship across the community and enhance quality of papers in the Transactions. The workshop will alternate between small group dialog and large group exploration of findings reported by small groups. Small groups will explore in greater depth the meaning of review criteria in the areas of application, integration and discovery as applied to the field of education in electrical and computer engineering.

A. Schedule

An overview of the workshop schedule is provided in Table I.

TABLE I. WORKSHOP SCHEDULE

Start Time	Duration	Activity
0:00	10 minutes	Introductions: Facilitators and participants will introduce themselves, describe their purposes for participating in the workshop, and describe their familiarity with Boyer's three areas of scholarship.
0:10	10 minutes	Introduce the scope of the IEEE Transactions on Education, provide an overview of the review process for the Transactions (including timing), and provide an overview of Boyer's scholarship of application
0:20	15 minutes	Introduce Criteria for Scholarship of Application
0:35	20 minutes	**Activity:** Pick a criterion. Ask groups of 4 persons to work on approaches that manuscript authors could use to address the criterion effectively. Reports from groups will be solicited. Questions and comments will be shared.
0:55	20 minutes	**Activity:** Pick a criterion. Ask groups of 4 persons to work on approaches that manuscript authors could use to address the criterion effectively. Reports from groups will be solicited. Questions and comments will be shared.
1:15	15 minutes	**Summary:** Synthesize findings, consider next steps, wrap-up workshop

IV. Possible Prerequisite Knowledge

No special technical prerequisite knowledge is needed. All FIE participants would be welcome. Familiarity with the IEEE Transactions on Education would be desirable. Some familiarity with Boyer's model of scholarship would be helpful. Useful references include Boyer [2] and Glassick [3].

V. Workshop Facilitators

A. *Jeffrey E. Froyd, Texas A&M University, Editor-in-Chief, IEEE Transactions on Education*

Dr. Jeffrey E. Froyd received the B.S. degree in mathematics from Rose-Hulman Institute of Technology and the M.S. and Ph.D. degrees in electrical engineering from the University of Minnesota, Minneapolis. He is a TEES Research Professor in the Engineering Student Services and Academic Programs at Texas A&M University, College Station. He has been an Assistant Professor, Associate Professor, and Professor of Electrical and Computer Engineering at Rose-Hulman Institute of Technology. He served as Project Director for the Foundation Coalition, a National Science Foundation (NSF) Engineering Education Coalition in which six institutions systematically renewed, assessed, and institutionalized innovative undergraduate engineering curricula. At Rose-Hulman, he co-created the Integrated, First-Year Curriculum in Science, Engineering and Mathematics, which was recognized in 1997 with a Hesburgh Award Certificate of Excellence. He has authored over 70 papers on faculty development, curricular change processes, curriculum redesign, and assessment. Prof. Froyd is a Fellow of the IEEE, a Fellow of the ASEE, an ABET Program Evaluator, the Editor-in-Chief for the IEEE Transactions on Education, and an Associate Editor for the Journal of Engineering Education. He has served as the general chair for the 2009 Frontiers in Education Conference and a program co-chair for three other FIE conferences.

B. *Susan M. Lord, University of San of Diego, Associate Editor, IEEE Transactions on Education*

Dr. Susan M. Lord is Professor and Coordinator of Electrical Engineering at the University of San Diego. She received a B. S. in Electrical Engineering and Materials Science and Engineering from Cornell University and the M.S. and Ph.D. in Electrical Engineering from Stanford University. Author of over eighty publications, her teaching and research interests include electronics, optoelectronics, service-learning, feminist pedagogy, lifelong learning, helping military veterans transition to engineering programs, and engineering student persistence. Dr. Lord's industrial experience includes AT&T Bell Laboratories, General Motors Laboratories, NASA Goddard Space Flight Center, and SPAWAR Systems Center. Dr. Lord's research in engineering education has been supported by the National Science Foundation. She is a member of the IEEE, the Society of Women Engineers (SWE), ASEE, and Tau Beta Pi. Her leadership positions include President of the IEEE Education Society (EdSoc), Frontiers in Education (FIE) Steering Committee Member, General Co-Chair of FIE 2006, FIE 2005 Program Co-Chair, and elected member of administrative board of ASEE's Education and Research Methods (ERM) Division. Dr. Lord and coauthors received best paper awards in 2011 from the Journal of Engineering Education and the IEEE Transactions on Education. She was Guest Co-Editor of the 2010 Special Issue of the International Journal of Engineering Education (IJEE) on Applications of Engineering Education Research. Dr. Lord is an Associate Editor of the IEEE Transactions on Education and a member of the Editorial Board for IJEE.

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Assessing Lifelong Learning

The Role of Information Gathering and Application Skills

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Abstract – **This special session will explore different approaches to measuring and promoting lifelong learning skills in support of fulfilling ABET student outcome criterion 3.i. "The recognition of the need for, and an ability to engage in life-long learning"[1] is mult-faceted and challenging to both define and measure and is comprised of a mixture of skills, abilities, and habits, and attitudes. This session focuses on those aspects of lifelong learning associated with self-directed learning, and in particular the information gathering and application skills required for effective independent learning. As a result of this session, we will develop some shared understandings of these skills, our ability to measure them, and an agenda for future research on measuring and supporting activities related to student outcome criteria 3.i.**

Index Terms – lifelong learning; assessment; information literacy

GOALS OF THE SESSION

This session will provide examples of assessment tools that probe lifelong learning and related information literacy competencies. The special session participants will cooperatively develop criteria for measuring lifelong learning skills, which will be folded into the development of future standardized assessment instruments. Ultimately, this will improve the ability for engineering educators to measure ABET lifelong learning outcomes.

SESSION RATIONALE

Lifelong learning is one of the least understood and studied ABET criteria in terms of measuring student achievement. In a recent study, students rated their performance lowest in lifelong learning, of all the ABET outcomes, and it had the least growth in achievement of any of the criteria [2]. Many assessments of lifelong learning, furthermore, are based on student self-assessments or participation in formal post-graduate educational activities (seminars, workshops, advanced degrees). However, much of lifelong learning takes place independently and through the initiative of the engineer at a point of need [3], and these qualities are not addressed by simply inventorying educational activities attended. What is needed are assessments that probe the skills students need in order to be successful self-directed learners. This session provides an example of some such assessments and a venue for discussion to increase the educator community engagement with lifelong learning and refine and suggest assessment tools to measure the lifelong learning capacity of our students. Once we can assess those outcomes, we can better measure the effectiveness of instructional interventions and make sure lifelong learning no longer languishes as the least-achieved of the ABET criteria.

SESSION DESCRIPTION

After asking participants to reflect on their own understanding and experience working with lifelong learning outcomes, the facilitators will briefly review lifelong learning and self-directed learning theories and how they have been interpreted by the engineering education community. We will review different assessments that have been used to measure self-directed learning and information skills and explore their strengths and weaknesses. The facilitators will then discuss standardized assessments they developed as a result of an institutional seed grant that was recently funded for further development. Participants will take one of the assessments and reflect on whether they believe it measures skills associated with their perception of lifelong learning. The following discussion will help spark thinking about lifelong learning and how it can be measured, whether through refining existing instruments or the development of new approaches entirely.

SESSION AGENDA

Introductions/Warm-up Activity 15 minutes -- Instructors will introduce themselves. In small groups, participants will introduce themselves, explain what they think lifelong learning is, and give two or three examples of how they measure lifelong learning at their institutions, including at least one way they measure non-formal lifelong learning (e.g., outside of continuing education courses or advanced degrees).

Review of Lifelong Learning Literature 15 minutes – Instructors will provide context of how the education

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community and the engineering community has historically defined lifelong learning and the characteristics, skills, and abilities of lifelong learners.

Review Types of Assessments Used 15 minutes - Discuss advantages/weaknesses of different kinds of assessments (e.g., multiple choice, performance, self-assessments), with examples of each.

Participants Take Sample Assessment 10 minutes (1st part of CELT, the Critical Engineering Literacy Test, an assessment designed by the facilitators) - This provides a concrete example of one assessment method.

Small Group Reflect on Assessment 20 minutes - Gather feedback on whether this assessment is measuring the skills and abilities students need for informal lifelong learning. What challenges did the participants have with the assessment, what did they think the assessment was measuring? Small groups will document their discussions, which will be turned in to the instructors.

Entire Group Reflection/Report 15 minutes - Opportunity for discussion, sharing information between groups. Determination of consensus skills and abilities needed by lifelong learners and appropriate assessment tools to measure them.

LITERATURE REVIEW

Lifelong learning encompasses the skills, abilities, and inclinations to learn outside the academy. While formal learning opportunities, such as workshops, seminars, and advanced degrees provide some venues for lifelong learning, the bulk of post-graduate learning occurs at point of need and in the context of authentic work-related activities [3]. These situations require self-directed learning skills, defined by Knowles as the ability to "identify their learning need, determine a learning plan to acquire the skills or abilities to meet the need, actually implement the plan, and be able to determine whether they met their learning goals."[4] Similarly, Shuman *et al.* propose that lifelong learners be able to "demonstrate reading, writing, listening, and speaking skills, demonstrate an awareness of what needs to be learned; follow a learning plan; identify, retrieve, and organize information; demonstrate critical thinking skills; and reflect on one's own understanding."[5] Costa and Kallick describe self-management, self-monitoring, and self-modifying, as the three categories of skills, with several attributes and competencies for each category [6]. Garrison substitutes motivation for self-modifying in his classification of skills [7], and the Association of American Colleges and Universities created the VALUE rubric for lifelong learning, which is comprised of the core characteristics of curiosity, initiative, independence, transfer, and reflection [8]. The common pieces in all of these descriptions of lifelong learning are an ability to determine what the knowledge gap is, how to find information to meet that need, actually apply that information, and determine if the task is complete or if more needs to be done. When the attributes of lifelong learning are summarized in this fashion, the link to information literacy skills, the ability to determine an information need, locate relevant information, and to apply it appropriately and ethically [9], can easily be seen.

Many attempts at assessing self-directed learning focus on student self-assessments [10], which mostly provide information on attitudes toward lifelong learning, or information about learning style preference [11] rather than actual habits or skills. Standard assessments of information literacy [12] are often decontextualized, so transfer of skills is more problematic. The facilitators of this session created a scenario-based assessment to provide a better indicator of student skills in a context similar to that they will experience in their professional careers [13]. They also developed a rubric-based tool for assessing authentic student work [14], in particular student project reports that evaluate not only the number and type of resources students use in their documentation, but also the quality and relevance of the information in the context of the task and the appropriateness of the application of the resources.

Although some progress has been made in the construction of appropriate assessments of lifelong learning, more work needs to be done. It is the hope of this program that participants help uncover new ways of thinking about lifelong learning and potentially new lines of research to understand the connection between different skills, abilities, and attitudes and success as a lifelong learner.

ANTICIPATED AUDIENCE

Our anticipated audience includes engineering educators, faculty, graduate students, and librarians.

EXPECTED OUTCOMES & FUTURE WORK

The results of this session will be folded into further revisions of the instructors' lifelong learning assessment tool. The tool will be made openly available to the education community by depositing it in the STEMEdHub repository. Participants will also be recruited to test the assessment at their institutions and to increase content validity of the instrument. The outcomes of the session may also spark further research into other methods of assessing lifelong learning.

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Ruth Wertz is a doctoral candidate in the School of Engineering Education at Purdue University. She holds a Master of Science degree in Civil Engineering from Purdue University and a Bachelor of Science degree in Civil Engineering from Trine University (formally Tri-State University). Ms. Wertz is a licensed Professional Engineering in the state of Indiana with over six years of field experience and eight years of classroom teaching experience. Ms. Wertz’s research interests include teaching and learning engineering in online course formats, and the development of information literacy in engineering students.

Green Construction in Civil Engineering Instruction

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Abstract – **Teaching sustainability in civil engineering curriculum fulfills ABET 2000 Outcome 3c and the codes of ethics of NSPE and ASCE. The US Green Building Council (USGBC) has published the Leadership in Energy and Environmental Design (LEED) criteria since 1998. LEED is an optional criteria in private construction and is mandated or encouraged by many federal, state, and local governments for public construction projects. Learning about LEED criteria will help to prepare civil engineers to understand how civil systems interact with and operate in a more complementary manner with the natural world as well as to reduce water, energy, and material usage. The authors describe the process of learning about the LEED v3 (2009) criteria to apply it to two existing buildings to build a scorecard. In the process of building the scorecard, the authors learned about sustainable construction techniques. Future guidance on applications of the LEED criteria across the undergraduate civil engineering curriculum is discussed.**

Index Terms – Civil Engineering, Sustainability, LEED, USGBC, ASCE, ABET, Ethics, Environment, Construction

INTRODUCTION

Incorporating sustainability into the civil engineering curriculum is consistent with ABET Outcome 3c as well as ASCE, NSPE, and ASME codes of ethics [1, 2, 3, 4]. The primary roadblock to implementation is that many of today's current engineering educators have not studied or been trained in sustainable engineering practices.

The term *sustainability* refers to the ability of the people of the present to maintain a high quality of living while ensuring that future generations will have access to the resources that they need to also maintain a high quality of life. This means that the people, businesses, and governmental organizations of today need to examine their actions in regard to production and consumption of goods and services, infrastructure, water and energy usage, and end-of-service life such that those actions maximize the quality of life and economic growth while minimizing degradation to the natural environment. The common refrain of *reuse, reduce, and recycle* summarizes the goal of sustainability initiatives.

A great source of information on sustainability in construction is the multidisciplinary US Green Building Council (USGBC). Engineers (civil, mechanical, and electrical), architects, contractors, and other stakeholders have come together with the market-driven approach of the USGBC to create the Leadership in Energy and Environmental Design (LEED) family of specifications to incorporate sustainability into construction projects. USGBC has specifications for homes, neighborhoods, new and existing construction, and schools that give guidance on how to make projects more sustainable by reducing environmental degradation, water, energy, and material usage while also making the project more conducive to human health and well-being.

Work at West Texas A&M University (WTAMU) began in May 2012 to learn about the LEED criteria. Work began by studying the LEED Green Associate (lower-level) certification materials, published by the USGBC [4]. Examinations are administered by the independent Green Building Construction Institute (GBCI). Dr. Leitch successfully passed the LEED Green Associate examination in August 2012.

The upper-level certification for LEED is specific to individual specialties in construction. For example, one specialty is in neighborhood development while another is in new building construction. Each specialty has a set of LEED criteria prerequisites that must be met before certification and scorecard values related to water, energy, materials, indoor air quality, and site location plus bonus points related to regional priorities and innovations in design. Certified buildings have 40 – 49 points, silver certified 50 – 59 points, gold certified 60 – 79 points, and platinum certified are 80 or more points.

PREVIOUS WORK

Many civil engineering programs in the United States are incorporating elements of sustainability across their curriculum, with a few examples noted here. A review by Ahn, et. al (2008) and Cottrell and Cho (2009) [6, 7] provided a list of universities incorporating elements of sustainability into civil engineering curriculum such as Pennsylvania State, the University of Florida, Texas A&M, Texas Tech, the University of Colorado, and Virginia Tech. Instructors at Lamar University [8] write about using the Shangri La Botanical Gardens and Nature Center in Orange, Texas (the first Platinum certified project in Texas) as a teaching tool. Since 2000, the Oregon Institute of Technology [9] has implemented a three-term sequence in senior civil engineering design that emphasizes sustainability by using the LEED criteria. George Mason University [10] uses the LEED Neighborhood Development criteria for its senior design project to address all major subareas of civil engineering. In 2012, Sattler et. al at the University of Texas at Arlington addressed integrating sustainability across the civil, mechanical, and industrial engineering curriculum including a multi-disciplinary senior design experience to design a biodiesel production facility [11].

SUSTAINABILITY INITIATIVE FOR THE CIVIL ENGINEERING CURRICULUM

The civil engineering program began at West Texas A&M University (WTAMU) officially in the Fall 2010 semester. WTAMU is a member of the Texas A&M system, serving the Texas Panhandle and surrounding region. The university has approximately 8,000 students with over 500 in the School of Engineering and Computer Science (ECS). The civil engineering program currently has about 50 declared majors, with the first graduates in 2013.

The sustainability initiative consists of three distinct parts. The first part was completed in Summer 2012 when Dr. Leitch and an undergraduate student developed a series of 50-min sustainability modules for several civil engineering courses which include the introductory engineering course, civil construction materials, transportation engineering, and senior design. This phase also included study of the LEED Green Associate material.

The second phase will be discussed in depth in the next section. Three students learned the LEED Green Associate Material as well as the LEED AP (Accredited Professional) specific material necessary to evaluate one remodeled and one new building on the WTAMU campus.

The third phase incorporated elements of the LEED and sustainability criteria into civil engineering senior design in 2013. Civil engineering senior design addresses multiple subdisciplines such as structural, transportation, environmental, hydrology and water resources, and construction in a group project within a 3-credit semester course. Additionally, elements of engineering finance, technical communication, ethics, and sustainability are addressed within the project.

LEED CRITERIA

The LEED scorecard is comprised of five primary categories with prerequisites and credits (up to 100 points total) and two bonus categories (up to 10 points). A brief overview is given here, but readers are urged to consult each LEED AP specific category for prerequisites and credit values.

The first major category is for *Sustainable Sites* and promotes responsible, innovative, and practical site design strategies that are sensitive to plants, wildlife, water, and air quality. LEED rating systems address project location and site design and maintenance by the following five main subtopics: location and linkages, neighborhood pattern and design, transportation facilities, storm water management, and heat island effects. Credits are earned for redevelopment efforts located near major transit services that allow for ease of walking and for mitigation of environmental damage.

The second major category is *Water Efficiency*. Efficient fixtures save potable water and reduce wastewater treatment demands. Water reuse can also result in credits. For example, a rainwater capture system can channel non-potable water (greywater) for use in irrigation of native or adapted plants (xeriscaping) and for toilet facilities.

The third major category is *Energy Efficiency*. Rising fossil fuel costs have made efficient heating/cooling systems, appliances, and low-energy electric devices important to reduce energy costs and environmental effects. An integrated process helps to identify synergy-promoting strategies in the following areas: energy demand, energy efficiency, renewable energy, and operational performance.

The fourth major category, *Indoor Environmental Quality*, focuses on building air quality, lighting, thermal conditions, ergonomics, and the effects it has on the occupants of the building. Indoor air quality can be more polluted than outdoor air, and yet, people spend about 90% of their day indoors. Indoor contaminants are generated by smoking, cleaning materials, HVAC equipment, and building materials that emit volatile organic compounds (VOCs). VOCs are defined as substances that vaporize at room temperature, and have the ability to cause health problems. Ventilation is vital in removing pollutants that enter a building. But the best way to improve indoor air quality is to reduce pollutants at the source of production.

The final major category *is Materials and Resources*. When deciding on materials for a project, the production, transportation, consumption, and eventual disposal must be taken into account. Three main points to remember in regard to materials and resources: conservation of materials, selection of environmentally preferable materials, and for waste management and reduction.

There are two bonus categories. *Innovations in Design* credits are awarded to projects that go above and beyond what is required of the LEED scorecard. Innovative strategies expand the scope of green building practice by putting new techniques, processes and products into place. *Regional Priority* credits recognize environmental issues that are unique to a locale, outside the scope of the five main categories.

CURRENT STUDY

A team of three senior-level civil engineering students was tasked with learning about the LEED criteria in the Fall 2012 semester and applying it to two structures on the WTAMU campus. The students were also tasked with studying the LEED Green Associate examination study materials and taking a mock 100-question exam. The mock exam is similar to the actual Green Associate examination, and is intended to prepare the students to take the certification examination.

The two structures evaluated were a remodeled facility (ECS Building opened in 2012) and the recently constructed Centennial Hall dormitory (opened in 2010), both located on the WTAMU campus. Construction documents and specifications were graciously provided by the WTAMU Physical Plant.

The team of students reviewed several hundred pages of documents to determine scorecard values for both buildings. These scorecards are given for reference in Figures 1 and 2, respectively. As can be seen in the scorecards, the renovated Engineering and Computer Science Building scored 32 points, eight points shy of Certified status. The new Centennial Hall dormitory scored 45 points, indicating Certified LEED status, if the university had chosen to submit the required documentation. As shown in Figures 1 and 2, most points were awarded for sustainable sites and for indoor air quality, due to the use of low VOC emitting materials. The new dormitory building was awarded significant points for its greywater system that can use rainwater for flushing toilets, saving potable water usage. Both structures also received points for reused and locally sourced materials. Some examples of sustainable features for these two buildings are given in Figures 3 through 7.

With this group of students trained in sustainable development techniques, these concepts were applied to their senior design project. This project involved the creation of a new outdoor engineering lab facility with structural, transportation, geotechnical, water resources, and environmental elements that adapt ideas from the LEED sustainability criteria.

FUTURE DIRECTIONS AND CONCLUSIONS

The immediate near term goal is to incorporate sustainability into the civil engineering curriculum, in the spirit of ABET Outcome 3c and the ASCE and NSPE codes of ethics. The authors plan to share their findings with other faculty at WTAMU. The concepts of sustainability are readily adapted in related fields such as for

FIGURE 1
LEED Scorecard for ECS Building (Building Renovation)

FIGURE 2
LEED Scorecard for Centennial Hall (New Construction)

FIGURE 3
Recycled Terrazzo Flooring

FIGURE 4
Low VOC Carpet, Paint, and Furniture

FIGURE 5
Reclaimed Water for Irrigation of Xeriscape Vegetation
(Centennial Hall only)

FIGURE 6
Motion Sensing Lighting and Room-Adjustable Thermostat

FIGURE 7
Recycling Receptacle

mechanical engineering and engineering technology.

Sustainability is important for all engineers, but especially for civil engineers, as they are responsible for the design, construction, and maintenance of infrastructure necessarily for a high standard of living and for the economic growth of nations, such as the United States. Major engineering societies and accreditation bodies recognize the importance of sustainability. As such, civil engineering programs are beginning to incorporate elements of sustainability across the curriculum.

The LEED criteria provide a market-driven mechanism for recognizing construction innovations that promote sustainable practices. Since 1998, over 43,000 projects in the USA have been certified (more than 50,000 total worldwide), according to the USGBC database (2012) [12]. The US General Services Administration (GSA) has been directed by Presidential Executive Orders in 2007 and 2009 to utilize LEED criteria for federal construction projects [13]. Many states and cities are also implementing incentives for applying LEED strategies in public projects. The LEED project database reflects that corporations and private citizens seeking certification as well.

Incorporation of LEED criteria and concepts of sustainability across the curriculum are essential in preparing engineers of 21st century so that the engineers of the 22nd century and beyond can continue to provide a high quality of life for future citizens.

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On-professional competences in engineering education for XL-Classes

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***Abstract*— Far reaching changes in university higher education have taken place in the last ten years. Different factors, e.g. necessity of on-professional competences in engineering education, rising or vast student numbers and new technical possibilities, have influenced the academic teaching and learning process. Therefore interdependence between requirements and didactical-educational possibilities is given. Because of changed circumstances an adaption of teaching methods and concepts is required. At the same time Bologna arrogates students to be placed in the centre of the teaching and learning process and claims on-professional competences for today's students. Especially for XL-Classes this is a specific challenge. One of the questions ensuing is how to increase learning success by the use of specific didactical methods? With a research approach connecting different proven didactical concepts and considering the previously shown conditions, the concept of the lecture "communication and organizational development" (KOE) at RWTH Aachen University has been redesigned. This lecture, organized by the Institute Cluster IMA/ZLW & IfU at RWTH Aachen University, is mainly frequented by up to nearly 1.300 students of the faculty of mechanical engineering and inherent part of the bachelor-curriculum. The following practical example prospects the multi-angulation of didactical concepts and shows up innovative educational teaching.**

Keywords— engineering education; audience response system; on-professional competences; best-practice

I. Introduction

Innovative teaching techniques and concepts have been developed in the last years against the background of different factors of influence in the teaching process of higher education. This paper presents a best-practice example, which implements and combines different didactical concepts in higher education. The combination of different concepts is necessary as set out in chapter II – Challenges in context of higher education.

In the course of years multifarious didactical concepts have been created. Research reveals different human learning types and success, depending on learning environments [1]. It follows and carved out that integration of learning methods and styles is essential.

Bologna claims the design of student-centered education formats and conveyance of on-professional competences [2], which is challenging especially in large-audience courses, the so-called "XL-Classes". On-professional competences are understood as competences which enable students to deal with their theoretical specialized knowledge and prepare them for working life. These competences comprise e.g. methodological-, social-, self-reflecting- and media-skills.

By means of the lecture "communication and organizational development", organized by the Center for Learning and Knowledge Management (ZLW) of the RWTH Aachen University, it is highlighted, how and against which backdrop the lecture was subjected to a whole redesign to cope with the changed influence-factors, technical possibilities and student-requirements. This redesign is mentioned in chapter III – Redesign of the lecture 'KOE'.

II. Challenges in context of higher-education

During the last decade far reaching changes in higher education teaching took place. Different factors have influenced the design of higher education, for example conveying on-professional competences in higher education, the high number of students at German universities and (new) technical opportunities. These most important challenging factors will be elaborated in the following.

A. The challenge ‚XL-Classes'

In Germany, many Universities face the challenge of a vast number of students each semester, especially in engineering education degrees at RWTH Aachen University [3]. This challenge is tightened by the reduction of school time by one year due to a change in German educational policy. In addition to that the demand for engineers in Germany is growing [4]. More than ten years after implementing the Bologna Declaration, the higher education system in Germany has changed significantly [2]. Since then students and their learning process represent the core of the teaching and learning process. This change, also known as a 'shift from teaching to learning' [5], is a more student-centered and involvement-oriented design of teaching. 'It is characterized by innovative methods of teaching which aim to promote learning in communication with teachers and other learners

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and which take students seriously as active participants in their own learning, fostering transferable skills such as problem-solving, critical thinking and reflective thinking' [6]. Instead of being 'content-oriented', which means focusing on the transmission of content, the design of teaching now focuses on 'learning outcomes', hence the students' learning results and the way of achieving these results. This is, however, a major challenge to lecturers of XL-Classes, as they predominantly focus on the transmission of content due to their difficulties of involving a large number of students at the same time. Therefore the question arises how a lecture can be student-oriented in XL-Classes.

B. Conveyance and promotion of on-professional competences

Due to the huge number of students attending lectures-XL-Classes have the problem of a content-oriented focus. Therefore the conveyance of on-professional competences to students in XL-Classes is often in a theoretical way. Indeed the transmission of on-professional competences plays an important role in higher education in general and particularly in engineering degree programs [7]. Not only professional knowledge is required to be the output of higher education, but also soft skills like method-, self-, organizational - and social competences are expected from today's students [8].

Against this background the required competences are considered at the redesign. From its multidisciplinary and holistic approach, the ZLW aims at designing and conducting lectures also including the transmission of on-professional competences. Thereby the ZLW tries to accomplish one major goal of the Bologna Process, which is "to create a European space for higher education in order to enhance the employability […]" [2]. Students should be educated in a way which makes them available for the employment market in a fast, efficient and adequately educated manner [9]. This means students should be enabled to convert learned knowledge in higher education in later working life [10].

C. Combination of didactical concepts

Didactical concepts are the tools of today's lecturers. Those concepts and methods are combinable and applicable in various ways. Due to the didactical diversity of methods a student-centered alignment of lectures is possible. The students learning process is further supported through didactical multi-angulation [11].

Additionally, the students obtain skills in dealing with various methods through methodical diversity (e.g. with presentation techniques). Böss-Ostendorf and Senft confirm that useful methodical diversity is a factor of success for university education, because of the multiplicity access to teaching content [12]. The reasons for integration and combination of different didactical concepts are mentioned by Flechsig [1]:

- Various learning styles and types of students with different learning success
- Diversity of study motivation and interest
- Variety of competences and fields of knowledge
- Variety of context in which learning is placed

Any didactical method aims at enforcing learning and knowledge permanently [13]. As a result a sensible combination of didactical methods and concepts to increase learning-success for students is necessary. As a consequence concepts, explained in the following, have been integrated in the lecture 'KOE'.

III. Redesign of the lecture 'KOE'

The compulsory lecture "communication and organization development" (KOE) is held every winter term. Almost 1300 students, mostly engineering students, participate in this weekly lecture. In addition a laboratory session takes place, in which students experience a simulated company situation in an authentic environment [14]. Based on the changed influence factors, which are mentioned before, and with the premise to maximize learning success and also among the maxim of sustainable teaching of practice-oriented and on-professional contents, the lecture is continuously refined and was subject to a complete redesign in the winter term 2012/2013. Existing elements were further developed and new didactic elements were implemented. The lecture's elements (shown in Figure 1) will be explained in the following.

Didactical multi-angulation of the lecture 'KOE'	
A	**Theoretical inputs and lecture modules**
B	**Practice oriented theoretical inputs through expert-lectures with professional practice**
C	**Interaction in XL-Classes through Audience Response Systems (ARS)**
D	**Learning on demand through medial preparation**
E	**Teaching and learning online portal/platform**
F	**Simulation based learning through organizational simulation**
G	**Online examination system**

Fig. 1. Didactical elements 'KOE' lecture at RWTH Aachen University

A. Theory input and lecture modules

The lecture consists of twelve modules, including the basics of communication and organization development, learning- and knowledge management concepts and intercultural aspects of global work division management as well as system-theoretical approaches and practical inputs by experts from industry. The whole concept of teaching follows a linear structure. Practical lectures tie in with earlier taught theoretical contents. Thus an ideal transfer from theory to praxis is established. At the end of every module contents are reflected and summed up. For this purpose the 'KOE funnel' is applied (Fig. 2). Both the systemic view and the different levels of a company are included. Thereby communication and organization are regarded as the most important requirements for the development of interaction between humans, technique and organization on the different organizational levels, for example within departments or project teams.

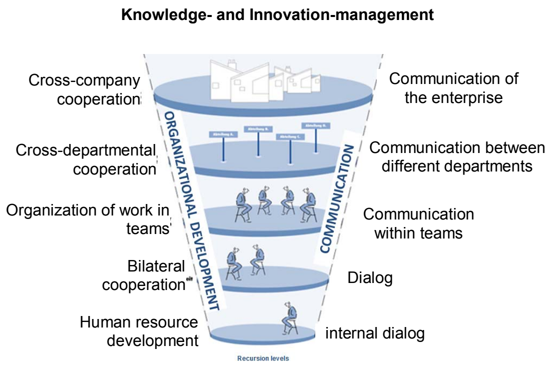

Fig. 2. 'KOE' funnel/recursion-layers [14]

B. *Expert lectures*

As already stated the lectures redesign aims for an increasing relation to practice applications and does not only focus on technical expertise. Additionally it also aims at increasing the ability of understanding the complexity of working life. The inclusion of on-professional competences in studies is not only an issue since the Bologna reform [15]. Furthermore it is important to connect the studies with professional practice, not only from the student's perspective, but also from the perspective of company representatives [16]. For this reason, it is more important to connect teaching with practical insights [15]. Based on this, guest speakers with professional industrial background give an insight into their companies and working experiences (e.g. Vodafone Group, Capgemini, p3 group, inside group of companies). For example: Lecture contents are the experiences in handling international projects as well as interdisciplinary challenges. The experts as well as the lecturer try to establish the connection between already taught theoretically contents and the meaning of communication and organization development in daily processes. In this way theories are linked to praxis and relevance is outlined. In order to solve the area of conflict between the teaching of basic sciences and practical teaching at the expense of theoretical essentials [17] the distribution of proper contents and basics is kept reasonable.

C. *Interactivity throug the application of "Audience Response Systems"*

As outlined by Prensky, that "our students have changed radically" and that "today's students are no longer the people our educational system was designed to teach" [18], (new) technologies e.g. in the form of 'Audience Response Systems' (ARS) may improve the learning outcomes of students [19]. Due to the application of an ARS, students are further involved in the education process.

The ARS is a valuable didactical element as already mentioned by Brinker/Schumacher in 2009 [20]. Capabilities to participate in a lecture are quite diverse for students, which means that they can choose particular contents, recap their knowledge, interpret, reflect and prepare for examinations. Taxonomies of learning goals, like knowledge, understanding, application and analyzing [21] [22] are addressed holistically by the use of knowledge and comprehension checks. As a result problem-solving skills can be improved. The barriers for participation are marginal. Only an end device with access to the internet is required.

To satisfy the student's demands and with the objective to enable interactions between lecturer and students [23], an ARS is used since the winter term 2012/2013. The implementation of the described system demands a redesign of the lecture with special regards to the content. Questions have to be developed that allow the students to interact with the lecturer as well as with each other. This variety of questions ranges from multiple-choice questions to the inquiry of calculation results etc. [19]. Furthermore iteration-loops, to repeat misunderstood content, can be taken into account.

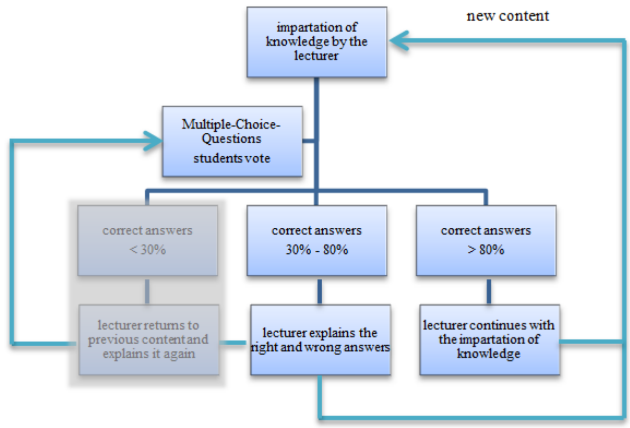

Fig. 3. Didactical concept of using the ARS [23]

Figure 3 illustrates the didactical concept of an Audience Response System, which is treated in the 'KOE'. Two fields are shaded grey, as this case is not applied in the lecture. If there are less than 30% correct answers, an explanation on the right answer is given. Provided that the content is understood (>80% correct answers), the lecturer switches to the next topic.

Evaluations of the success of the implementation of ARS in large university lectures show that the application of this "tool" has led to e.g. higher motivation of attendance, more attention of the students during class and even higher knowledge acquisition than in conventional (non-interactive) classes [19]. If and how the new didactical implementation of the media Audience Response System influences the learning process of students in the lecture 'KOE', has to be evaluated during the next terms.

D. *Video documentation*

In the winter term 2012/2013 the whole lecture was recorded by a professional camera crew, edited and afterwards provided to the students via the online teaching and learning platform L²P of RWTH Aachen University to support the learning process in auto-didactical-phases of the students. As shown in Figure 4 it is a matter of an interactive video documentation. For each module the chapters can be retrieved individually. Knowledge is thereby no longer appropriated as a lecturer-reserve, but accessible for students on demand. This form of making content available for students resembles the concept of learning on demand [25] and results in time saving potential for student learning [26]. Through this video documentation, the students can recapitulate content without any limit and at any time. Furthermore the presentation papers and manual sketches as well as animations and explanations of the lecturer are shown (see Fig. 4). The moderator works as a mediator and presents contents using different channels based on corporate learning. This way offers the possibility to review important contents and especially the preparation of exam papers could be done in a more efficient way. The result is an approach to the teaching for "individual learning", because students can decide when, where and how fast they organize their learning process [27].

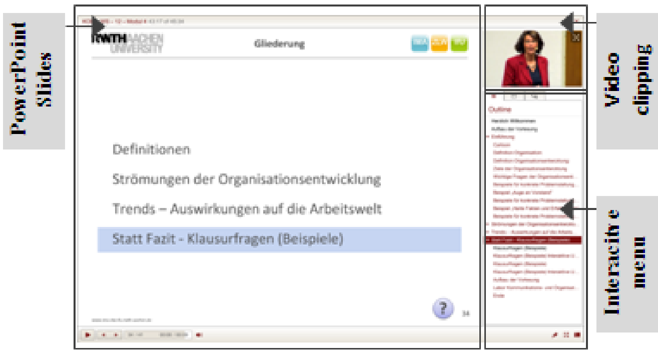

Fig. 4. Surface of the video recording of the lecture

E. Exchange and dataplatforms

As a reaction to the various influencing factors like the new technical possibilities, the teaching and learning platform L²P is used since the end of 2007. The learning platform is password secured and is just accessible for registered students.

The platform is implemented in order to provide important contents like teaching materials (e.g. lecture notes, videos and presentations of experts) and (further) literature for the students on a web based server to support time-consuming and complex teaching and learning processes [28] [29]. Additional L²P can be used to conduct surveys and simulate electronic tests.

Moreover the students have the possibility to discuss certain topics in an online forum talking to professors, mates or coaches and to obtain important clues to further arrangements. Thus discussion and dealing with lecture-content is supported and promoted. The aim is to influence the learning process to the effect that knowledge is understood by the students and can be applied. According to Palloff & Pratt the use of L²P in the lecture 'KOE' can be described as a "web-enhanced course" [30]. That implies physical as well as virtual components and thus copes with the European university-tradition in independent preparation of subject-specific content [31].

F. Laboratory tutorial

XL-Classes are faced with the challenge of a theoretical conveyance of on-professional competences to students. During the lecture 'KOE' not all contents can be taught within XL-Classes [32]. Therefore parallel to the lectures a laboratory tutorial of one and a half days takes place. The laboratory tutorial is based on the concept of 'simulation-based learning' which is a research or training method that tries to create a realistic experience in a controlled environment [33]. According to this, simulation replaces or boosts real experiences [34] and thus offers enormous advantages in mediating knowledge long-acting [34] [35]. In groups up to 40 students a foundation of a fictitious automotive company with different branches is simulated. Target systems and various strategies are developed and communication ways are defined and coordinated. An innovative vehicle is constructed under the guidance of 40 professional coaches. The basic knowledge for the realization of this task is mediated via microteaching units. In the next step, earlier learned theoretically basics are applied practically during a company simulation in order to obtain first practical experiences in organizational communication and working processes. Students try to construct an abstract concept in a theoretical framework to finally put their findings in an active experiment. The teamwork and the communication between the different branches demonstrate the importance of the lecture as well as the relation to working life. Additional to the contents of the lecture 'KOE', key skills such as team building, time management and project management are applied, experienced and trained in the simulation.

G. Online examination system

In order to examine around 1300 students efficiently and content orientated, a digital online examination system (called OPS = Online-Prüfungssystem | developed externally especially for 'KOE') is used and applied since 2007 [36] [37]. Examination questions are derived from the lectures contents and distinguished in different taxonomy levels (degrees of difficulty). Thereby the whole taxonomy-spectrum by Bloom 1956 [25] on a cognitive base is addressed to the students. The taxonomy levels are: knowledge, comprehension, usage, analysis, synthesis and evaluation. For the preparation of exam questions it is important to take into account, that the taxonomy levels are hierarchically arranged [38]. Hence the mediated competences for each taxonomy level must gain a specific manifestation before they can be applied in the next taxonomy level [39]. For example, without knowledge, usage of taught content (transfer capacity) is impossible [39].

Supported by a holistic handling of the mentioned difficulty degrees, the OPS enables to retrieve the student levels of awareness. With the help of the OPS knowledge and transfer capacity can be interrogated and evaluated electronically within a few minutes, so that no further staff is required.

IV. CONCLUSION & VISION

Each semester a university and lecture wide evaluation is stated. First evaluation results indicate that the adaption of the lecture concept and the implementation of new technical and didactic elements have a positive impact on the student evaluation of the course, especially the use of technical aids and demonstrations as part of the lecture as well as the teaching of contents by the lecturer.The average evaluation grade rises in the order of 0.5 (arithmetic average; scale from 1 (very good) to 6 (very bad)). For example the usage of devices and demonstrations in the lecture are evaluated with 1.7 (arithmetic average). The mediation of contents also has a positive trend. Lecture records as well as implementations of ARS Systems are inter alia reasons for that.

Altogether the multi-angulation of various didactical concepts can be outlined as a success for the lecture 'KOE'. This educed concept states that students are centered in educational learning process. In a next step the transferability of the redesigned concept of the 'KOE' lecture must be elaborated. Therefore indicators for a survey will be operationalized and developed.

Based on the already mentioned scientific studies of combining various methodical concepts to increase learning-success and the first positive evaluation after the 'KOE' redesign, more innovative teaching and learning methods will be developed, taken up and implemented for this purpose in the next few years.

Furthermore there is still potential for a continuous and appropriate optimization of the lecture 'KOE'. A long-term goal is to implement additional to the existing concepts the method of 'just in time teaching' to optimize and adjust lecture contents [40].

Accordingly presence lectures are not used anymore for conveying contents, but rather to motivate the students to participate and interact in the presence lecture and to discuss questions and problems with the lecture content. Therefore questions and tasks are provided online before every presence lecture. So the lecturer can see the student's results before every lecture 'just in time' and develop the lecture according to the level of awareness. This method is used to obtain feedback related to the student knowledge. This can be used in order to precisely react to the students demands on certain contents. In addition, students get to know on-professional competences while formulating their own questions as well as working on tasks independently. The continuous development of the lecture 'communication and organizational' primarily serves the goal of creating demand-oriented and target group-oriented courses for XL-Classes.

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Incorporating Augmented Reality Content in Engineering Design Graphics Materials

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***Abstract*— This paper describes the development and integration of augmented reality content with traditional Engineering Design Graphics materials, and presents the results of a preliminary usability study conducted with Freshman Engineering students. The resources developed combine printed text and images with interactive three-dimensional content with the purpose of enhancing the understanding of technical graphics concepts and improving the students' visualization skills. In general, students had a very positive reaction when first presented with the materials and showed an optimistic attitude while interacting with the content. Additionally, augmented reality materials promote the development of self-directed learning skills and self-assessment.**

***Keywords*— augmented reality; spatial skills; engineering graphics**

I. Introduction

Engineering design graphics play a fundamental role in the engineering product development cycle. From an academic standpoint, the development of 3D spatial skills has been cited and recognized by many authors as a key factor in many scientific and technical disciplines [1, 2]. Studies have consistently shown that proper spatial skills are directly related to academic success in science, technology, engineering, and mathematics (STEM) [3-5]. Additionally, the use of CAD packages and the ability to create professional engineering drawings are common requirements both in upper-level capstone design courses and certainly in industry.

In engineering education, the development of three-dimensional visualization and spatial skills is often listed as a major objective in engineering design graphics courses. In many cases, these skills are developed indirectly, through the use of sketching or hand-drawn exercises, or as a side effect that occurs when studying topics such as orthographic projection or sectional views [6, 7]. Some approaches have used CAD applications [5, 8], multimedia [9], games [10, 11], and even virtual reality to train spatial abilities [12, 13].

While engineering design graphics are concerned with processing and describing three-dimensional information, the intrinsic nature of books and traditional printed materials is two-dimensional. This creates a learning barrier that has existed for years. On the other hand, the digital literacy and technological profiles of current students demand new and motivating teaching resources and methods that take full advantage of the existing technology [14]. Furthermore, it has been proven that the more immersive the learning process is (the more senses that are involved), the more effective and engaging the learning experience becomes [15]. In this regard, augmented reality technology can help overcome the limitations of traditional printed media, allowing students to truly visualize the concepts described on paper in full 3D.

This paper presents the use of Augmented Reality (AR) technology as a tool to enhance the delivery of traditional engineering graphics materials. For our study, printed resources, three-dimensional computer models, and visualization software were combined and integrated into a unique system intended to facilitate the learning process. The results of a pilot usability study of our system conducted with freshman engineering students are also reported.

II. Augmented Reality in Education

Augmented Reality can be understood as a variation of Virtual Reality [16]. AR is a visualization technology that combines real-time three-dimensional computer graphics with real video, creating a modified or enhanced representation of reality. Unlike Virtual Reality, where an entire world is artificially generated and users are completely immersed inside a simulation without perceiving their surroundings, AR allows users to experience a modified version of the world. In AR, virtual imagery is seamlessly overlaid onto real live footage providing an "augmented" view of reality. While Virtual Reality aims at replacing the real word with a simulated one, Augmented Reality complements or enhances the real world with virtual elements. Augmented worlds are typically experienced via computer screens, projectors, or head mounted displays (HMD).

The flexibility of Augmented Reality technologies has made possible the emergence and rapid growth of new applications. AR systems have been proven particularly effective as educational tools in different fields, including geography [17], architecture [18], medicine [19, 20], archeology [21], and geometry [22]. In medical areas, for example, AR has been used to train professionals in the use of new equipment and the implementation of new procedures, as

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well as to teach students anatomy and biology [23]. Remarkable visualizations have also been created for archeological sites and architectural applications.

In the engineering graphics domain, studies have shown that the development of spatial abilities can be trained and improved by the use of Augmented Reality [12, 13]. In previous research, Do and Lee [24] developed an augmented reality game that used virtual LEGO blocks as a tool to analyze structures, create models, and assemble components to create complex configurations. The authors concluded that the game significantly improved the player's spatial abilities and visualization skills. In a different study by [25], the authors used augmented reality to develop resources that would help engineering students understand projections methods. Their students showed a higher level of engagement during the learning process. Various projects aimed at exploring the educational applications of AR have been promoted. Examples include CONNECT [26] and ARISE [27].

A. *Augmented Reality Books*

The concept of Augmented Reality Book has been explored by many scholars, and more recently by some commercial publishers, as educational alternatives to traditional books. When used without special AR devices, Augmented Reality books do not look any different from their traditional counterparts. Users can flip through the book and see the text and graphics printed on the pages. However, when read through the proper AR device, virtual content is rendered in real time creating the illusion that three-dimensional models are coming out of the page. The "MagicBook" is one of the most popular examples of educational books that use an AR interface to blend reality with virtual imagery [28]. Previous studies by [29] and [30] have concluded that books provide a familiar, intuitive, and accessible interface to interact with three-dimensional content, creating innovative and engaging experiences for the user.

The augmented engineering graphics materials presented in this paper are an extension of the work done by [31]. In their research, an augmented reality book was produced with the objective of improving visualization and spatial skills in engineering students. Their text, conceived as a workbook, contained traditional visualization exercises based on orthographic and pictorials representations of complex objects organized according to five levels of difficulty. The material was used successfully in freshman level courses, including remedial and intensive training sessions.

III. DESCRIPTION OF THE LEARNING TOOL

For our work, we selected two complete educational modules, orthographic projection and pictorials, from a classic engineering graphics curriculum. We developed the material incorporating augmented reality technology to both the content and the exercises.

The augmented reality system we present is low cost and easy to implement. In addition to the printed materials, only a computer with the proper software installed and a web camera are required. The "augmented" world is experienced through the computer screen. Usually this approach is known as "desktop augmented reality".

In order to activate the AR content, the user's web camera must be pointed at specific areas of the printed materials. These areas are defined by a series of square patterns, called markers (Fig. 1), which are automatically recognized by the augmented reality software. The markers are seamlessly integrated within the pages and linked to specific 3D models (Fig. 2).

Fig. 1. Examples of AR markers embedded in the graphics materials

A second marker is used to manipulate the augmented reality content, which is rendered in real time in the user's computer screen. The markers are black and white patterns used to trigger the AR content. They are recognized by computer vision techniques implemented in the software to determine the position and orientation of the marker relative to the camera.

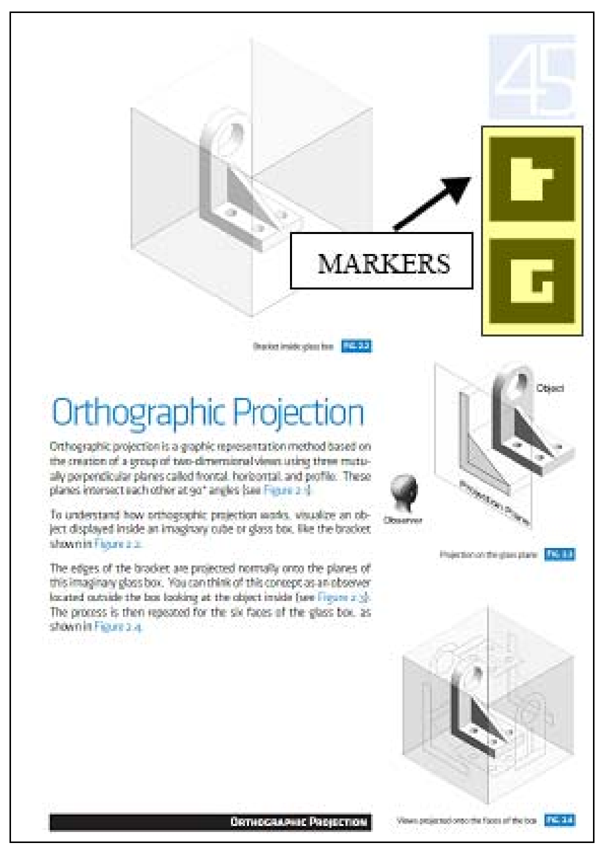

Fig. 2. Integration of AR markers within the page

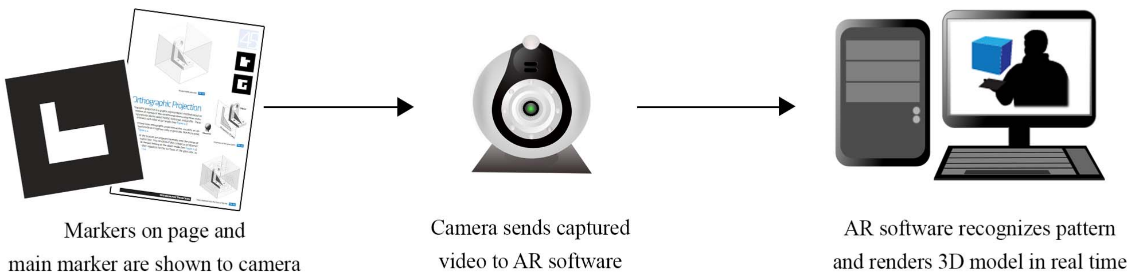

Fig. 3. AR System Diagram

Once a set of markers is recognized, the corresponding three-dimensional model is rendered over the video captured by the web camera using the calculated coordinates of the marker. The basic functioning of the system is shown in Fig. 3. Some of the AR models used in our system are shown in Fig. 4, as rendered by the software in the user's computer screen.

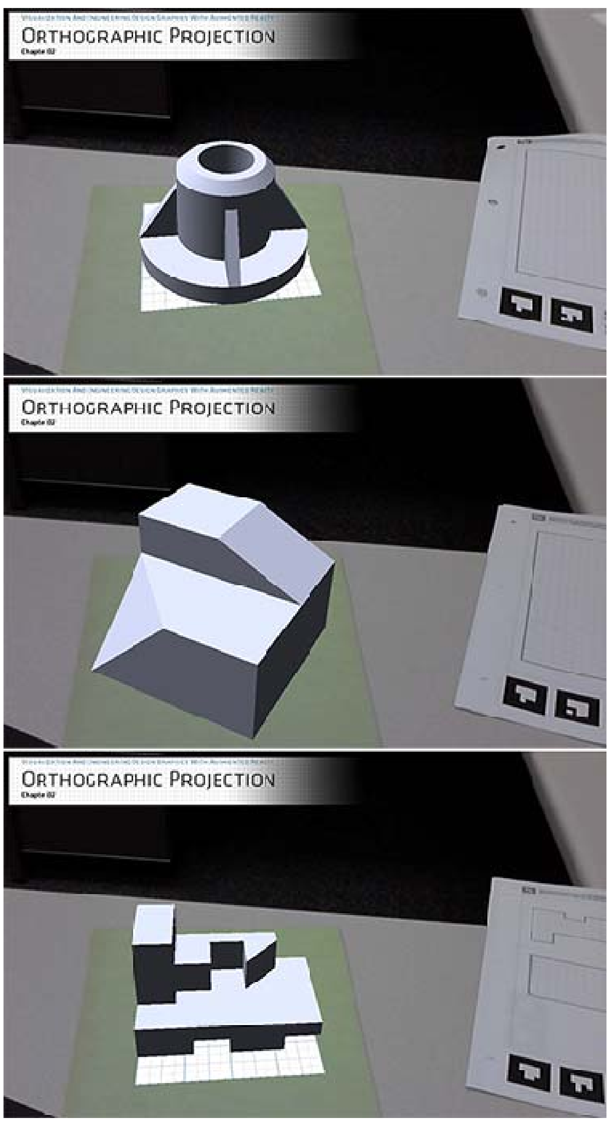

Fig. 4. Examples of AR models as seen by the users

IV. Pilot Usability Study

A pilot study of the AR system was conducted with freshman engineering students at Texas A&M University to determine whether the tool has adequate usability for its possible integration into the classroom. The study was prepared according to usability factors defined by [32]:

- Effectiveness: "accuracy and completeness." It refers to how accurately a system completes a set of tasks to achieve the desired result.
- Efficiency: "resources expended." It refers to the extent to which effort, cost, and time are well spent to perform the desired task.
- Satisfaction: "positive attitudes toward the use of the product." It refers to the extent to which expectations are met. Satisfaction is essential for keeping users motivated and engaged.

A total of 60 volunteers participated in this pilot study, all with recent training in engineering design graphics. This number widely exceeds the minimum number of participants recommended by [32] (more than 8) for usability studies.

The experiment was conducted in a computer laboratory environment, where the every participant had a computer with a web camera and the AR software already installed. Each participant was able to use and test the Augmented Reality system individually. A set of printed materials with the corresponding markers were provided and the individuals were given time to test the application and complete a series of exercises. The content of the engineering design graphics materials was limited to orthographic projection and visualization exercises.

To measure the different aspects of usability, a psychometrically validated questionnaire similar to the one proposed by [30] was distributed at the end of the exercise. A set of questions divided into two categories was presented to participants using a standard five-point Likert scale: Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. To assign a quantitative value to these Likert items, progressive positive integer values from 1 (Strongly Disagree) to 5 (Strongly Agree) were used, which allows the use of mean and standard deviation to quantify the parameters of interest.

The questions in the first category were intended to evaluate the effectiveness and efficiency of the materials. The questions in the second category were used to test user satisfaction levels in terms of the technology. Effectiveness, efficiency, and satisfaction levels are measured using the mean and standard deviation of the data obtained from the participant's responses.

The questions presented in the first category as well as the statistical measures used to analyze the results are shown in Table I.

TABLE I. QUESTIONS AND RESULTS OF EFFECTIVENESS AND EFFICIENCY

	Question	Mean	Std. Deviation
A1	The material is presented in a clear and concise manner and the topics are well structured.	4.533	0.536
A2	The number of exercises proposed in the chapter is sufficient for the topic discussed.	4.433	0.673
A3	The examples, types of 3D models, and difficulty of the exercises are adequate to comprehend the material.	4.483	0.624
A4	It is easy to locate the examples, exercises, and markers in the pages.	4.667	0.542
A5	The manipulation of the markers/virtual objects is easy and intuitive.	4.45	0.79
A6	The Augmented Reality application is stable and works well (doesn´t freeze).	4.033	0.78
A7	The Augmented Reality application is responsive, i.e. there is no lag in the screen when manipulating virtual models.	4.1	0.858
A8	The visual quality of the three-dimensional models on the screen is adequate. The models are clear and easy to recognize.	4.5	0.597
A9	The combination of printed materials and Augmented Reality technology is easy to use and intuitive.	4.6	0.527

Both AR technology and materials scored notably high. The vast majority of participants considered that the content was appropriate and well structured, and that the AR technology worked well. None of the participants experienced major difficulties manipulating the markers or using the AR software. This observation agrees with the responses given in the questionnaire, as most students reported that the system was intuitive and easy to use.

The AR software is robust, although a few participants detected some problems with the application that caused the AR models to flicker or momentarily disappear from the screen. This can explain the low scores on questions A6 and A7. We tested the application after all participants completed the exercises and found that the lighting conditions in certain seats and the print quality of some of the markers used in the experiments were not ideal.

User satisfaction questions and results are shown in Table II. For the last question, participants were asked to score the overall quality of the materials and technology presented. Since the Likert scale used in previous questions didn't apply to this question, the items of the scale were changed from Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree to Very Bad, Bad, Average, Good, and Excellent. The numerical values assigned to the items remained unchanged.

TABLE II. QUESTIONS AND RESULTS OF USER SATISFACTION

	Question	Mean	Std. Deviation
B1	The use of Augmented Reality in an Engineering Graphics course is valuable and useful to improve the understanding of engineering graphics topics.	4.55	0.565
B2	I could complete the exercises without any help other than the Augmented Reality software.	4.033	0.843
B3	The use of Augmented Reality technology is interesting and engaging.	4.833	0.376
B4	The use of Augmented Reality provides a significant advantage over traditional written materials.	4.383	0.761
B5	The use of three dimensional tools can increase attention and motivate students to study Engineering Graphics subjects.	4.617	0.613
B6	Augmented Reality is a good tool to help students comprehend engineering graphics and improve visualization skills.	4.683	0.537
B7	The use of Augmented Reality technology can be beneficial for students in other engineering and technical courses.	4.617	0.524
B8	Overall Opinion of the material (Very Bad, Bad, Average, Good, Excellent)	4.683	0.504

The material was received with enthusiasm and the participants showed a very positive reaction. The general opinion was that AR technology is valuable, engaging, and useful in the engineering design graphics domain, particularly when visualizing challenging models. Excitement and engagement could be easily observed in the participants during the exercise, although this could be attributed to the fact that many had never used or experienced AR technology before.

The frequencies of the students responses to the questions provided in the study are shown in Table III and illustrated in the chart shown in Fig. 5. The item "Strongly Disagree" has been omitted from the chart because the frequency of such response is zero for all the questions.

TABLE III. FREQUENCIES OF PARTICIPANTS' RESPONSES

	Disagree	Neutral	Agree	Strongly Agree
A1	0	1 (1.67%)	26 (43.33%)	33 (55%)
A2	0	6 (10%)	22 (36.67%)	32 (53.33%)
A3	0	4 (6.67%)	23 (38.33%)	33 (55%)
A4	0	2 (3.33%)	16 (26.67%)	42 (70%)
A5	1 (1.67%)	8 (13.33%)	14 (23.33%)	37 (61.67%)
A6	1 (1.67%)	14 (23.33%)	27 (45%)	18 (30%)
A7	2 (3.33%)	13 (21.67%)	22 (36.67%)	23 (38.33%)
A8	0	3 (5%)	24 (40%)	33 (55%)
A9	0	1 (1.67%)	22 (36.67%)	37 (61.67%)
B1	0	2 (3.33%)	23 (38.33%)	35 (58.33%)
B2	3 (5%)	11 (18.33%)	27 (45%)	19 (31.67%)
B3	0	0	10 (16.67%)	50 (83.33%)
B4	1 (1.67%)	7 (11.67%)	20 (33.33%)	32 (53.33%))
B5	0	4 (6.67%)	15 (25%)	41 (68.33%)
B6	0	2 (3.33%)	15 (25%)	43 (71.67%)
B7	0	1 (1.67%)	21 (35%)	38 (63.33%)
B8	0	1 (1.67%)	17 (28.33%)	42 (70%)

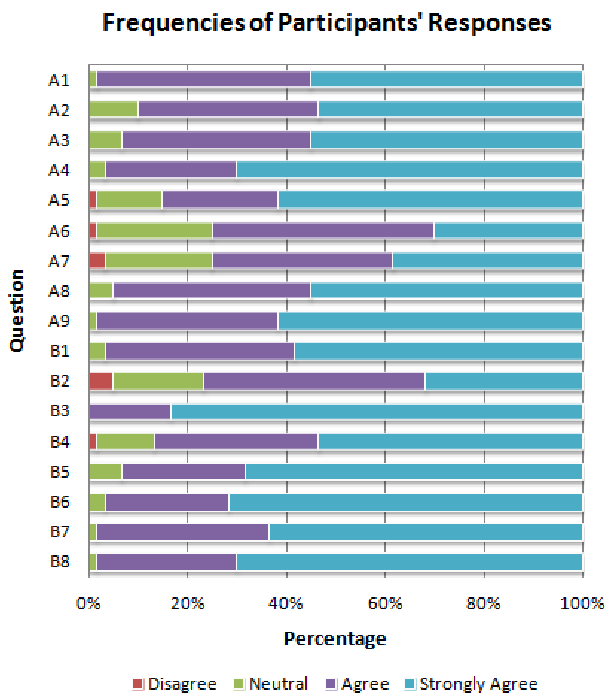

Fig. 5. Frequencies (%) of the participants' responses

A great percentage of the participants agreed or strongly agreed with the statements that AR provides a significant advantage over traditional printed resources and that AR could also be beneficial in other engineering courses, which indicate a high level of acceptance, motivation and interest in the technology. On the other hand, question B2 received some low scores, which seems to reveal that some participants see AR technology supporting traditional materials rather than entirely transforming them into self-study resources.

V. CONCLUSIONS AND FUTURE WORK

Our study has shown that the use of Augmented Reality has the potential to become an effective tool to deliver engineering graphics modules. AR technology provides an attractive and engaging new way to complement and enhance traditional teaching and learning materials (usually based on pen and paper exercises), while moving education one step closer to the technological profiles of today's students.

The system we present was designed to be low cost and easy to use. Users learn to work with the application almost immediately and the physical manipulation of the markers becomes natural very rapidly. The minimalistic interface of the software ensures the students remain focused on the actual activity they are performing without getting distracted by other elements.

As shown by the results of our usability study, the system scored remarkably high in all categories. The materials were widely accepted, with very positive reactions from the majority of the participants.

In the future, we plan to perform a comparative study to more accurately test the impact of AR technology in the students' understanding of engineering design graphics materials. Although the technology looks promising and many students and instructors have already ventured to use it (at least partially) in the classroom, we are interested in determining if there is a significant statistical difference between engineering students that use traditional materials and students that use AR-based materials.

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Aptitude Digging Education in Project-based Course

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***Abstract*—Students from China are always intelligent but lack of creativity. These are somewhat stereotypes. This is partially because of the reserved or implicit culture. In an objective point of view, it is also because of the limited education resources. In the single assessment criterion education circumstance, students chase for the high marks even without knowing their interests or aptitudes. In a 12-week open experimental course, *Optoelectronic Instrument Experiments* (OIE), we try to encourage the students to dig their aptitudes and bring them into full play to earn more credits for the course. Self-assessment and mutual-evaluation for technical proficiency, communication skills, collaboration and leadership are carried out for the final evaluation. We also communicate with the students the speciality and skill a qualified engineer needs. We hope to help them prepare themselves for engineering-related jobs in the further.**

Keywords—Project-based learning, engineering-involved courses, aptitude digging

I. INTRODUCTION

Students from China are always intelligent and shy. They are good at mathematics but lack of creativity. These are somewhat stereotypes. This is partially because of the reserved or implicit culture. In an objective point of view, it is also because of the limited education resources. The traditional teaching and assessment criterion for a good student is high marks in the examination. Struggling for the standard answer, most students do not have their interests or even their own time. This is terrible and some of the students get lost in job hunting or even their life because standard answer no more exists. They only know what they dislike, but do not know what they are fond of or good at. This is the common case in the current generation.

The purpose of education is not teaching what to do but instructing how to do things correctly and effectively. However, the “standard answer” education mode can hardly help students develop or even realize their aptitude and personality. Since self-knowledge is the basis for the choice in life, the situation should be changed gradually. Unfortunately, it is still hard to do personal evaluation and education for each college student in China. So at least one course involving and encouraging personal thoughts, trails or even failures should be arranged. It is a pity in many colleges in China such kind of compulsory course does not exist.

We have launched a project-based course Optoelectronic Instrument Experiments (OIE) in Beijing Institute of Technology since 2009 [1]. Several optoelectronic instrument systems are set as the subjects of experimental project. After learning some general topics on optoelectronic instruments and design examples, the students are grouped and each group can choose one project. They are required to develop the whole system within 12 weeks. The final assessment includes the performance of the system, the collaboration, the presentation, and etc. It is an open experiment course and there is no standard answer. In the previous years, we find that some of the students turned more enthusiastic about his major during the course; some all-around ones found their shorts and some discovered their speciality. These are all good phenomena. They proved that the course could help students improve their self-knowledge. We call it aptitude digging.

In this year we are preparing a segment which systematically emphasizes aptitude digging through the project process. The detailed methods are given in the following sections.

II. APTITUDE DIGGING PEDAGOGY AND ISSUES IN OIE

A. OIE: The Open Project-based Course

OIE is a lecture-lab course which aims to familiarize students with the principal ideas of optoelectronic apparatus design and train students to apply the knowledge to identifying, analyzing and solving problems in optoelectronic system construction. We try to expose the students to “real” engineering early. After some brief general topics on optoelectronic instruments and introduction to several successful design examples, the students are assigned to teams and each team chooses one project to implement in twelve weeks. Through the mini simulative “Cycle of Professional Practice” [2], students will learn how to integrate the knowledge and techniques they have learned previously, and use different kinds of components and devices to construct an optoelectronic instrument.

The main difference from the other project-based courses is that the OIE course is compulsory, which means every student must take this course. In our opinion, students are the products of their college. Elite education may help several excellent students to achieve huge success, but we prefer to the results that all the students turn to be qualified products. All the students who are majoring in Measurement & Control Technology and Instruments have to gain the OIE credit to get their bachelor degree. Our purpose is to help all the students in this major, at least most of them, to improve their engineering practical, personal and interpersonal skills. We are trying our best to impel them to be prepared for the real engineering environment they have to throw themselves into soon.

B. No Standard Answer in the Open Experiments

As introduced above, in OIE, we don’t set any exams or established experiments. The entire detailed target, schemes, budget, schedules are proposed and organized by the students in group. They can solve the scientific and technic problems by any means they can afford. This is similar with the situation in real engineering research environment. However, this does make it more difficult to conduct and grade them. Their questions are divergent and some of the jobs are really demanding while some are regular.

In order to technically help them better, we organized a 6-member instructor team, including full professors, associate professors and lecturers. The members are also distinct in major, which includes optics & photonics, mechanics, electronics, and computer hardware & software. We also involve experienced researchers and technicians into the course as consultants. As for the assessment of students doing jobs with different difficulties, we do the grading considering the difficulty as a factor.

What we are trying to do is to create an environment without standard answer and with diversification. We hope this will help inspire the students with creativity and confidence.

III. What's New This Semester

With the environment created as above, in this semester, we emphasize aptitude digging through the project process. We set two sections at the beginning and end of the course.

A. Self-assessment and Mutual-evaluation in the Group

The first class of OIE is arranged for team grouping. In this semester, the students are grouped "providentially". Some poker cards with funny pictures are prepared before, the total number of which equals to number of the students who have signed up for the OIE course. Every student is asked to draw a card from the poker card pile when he enters the classroom. Just when they enjoy the funny view on their cards and become curious what it is for, the grouping rule is announced. The students who got the same suits and numbers are grouped as a team.

Because it is impossible for the students to choose their partners, they have to position themselves in the group at the beginning. They also have to elect the team leader and choose the experimental topic. We organize self-assessment and mutual-evaluation section to help them visualize the process.

Self-assessment is done through questionnaire. Two choice questions are included. The aptitude related to modern engineering realization can be divided into two general categories: academic and interpersonal capability. We call them specialized skills and teamwork capability. For the specialized skills, we further classify it into

(1) optical design and optical path setup;

(2) mechanical design and system setup;

(3) electronic design and realization;

(4) programming and debugging, and

(5) others.

The first question is that *Do you know your specialized skill*? Five options are given as

A. Yes, I know. It is the above ( ) and ( ) (no more than two choices) because I had relevant experiences.

B. Yes, I know. I am good at all of them.

C. Yes, I know. I am not good at any of them.

D. No, I do not know. I am good at getting high scores in examinations maybe, but I really do not know my skills in solving real engineering problems.

E. None of the above. My opinion is ( ).

For the teamwork capability, we focus on the personal localization. We design classification as

(1) I am suitable for the team leader. I am responsible and good at organizing and coordinating teammates.

(2) I am suitable for a backbone in the team. I am responsible for my own work and willing to help other teammates, but I do not want to organize.

(3) I am suitable for a common member. I can finish my work but I am not interested in others' work. I will do what team leader asks me to do.

(4) I am not interested in this class, and I will spend as little time as possible on it.

The second question is *Do your know your teamwork capability? What is your localization among your teammates*? Three options are given as

A. Yes, I know. I localize myself as ( ) in the above. I am not willing to take other characters.

B. No, I do not know. I can be any of the above.

C. None of the above. My opinion is ( ).

After the self-assessment, students are asked to do the mutual-evaluation by sorting the teammates according to leadership, fundamentals in mathematics and physics, experiences in engineering and preliminary intention for the division. Results are made public anonymously or not according to the students' opinions. Then the division inside the group is made by the students according to the sorting results and discussion.

Members with different specialities and personalities may constitute a reasonable and efficient team. Communications based on self-knowledge and mutual-understanding may lead to success. There is an old saying in China, *knowing yourself as well as the enemy*. It is also true that *knowing yourself as well as the partner*. Students are expected to preliminarily position themselves in unfamiliar members.

In this section, most of the students showed enthusiasm in self-dissecting and mission division. Some received different opinions about their characteristics. Very few acted negatively and replied "whatever". We arranged the division according to their voting and each student was assigned a particular mission by his team.

B. Reassessment at the End of the Course

During the experiments, the students are asked to try their best to solve the problems in their own division. Up to now, they act very actively. Since this is the first time for most of them to join in a practical engineering project, overestimation and underestimation happen in almost every class.

When the students finish the scheme design and realize that all the knowledge is available from the text book, they tend to take the problem lightly and complain it is too easy. They even believe they can finish the whole system in one week. However, when they begin to assemble a specific functional device and encounter a small failure, they turn blank and complain it is too difficult. The project also turns impossible to them. This reflects the fact that they do not know how to solve practical problems and how to deal with unexpected failures. They will even become less confident in front of a failed basic circuit with only 4 components.

Facing this current situation, we try to guide them not only with technical skills but also open mind. We plan that at the end of the course, the students should evaluate all the group members including themselves again in the same aspects. The questionnaire after the whole course is similar with that before the experiments. Still two questions are included. The classification for specialized skills and teamwork capability are exactly the same. But the options are changed as follows. For specialized skills, options are

A. Yes, I know. It is the above ( ) and ( ) (no more than two choices) and I had more relevant experiences in this course.

B. Yes, I know. It is the above ( ) and ( ) (no more than two choices) and I had first relevant experiences in this course.

C. Yes, I know. I still think I am good at all of them.

D. Yes, I know. I still think I am not good at any of them.

E. No, I still do not know. I do not have the chance to try.

F. None of the above. My opinion is ( ).

For teamwork capability, options are

A. Yes, I know. I am suitable for ( ) in the above. It is proved in the course.

B. Yes, I know. I am suitable for ( ) in the above. It is a pity I cannot prove it in the course because of the grouping and division.

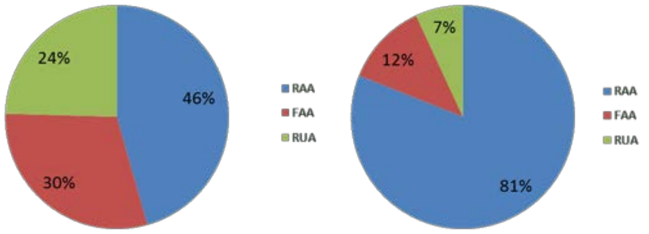
C. Yes, I know. I am suitable for ( ) in the above. I changed my mind in the course.

D. No, I still do not know.

E. None of the above. My opinion is ( ).

C. Results and Analysis

In all, 57 students took the questionnaire before and after the experiments, and we counted their answers as follows. For the specialized skills questions before experiments, Option A is taken as Real Awareness of the Aptitude (RAA), Option B and C are taken as False Awareness of the Aptitude (FAA), Option D is taken as Real Unawareness of the Aptitude (RUA), and Option E is taken as others. For the specialized skills questions after course, Option A and B are taken as RAA, Option C and D are taken as FAA, Option E is taken as RUA, and Option F is taken as others. The choices of the students before and after the experiments are counted and visualized as in Fig. 1. More than 30% of the students get better understanding and recognition of their academic aptitude.



(a) (b)

Fig. 1. Statistics of specialized skill recognition (a) before and (b) after the couse.

For the teamwork capability, similar results can be obtained. 14% of the students get better localization of themselves.

IV. Conclusion

Since self-knowledge and confidence are the basis of work and life, we launched a project-based open experimental course, *Optoelectronic Instrument Experiments*, and tried to create an environment without standard answer and with diversification. We organize self-assessment and mutual-evaluation section to help students dig their aptitudes. Currently, overestimation and underestimation happen in almost every class. We try to guide the student to establish confidence and accumulate experience during solving open engineering problems. According to the self-assessment questionnaire before and after the course, the students get better understanding and recognition of themselves in both academic and interpersonal capabilities. We will improve the mutual-evaluation process next time.

Acknowledgment

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Redesigning engineering courses by introducing digital ink technology

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Abstract*— We applied the How People Learn framework (HPLf) in two different higher education contexts. On one hand, a first-year core course on Computer Technology, taught at the Computer Engineering Degree Program at Universitat Politècnica de València, Spain. On the other hand, two Food Chemistry related courses, taught at Universidad de las Américas Puebla, Mexico, as part of food engineering undergraduate and food science graduate programs. The goal of these works was to redesign studied courses at both universities from a lecture-based format to a "challenge-based" format by using Tablet PCs and digital ink. In order to support the studied approach, different ink-enabled software tools were utilized. Class sessions were enhanced through the usage of Classroom Presenter, a pen-based interaction system that supports the sharing of digital ink on slides between instructors and students. InkSurvey also allowed teachers to pose questions, receive instantly digital ink responses, and provide real-time formative feedback. Some other tools such as PDF Annotator and Ardesia helped instructors to review coursework and assignments and provide formative feedback as well. We studied our approach over the two last academic years by observing classes at both universities, obtaining selected student achievement indicators and conducting surveys with students and instructors.

Keywords—Tablet PC; Digital ink; How People Learn; Classroom Presenter; InkSurvey

I. Introduction

The *How People Learn* framework (HPLf) provides a convenient way to organize a great deal of information about the nature of competent (expert) performance and about ways to help students develop their own competence. This framework highlights a set of four overlapping lenses that are useful for designing learning environments. HPLf encourages that teachers promote student engagement both in and out of class, working in teams or individually, and what is more important, providing students with multiple feedback from different formative assessments.

Our challenge was to use HPLf to redesign different courses in two quite distinct contexts. Overall, the goal was to improve teaching and learning, creating learning environments that promote high quality interactive classrooms while formative assessment should be integrated in educational practices through the use of Tablet PCs and associated digital ink technologies.

Tablet PCs combine a standard notebook computer with a digitizing screen and a pen-like stylus device to produce a computer that allows users to easily input natural writing and/or drawing. Pedagogically, applications for the Tablet PC include lecture/presentation enhancement, problem-solving demonstrations, active learning support, guided brainstorming, reading, commenting, marking- up (providing feedback), and grading of student work. A review of the current literature supports the following advantages in using a Tablet PC: first, digital ink enables instructors to write "on the fly" during class as one would write on a chalkboard or on a transparency. This is especially meaningful for engineering and chemistry courses where examples and explanations are often mathematically and graphically intensive. Second, the freedom of marking-up significantly changes the way students and teachers interact. It facilitates bidirectional sharing of information, moving students beyond merely observing presentations to interacting with the material, the teacher, and each other. In addition, the use of Tablet PCs supports more efficient management of information. Dynamic working notes can be saved, while lecture notes with vivid annotations can become available for students' online viewing [1].

The rest of this paper is organized as follows. Section II describes the contexts where this approach was implemented. Section III outlines how the courses were redesigned and the ink-enabled software that supported these processes. Section IV summarizes the results on both contexts. Finally, section V draws some conclusions and outlines further work.

II. Context Description

As stated in the introduction, two different contexts have been used to validate our approach. On one side, at *Universidad de las Americas Puebla* (UDLAP), a Mexican private institution of higher education committed to first-class teaching, public service, research, and learning in a wide range of academic disciplines including business administration, the physical and social sciences, engineering, humanities, and the arts. Since 1959, the Commission on Colleges of the Southern Association of Colleges and Schools (SACS) has accredited

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UDLAP in the United States. On the other side, at *Universitat Politècnica de València* (UPV), a Spanish public educational institution that offers modern, flexible degrees that are designed to meet the demands of society, as well as official postgraduate programs that are subject to demanding quality control systems. It has three campus sites with a total of 36,187 students, 2,843 members of teaching and research staff, and 2,396 administrative and services staff. It is the only Spanish technological University ranked among the best in the world, according to the Academic Ranking of World Universities (compiled by Shanghai Jiao Tong University).

A. UDLAP courses

Concerning case studies, UDLAP selected 2 courses, *Food Chemistry (IA-332)* and *Advanced Food Chemistry (IA-530)* which are a junior level, 3 credit required course for food engineering and nutrition BS programs and a first- semester 3 credit required course for the food science MSc program and also an elective for the PhD in food science program at UDLAP, respectively. Approximately 10-25 students are enrolled in IA-332 per semester with 6-17 food engineering students and 4-8 human nutrition students, while approximately 5-10 graduate students are enrolled per semester in IA-530; these graduate students have already a BS in food engineering, food science, biology, agricultural engineering, chemistry, or pharmacy. IA-332 and IA-530 major goal is to help students think about the way a food chemist does. Thus, students are involved in answering two key questions: i) how the composition, structure and properties (especially in terms of quality and safety) of foods are affected by chemical changes the food experiences? And ii) how the understanding of key chemical and biochemical reactions can be applied to many situations encountered during formulation, processing and storage of food?

The fundamental concepts of the studied courses are, therefore, chemical and biochemical changes of food and its effect on food composition, structure, quality, and safety during formulation, processing and storage, while encouraging students think about and apply food chemistry in the same ways experienced food scientists and engineers do.

In an increasingly collaborative, mobile and globally inter-connected environment, UDLAP envisions ubiquitous computing as a natural, empowering component of every teaching, learning, and research activity. UDLAP is committed not only to adopting and adapting technologies to all its scholarly endeavors, but also to playing an active role in their development [2].

B. UPV course

In contrast to UDLAP courses, *Computer Technology (TCO-11544)* is a first-year core subject taught during the spring term (second semester) in the Computer Engineering Degree Program that was selected at the UPV as case study. The course has 6 ECTS credits (150-180 hours). 60 hours are dedicated to face-to-face classroom work and at least 90 hours are expected as students' personal study. On average, during the last academic years, the course has dealt with 11 lecturers and more than 450 students per year, divided into 11 lecture groups and 21 lab groups. The syllabus was compiled according to national and international recommendations, the main sources being the ACM/IEEE curricula recommendations, as well as the Computer Engineering Degree Program White Paper of the National Agency for Quality Assessment and Accreditation [3].

The course is included in the field of computer engineering in ACM/IEEE computing curricula, and matches the non-computing topic of electronics as it is focused on semiconductor devices and logic families. Computer Technology topics are not generally addressed in high school programs, so that the background of UPV students on electronics is virtually nonexistent.

III. Redesigning the Courses

A major aim is to help students developing the kinds of connected knowledge, skills, and attitudes that prepare them for effective lifelong learning [4][5]. This involves the need to seriously rethink not only how to help students learn about particular isolated topics but to rethink the organization of entire courses and curricula. The ability to design courses and corresponding high-quality learning environments require that we move beyond procedural strategies and models. We also need to understand the kinds of skills, attitudes, and knowledge structures that support competent performance. Thus, for the redesigning of the courses similarly as previously described [4]-[6] we "worked backwards" as suggested by Wiggins and McTighe taking into account Jenkins model as well as the HPL framework [7][8]. Especially important was knowledge of key concepts and models that provide the kinds of connected, organized knowledge structures and accompanying skills and attitudes that can set the stage for future learning [8].

Our redesigns involved a transformation of our courses from a lecture-based format to a "challenge-based" format. We use the term "challenge-based" as a general term for a variety of approaches to instruction that many have studied, these include case-based instruction, problem-based learning, learning by design, inquiry learning, anchored instruction, and so forth. There are important differences among these approaches, but important commonalities as well. We used the HPLf as a set of lenses for guiding the redesign of the lessons, development of our challenges but also the overall instruction that surrounded the challenges [5]-[7]. Our goal was to improve teaching and learning by creating high-quality learning environments that promote an interactive classroom while integrating formative assessments into classroom practices by means of Tablet PCs and associated digital ink technologies [4][9][10].

Particularly important were opportunities to make students' thinking visible and give them chances to revise. We also noted the importance of provided opportunities for "what if" thinking, given variations on the challenge and for new problems that also involved the lesson's concepts. Attempts to help people reflect on their own processes as learners (to be metacognitive) were also emphasized. We utilized several Tablet PC associated technologies to gauge student learning in real time, provide immediate feedback, and make real-time pedagogical adjustments as needed.

A. *Ink-Enabled Software*

To support the described approach, different ink-enabled software tools were utilized.

Communication within the classroom was enhanced through the usage of *Classroom Presenter* (CP) [11], a pen-based interaction system that supports the sharing of digital ink on slides between instructors and students. Instructors connect the Tablet PC to the lecture room screen to present contents, while showing their digital ink annotations in real time. CP makes possible to broadcast these contents to students' Tablet PCs, while allowing them to personalize the instructor provided materials with typed and ink annotations that each student can make, based on discussion during class (Fig. 1).

Using the work of Angelo and Cross [12], we identified Classroom Assessment Techniques (CATs) appropriate to each section of the course and then adapted them into the Tablet PC/CP environment. Instructor utilized CATs to gauge student learning in real time and made real-time pedagogical adjustments as needed. At various points during each session, students are asked to tackle a learning activity, whether a simple exercise or a more complex problem, as in the traditional approach. In this setting, students can anonymously respond by handwriting (or typing) their solution on the Tablet PC and submitting it wirelessly to the instructor. As soon as the exercises are received, instructors can preview the student responses, select one or more to display to the class, and make annotations as they are being displayed. This option provides immediate feedback to both students and instructor about misunderstandings and enables the instructor to adjust course material in real-time based upon student answers to in-class exercises. Additionally, student responses can be saved for review after lecture by the instructor or even made available electronically to the audience. According to the instructor judgment and course design, students are asked to deliver some in-class exercises through the virtual campus platform and thus, can be used as part of the student activity score, what enables a continuous assessment.

The instructor also made use of CATs that are already features within Classroom Presenter, like the polling features (true/false as well as multiple choice questions). Students respond by clicking the corresponding answer on their Tablets. Once instructors close the poll, CP shows the corresponding results in statistical form. This strategy is also useful as a way to quickly gather formative information and in turn, to provide immediate feedback to students to help clarify misconceptions.

In order to support group work, a virtual meeting room called *Vyew* [14] was also employed. It is a browser-based group screen and desktop sharing platform that also offers group video chat and includes ink annotation and drawing tools. Therefore, it proved especially suited to help students to address team assignments, problem-solving or projects that usually requires everyone to have access to the common information as well as a more rich communication ways. *Vyew* comes with a basic free version that offers unlimited use for up to 10 people, making it more than sufficient for typical team sizes at UPV.

InkSurvey [15], a web-based tool developed specifically to allow an instructor to pose open-ended questions to students during class and receive real-time student responses was also utilized (Fig. 3). Students by means of Tablet PCs respond to these questions with their own words/sentences/paragraphs entered manually via the keyboard, or with digital ink that allows handwriting, sketches, equations, graphs, derivations, etc. Confidence level can be included if desired (as was our case). The instructor received an instantaneous compilation of web-based student responses to receive feedback in real time [2][5].

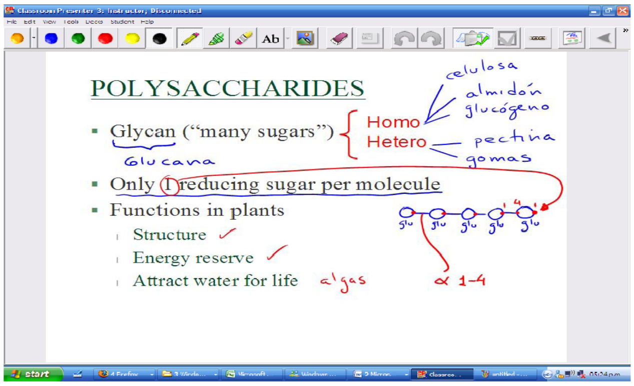

Fig. 1. Example of Classroom Presenter usage in Advanced Food Chemistry.

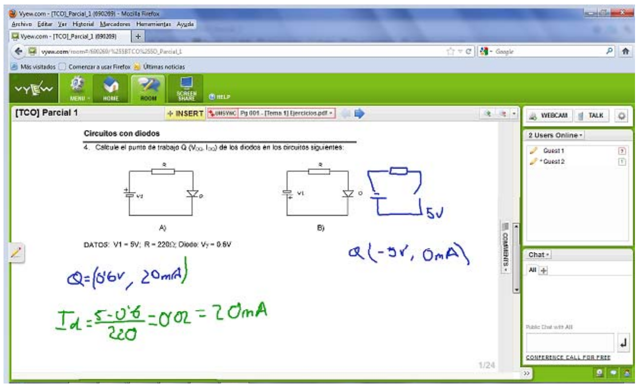

Fig. 2. Example of Vyew usage in Computer Technology.

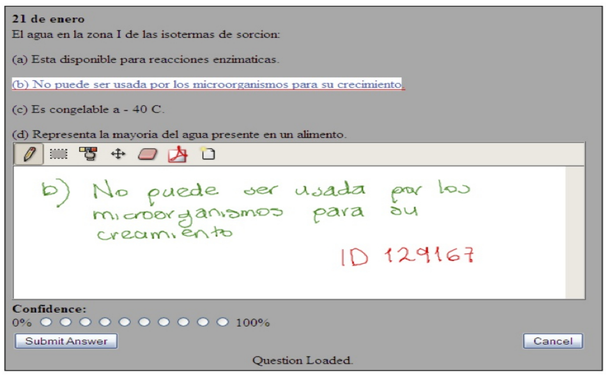

Fig. 3. Example of Inksurvey usage in Food Chemistry.

Some other tools such as *PDF Annotator* [16] and *Ardesia* [17] were used by UPV instructors to review and correct student coursework and assignments uploaded to the corresponding LMS. In the first case (Fig. 4), ink features were very helpful to make short comments on PDF documents, highlighting, or even adding drawings in order to better illustrate ideas. In case other formats or resources were delivered, a free digital sketchpad software called *Ardesia* was used to make colored free-hand annotations with digital ink everywhere, record it and return it to the student. According to White and Irons [18], these tools help faculty introduce some of the most useful types of formative feedback perceived by students and can therefore contribute to enhance their learning.

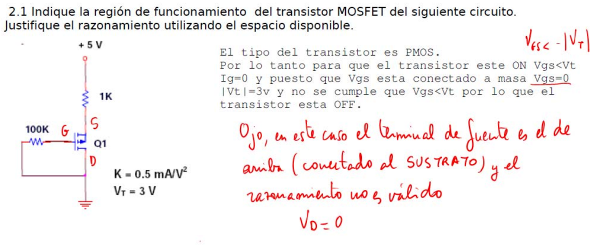

Fig. 4. Example of PDF Annotator usage in Computer Technology.

IV. RESULTS AND DISCUSSION

To measure the effectiveness of the experiences, we report here some quantitative and qualitative measures of the effectiveness of the studied approach.

A. *Quantitative measures*

In order to assess the approach presented in this paper two groups have been selected in Computer Technology (TCO in the figures) as the experimental ones, while the remaining followed the “traditional” teaching approach. As there were nine morning groups and two afternoon groups at UPV, and their features use to be different, we selected two morning groups as the experimental ones (Tablet groups in Fig. 5 and 6) in order to facilitate the comparison.

We utilized three quantitative indicators to assess UPV experiences: the student activity score (lectures and labs), the written exam scores and the final score, which was computed as the arithmetic average of the first two. In fact, these indicators represent the average score in a 10-point scale for the different groups. It is important to point out that the second one is the more reliable as all the students take exactly the same exams regardless their group. However, the definition of student activity mark and accordingly the final score can be different depending on the studied groups.

Fig. 5 shows that students in the Tablet groups had better results in the three indicators when compared both to the morning groups and to all the groups, although the difference in the written exams was the lowest. Concerning the second academic year, Fig. 6 shows that although student activity is quite similar in the different groups, in particular when we compare Tablet and morning groups, once again students at experimental groups performed better in written exams compared to the rest of the groups. Similar results were obtained in terms of pass, fail, and dropout rates. Tablet groups obtained better results in the two considered academic years; however, the differences were small.

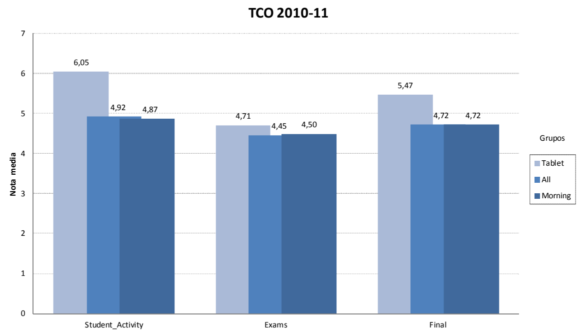

Fig. 5. Indicators for the academic year 2010-11.

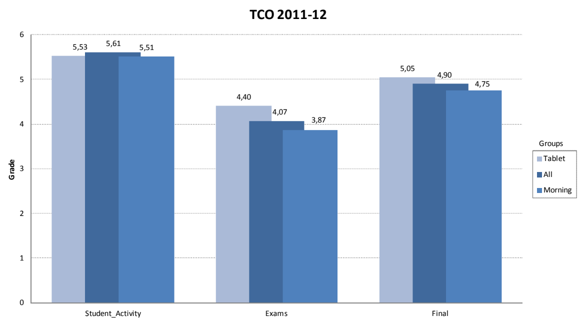

Fig. 6. Indicators for the academic year 2011-12.

Concerning UDLAP courses, in IA 332 (undergraduate) and IA 530 (graduate) were applied three quizzes, the courses were evaluated by obtaining scores of three quizzes, the third ones were part of the final exams. With the use of Tablet PCs and ink-enabled software (InkSurvey and Classroom Presenter) students improved their results in these summative assessments (final exam). In both cases, undergraduate and graduate courses, the formative assessment exercises performed with the Tablet PC and InkSurvey had a positive impact on the grades of the summative quizzes (Fig. 7).

Fig. 8 exhibits the mean scores (in a 10-point scale) of quizzes taken by undergraduate (IA332) and graduate (IA 530) students in the quizzes applied four years before implementing the use of the Tablet PCs (2005 to 2008) that were compared with results (after) obtained during the next four years (2009 to 2012) when the courses were redesigned and Tablet PC and associated technologies were utilized.

B. *Qualitative measures*

In order to examine how students perceived the use of Tablet PCs and associated technologies, at UDLAP we applied two online surveys to be answered by students (IA 332 and IA 530). The first survey was conducted at the beginning of the semester and the second one at the end. The first survey was related to the expectations of students in relation to the use of these technologies. The second survey was designed to assess the academic experience that students had with the use of these technologies. Both surveys have some open-ended questions.

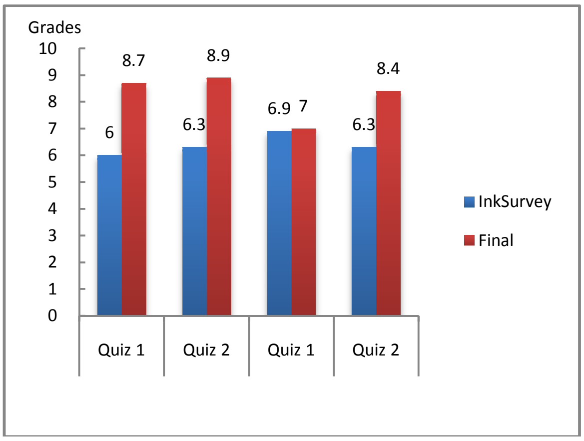

Fig. 7. Mean grades of undergraduate and graduate students in formative assessment (Inksurvey) and summative assessment (final) two first quizzes (years 2009-12).

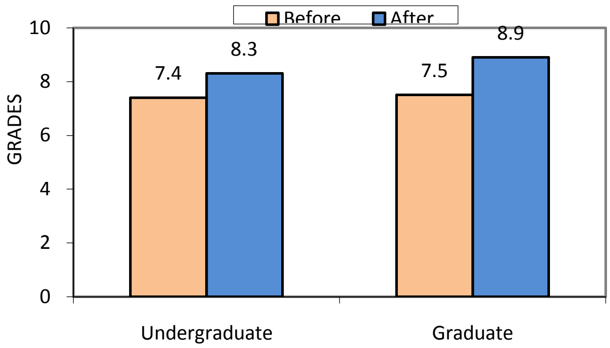

Fig. 8. Mean grades of quizzes taken by undergraduate and graduate students before (2005-08) and after (2009-12) course redesign and Tablet PC implementation.

44% of students had previous contact with a Tablet PC before UDLAP studied courses. Students responses regarding the advantages of using a Tablet PC include: to write on it and take notes on the teacher's presentations, the ability to do graphics or drawings, write with the digital pen like in a notebook, the ability to interact with the teacher and peers to exchange information or ideas; the simplicity to take notes.

The second survey indicated that students' experience with Tablet PC and associated technologies was very interesting and different. They emphasized that it was a chance to take more didactic classes, or a course that was more dynamic, interactive and not boring. They also highlighted the experience of taking notes and writing on the teacher's presentations, which allowed them both to pay more attention to the class and interact with their teacher and classmates. Furthermore, the opportunity to send questions to the teacher and interact with him was highly appreciated.

In addition, UDLAP students underlined the increasing interaction with the teacher through more dynamic activities where they could draw pictures, graphs, solve problems, etc. They also stressed that more exercises and assessments in real time were conducted and the fact that they can participate and give opinions by using the capabilities of the Tablet PC.

Another result of the use of the Tablet PC was a visible increase in the motivation of students to participate in class discussions and problem solving activities. Also, redesigning courses improved understanding and ability of UDLAP students to solve practical food chemistry problems and complete real-world engineering projects, evaluated directly in several work products made by students, such as projects, problems, homework, tests and engineering journals.

Additionally, in order to carry out a qualitative analysis of the experience held at the UPV, each student participating in the experimental groups was asked to complete a common survey, few days before finishing the term. The first part of the questions asked the students to indicate how the Tablet PC-based approach influenced some key aspects of their learning process, such as class attendance, motivation, class work, or learning achievement. The survey also included some open questions concerning pros and cons, as well as suggestions.

Fig. 9 shows that most UPV students perceive a positive influence of Tablet PCs on class attendance, class work, motivation and learning achievement, while an important percentage considered Tablet PCs a source of distraction. It is also remarkable that most of them would recommend its usage in other courses.

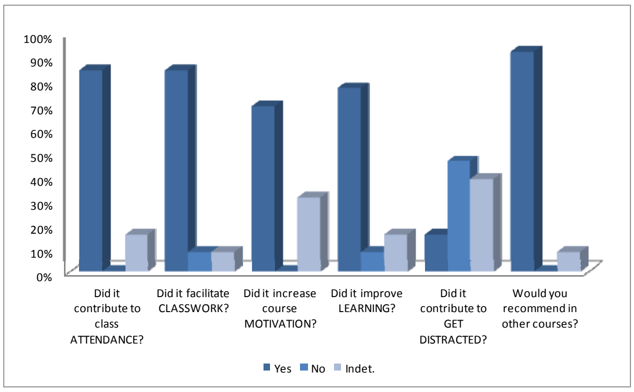

Fig. 9. UPV student post-questionnaire.

V. Conclusions

Thanks to the possibility to work in an anonymous way by Tablet PCs and associated digital ink technologies, students felt comfortable sharing their ideas with classmates, which enabled instructors to assess student understanding frequently during the process of instruction and problem solving. Formative assessments quickly identified the most common difficulties, allowed faculty to provide immediate feedback, redirect classroom activities, and/or refine instruction based on feedback received. Opportunities to make students' thinking visible were greatly enhanced, these gave them chances to revise their thinking, for "what if" thinking, as well as to help them reflect on their own processes as learners (to be metacognitive).

Students' initial conceptions provided the foundation on which more formal understanding of the subject matter was built. Further, frequent formative assessment helped make students' thinking visible to themselves, their peers, and their instructor. Facilitated by Tablet PC associated digital ink technologies, feedback (in studied courses) that guided modification/refinement in thinking increased.

Additionally, several other important impacts were achieved, particularly on instructor identifying the most common difficulties in UDLAP and UPV courses while providing immediate feedback of both written work products and oral presentations from students; helping students reflect on their own processes as learners; and instructor understanding of how through the use of Tablet PC associated technologies, student thinking can be revealed, and therefore the student learning experience in the classroom can be enhanced resulting in improvements in both instruction and student academic success.

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Understanding Engineering Identity Through Structural Equation Modeling

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***Abstract*—Understanding students' self-ascribed engineering identity may be one way to understand engineering choices and to help recruit new students to the engineering pipeline. In our framework, identity is composed of students' perceptions of their performance/competence, recognition, and interest in a domain. This paper outlines the creation of a model of engineering choice based on this framework. The data utilized in this analysis come from the nationally-representative Sustainability and Gender in Engineering (SaGE) survey. Distributed during the fall of 2011, the survey was completed by 6,772 college students across the United States enrolled in first-year English courses. A structural equation model was built using previously validated constructs of mathematics, physics, and general science identities. These three constructs predict an engineering identity which, in turn, influences the choice of engineering in college. The model is a step towards a better understanding of the choice of an engineering major in college.**

***Index Terms*—Structural Equation Modeling, Identity, Engineering Major Choice**

I. Introduction

Students who choose engineering after completing high school often have not been fully exposed to professional science practices, let alone engineering practices. Additionally, high school coursework is rarely differentiated for students pursuing specific STEM careers; students intending engineering careers are expected to take a similar or identical set of courses as students intending, for example, chemistry or physics careers. So the choice of an engineering major may not be a fully-informed decision. In recent years, there have been calls for more STEM graduates [1] with particular attention being paid to recruiting and retaining more engineers, but access to the engineering pipeline is relatively closed after the first year [2], [3]. One way to address the need for more STEM graduates is through an improved understanding of the factors that affect the choice of engineering and how to more effectively recruit students upon entrance into college.

A potential way to address this pivotal transition is through students' self-ascribed identity. Identity is the authoring of a self within a particular context [4]. In this case, the particular context is that of an engineering discipline. Identity is associated to a student's authorship of identity at a particular moment and how these beliefs may change or remain stable over time. The importance of understanding identity is highlighted by Brickhouse et al.: if more students are to enter science and engineering, they need to see themselves as the "kind of people who would want to understand the world scientifically"[5].

There have been calls for an increase in research on engineering identity by Brickhouse and others [5], [6]. Attainment value, which is related to engineering identity (being an engineer is related to the "sense of self"), has been found to be important for the persistence of engineering students during their undergraduate programs. Further, it has been found to be more important than interest or perceived utility to engineering persistence [7]. Other recent research on students' engineering identity has also focused on the college years, exploring both engineering and professional identity development. For example, Chachra et al. [8] studied the development of engineering identity during the undergraduate years and found a substantial dependence on the culture of engineering schools as well as students' beliefs about what constitutes engineering practice (e.g. "technical work" versus other aspects). The importance of school culture for the development of an engineering identity has also been found in other work [9].

Professional identity development has been another theme in recent years. Students who aspire to be engineers have been found to have more distinct professional and occupation-related identities, even at an early age [10], [11]. There are, however, few studies that focus on the effect of pre-college experiences and other identities on engineering identity development [10] although the importance of such factors and early exposure to engineering has been stressed [12]. Much of the prior research has acknowledged the importance of considering a multiplicity of identities, but little research has been conducted on the effect of other STEM disciplinary identities on the development of an engineering identity. Considering a multiplicity of identities is important since self-beliefs in related domains will lend to, and interact with, the development of an engineering identity. Subsequently, a focus on interwoven identities and pre-cursor identities (those beliefs that precede engineering identity development because students have had little early exposure to engineering) will help to develop a better understanding of the students who gravitate towards engineering and those who move away due to perceptions about engineering practices and performances which conflict with their views of themselves in other domains. This work is a first step toward understanding the engineering identity that precedes the choice of an engineering major in

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college, in concert with multiple STEM identities.

In the current conceptual framework, domain-specific identity is comprised of three measurable dimensions of students' beliefs: their performance/competence, recognition by others, and interest [13], [14], [15], [16]. The study of identity using this framework has proven useful in other domains but has not yet been fully applied to engineering [17]. This framework has been validated in physics and mathematics through large scale studies [13], [14]. The recognition component of identity consists of an individual's beliefs in the external recognition they receive (from parents, teachers, other students, ...) as a good engineering student. Interest in the subject material also plays a key role in the choice of engineering as a major: students should have some understanding of the realm of engineering in order to be be attracted to engineering and, hence, have the opportunity to develop an identity with respect to engineering. Performance/competence are an individual's beliefs in their ability to perform effectively (e.g. on an engineering exam) and be competent in engineering (e.g. understand engineering concepts). Traditionally, students have very few direct experience in an engineering community of practice before they make their choice of engineering as a career in the high school to college transition [18]. For this reason, multiple subject identities have been explored in this work to understand the identities that students who choose engineering in college have *before* their development of the traditionally-studied engineering identity within an engineering community of practice. These identities are important for choice of engineering in college in the path to developing an engineering identity. Previous studies have shown that students interested in engineering show interest and skill in the areas of math and science [19], [20]. Physics, when taught in a high school classroom, may mirror some engineering techniques (building bridges, analyzing statics, discussion of motion, etc.). Identities in math, science, and physics were chosen to explore the effects of these experiences on identity development for future engineers. The distinction between physics and science is subtle. Physics is part of science of course but other skills not specific to physics – say, in chemistry and biology – may be important for students interested in particular engineering majors (chemical, biomedical, environmental, etc.). Through exploring multiple subject-related identities from high school, a clearer picture of what experiences and attitudes are important for future engineers can be developed.

This paper reports on the development and establishment of an affective model which has predictive power for the choice of engineering as a college major through multiple subject-related identities. Understanding the particular identity or identities that students who choose engineering have is especially important for increasing the number and diversity of engineers in the workforce. The unique and simultaneously diverse approaches of engineers and the problem-solving strategies they employ are essential to national success in an increasingly competitive global marketplace, the ongoing restructuring of many industries, the increased use of technology in all facets of life, and the emphasis on new energy sources in the world.

The research questions explored in this paper are:

1) What is the effect of students' identities in physics, mathematics, and science (general) on their engineering identity?
2) To what extent is an engineering identity predictive of the choice of engineering as a college major?

II. Methods

In this paper, the analyzed data were collected as part of the Sustainability and Gender in Engineering (SaGE) survey (http://www.clemson.edu/~gpotvin/SaGE.pdf). This was a large-scale national study of students who were currently enrolled in introductory English courses at both two- and four-year institutions across the United States. The data collection methodology employs a cross-sectional design which relies on the natural variation in experiences and backgrounds of the student population. The SaGE project recruited institutions from a representative, stratified, random sample taken from a comprehensive list of four-year and two-year institutions, obtained from the National Center for Education Statistics (NCES). The list was divided by institution type (two-year or four-year) and stratified by institution size (small, medium, or large) into six lists to account for the size of the institution and ensured an appropriate sampling of the small but numerous liberal arts colleges across the U.S. In total, fifty schools agreed to participate in the survey. The survey was administered in each institution's "required" freshman English course to capture a sample that included both STEM and non-STEM majors. In all, 6,772 students completed the survey during the administration period in the fall semester of 2011.

The survey instrument focused on students' backgrounds, pedagogical and curricular experiences in their high school science classrooms, classroom achievement, and student attitudes toward STEM and sustainability. The goal of the study was to identify factors that influence students' attitudes toward engineering careers and to explore the connections between engineering and sustainability-related topics in students' experiences. The final version of the survey included 47 questions about students' career goals, high school science experiences, earlier math and science enrollment and achievement (including types of courses taken, the level of courses, the year courses were taken in high school, final grades, and AP test scores), student attitudes about sustainability, and demographic information. These questions primarily consist of anchored Likert-type, multiple choice, and categorical responses.

Multiple aspects of validity and reliability of the instrument were assessed. An open-ended hypothesis-generation survey was collected from 82 first-year engineering and 41 non-engineering students, as well as 83 high school science teachers (recruited via the listserv of the National Science Teachers' Association). Lending to content validity, these hypotheses were included in the survey. Questions were further refined based on feedback from assessors and the results of pilot testing in a first-year freshman engineering course. Thus, each item of the survey was further examined for face and content validity. Test-retest was also conducted to establish the reliability of the instrument.

Earlier work verified the measures of each of the identity and agency constructs [20]. Using these identity and agency measures, a structural equation model was built to reflect the identity framework utilized in this work [13]. The resulting model is shown in Figure 1. From previous work on physics and math identity [13], [14], [21], the constructs of physics and math identity were built with interest and recognition mediating the path from performance/competence to identity. The questions that ask students if they identify as a "physics person" or a "math person" were used as an overall measure of these identities. These identities predict an engineering identity that students have prior to their choice of engineering. The choice of engineering as a career is predicted by students' engineering identity.

The choice of engineering was determined by utilizing a question that asked students to "Please rate the current likelihood of your choosing a career in the following:" for a variety of science, math, and engineering careers on a Likert-type scale. A student's strongest response to any of the several engineering disciplines was used as a proxy for a student's interest in pursuing a career in engineering. This method was used in order to capture students interested in engineering in general (but undecided on a discipline) as well as students with a very well-specified interest in one or two engineering disciplines.

The students' belief model in Figure 1 was tested using the lavaan package in R [22], [23] with a subset of the SaGE data input as a correlation matrix. This matrix was imputed for missingness using an expectation maximization bootstrapping method from the Amelia II package [24]. There were 1,113 patterns of missingness found and the final sample size utilized in this analysis was 6,772. The variance of each latent variable was fixed to one. A Satorra-Bentler estimation method [25] was used to account for any non-normality in the data by setting the estimator to "MLM" [23].

III. Results

The standardized path estimates were inserted into the model pictured in Figure 1. All of the standardized path estimates were significant in the predicted direction ranging from 0.133 to 0.982 (all $p<0.001$).

Several fit indices and path significance tests were used to evaluate the model. The chi-square statistic for this model is 18,343 and is significant. Due to the large sample size, the chi-square statistic will be inflated and it can be expected to be significant without indicating a poorly fitting model [26]. The degrees of freedom reported are 685. The root mean square error of approximation (RMSEA) indicates a good fit of the model with the observed data with a value of 0.062 with a lower confidence interval of 0.061 and an upper confidence interval of 0.062. An RMSEA of 0.01, 0.05, and 0.08 indicate excellent, good, and acceptable fit, respectively

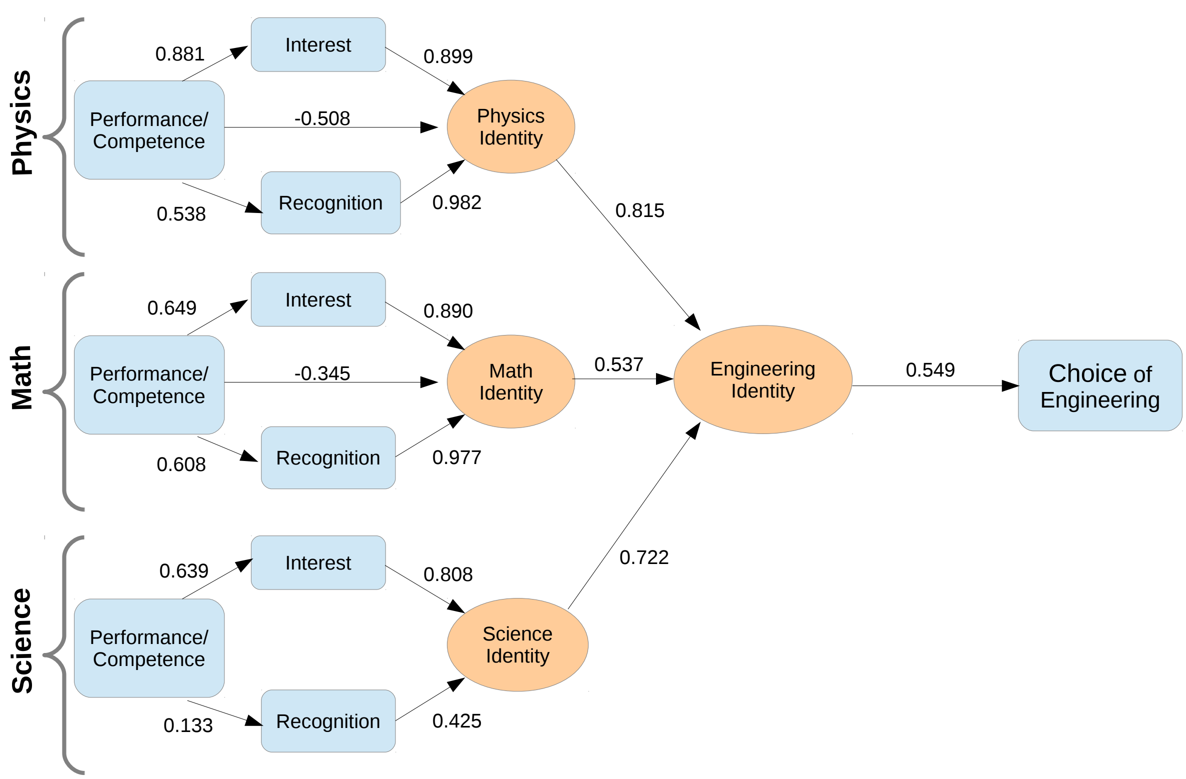

Fig. 1. Structural Equation Model of Engineering Students' Self-Ascribed Identities

TABLE I
CONFIRMATORY FACTOR ANALYSIS ESTIMATES FOR PHYSICS IDENTITY

Latent Variable	Indicator Variable	Standardized Factor Loading	Standard Error	Item Reliability (R^2)	Construct Reliability	Average Variance Extracted
Interest	Interest in physics	0.866	0.025	0.750	0.857	0.791
	Enjoyment of physics	0.912	0.025	0.832		
Recognition	Physics recognition from family, friends	0.898	0.013	0.806	0.861	0.796
	Physics recognition from teacher	0.886	0.013	0.785		
Performance/ Competence	Confidence in learning physics	0.886	0.014	0.785	0.919	0.724
	Confidence in understanding physics	0.877	0.014	0.769		
	Can do well on physics exams	0.903	0.014	0.815		
	Understand physics concepts	0.921	0.014	0.848		
	Others ask me for help in physics	0.787	0.012	0.619		
	Can overcome setbacks in physics	0.711	0.012	0.506		

[27]. Additionally, the RMSEA is largely invariant as the sample size increases and may be a better indication of fit than the chi-square statistic [28]. For sample sizes of 500 or greater, the RMSEA is sensitive to increasing misfit. Thus it may be appropriate to use this supplementary fit statistic in the presence of sample sizes of 500 or more cases, to inform if sample size is inflating the chi-square statistic, and hence its significance [29]. Since the RMSEA is in the acceptable to good range, the model does not show significant misfit. The comparative fit index (CFI) also suggested good fit with a value of 0.920 (acceptable values above 0.9) [30]. The Standardized Root Mean Residual (SRMR) is an absolute measure of fit and is defined as the standardized difference between the observed correlation and the predicted correlation. For this model, the SRMR is 0.079 which is below the acceptable cut-off of 0.080 [31]. This model does fall within the accepted criteria for a good fitting model, taking into account the large sample size ($n = 6,772$).

TABLE II
CONFIRMATORY FACTOR ANALYSIS ESTIMATES FOR MATH IDENTITY

Latent Variable	Indicator Variable	Standardized Factor Loading	Standard Error	Item Reliability (R^2)	Construct Reliability	Average Variance Extracted
Interest	Interest in math	0.866	0.013	0.750	0.854	0.788
	Enjoyment of math	0.909	0.013	0.826		
Recognition	Math recognition from family, friends	0.922	0.023	0.850	0.886	0.825
	Math recognition from teacher	0.894	0.021	0.799		
Performance/ Competence	Confidence in learning math	0.897	0.011	0.805	0.921	0.727
	Confidence in understanding math	0.875	0.011	0.766		
	Can do well on math exams	0.900	0.011	0.810		
	Understand math concepts	0.909	0.011	0.826		
	Others ask me for help in math	0.814	0.011	0.663		
	Can overcome setbacks in math	0.703	0.010	0.494		

TABLE III
CONFIRMATORY FACTOR ANALYSIS ESTIMATES FOR SCIENCE IDENTITY

Latent Variable	Indicator Variable	Standardized Factor Loading	Standard Error	Item Reliability (R^2)	Construct Reliability	Average Variance Extracted
Interest	Understand natural phenomena	0.677	0.028	0.458	0.850	0.639
	Understand science in everyday life	0.847	0.033	0.717		
	Explain things with facts	0.700	0.027	0.490		
	Tell others about science	0.877	0.034	0.769		
	Make scientific observations	0.873	0.035	0.762		
Recognition	Family interest in science	0.598	0.006	0.358	0.414	0.404
	Family thought science important for career	0.715	0.006	0.511		
	Family help with science schoolwork	0.476	0.006	0.227		
	Family arranged for science tutoring	0.518	0.006	0.268		
Performance/ Competence	Design an experiment	0.810	0.010	0.656	0.898	0.688
	Conduct experiment on own	0.809	0.011	0.654		
	Interpret results	0.865	0.010	0.748		
	Write lab report	0.799	0.011	0.638		
	Apply science to assessment	0.863	0.010	0.745		
	Explain science to someone	0.843	0.010	0.711		
	Get good grades in science	0.666	0.011	0.444		

IV. Discussion

The results of this analysis indicate that there is a strong connection between the development of multiple identities as a pre-cursor to an engineering identity for students just entering college. Based on the previously validated identities of physics and mathematics [13], [14], the measures for this model were found to be reliable. The confirmatory factor analysis (CFA) results supporting this claim are included. These loadings are not shown in the diagram but can be found in I, II, and III. The factor loadings ranged from 0.577 to 0.922 with the only loadings below 0.7 occurring for science identity items, particularly recognition which was less reliable. This is not surprising since the items used for science recognition, unlike math and physics recognition, were not developed specifically for examining identity.

In terms of the structural model in Figure 1, a significantly negative direct path from performance/competence to identity was found for both physics and math. This finding indicates that while performance/competence is needed to develop an identity in these domains, without interest and recognition as mediating factors, identity development will be hindered. Thus, if a person feels competent and able to perform in physics or math, both popularly considered to be difficult subjects, but she/he is never recognized or does not become interested, their likelihood of developing or reinforcing a physics or math identity is depressed. This is an important finding since self-efficacy, similar to performance/competence beliefs, is often cited as a key factor in persistence [32], [33] without a deeper examination of the nuance with which self-efficacy relates to identity. Although more nuanced examinations, such as Social-Cognitive Career Theory [SCCT]), identify the moderating effect that interest plays between self-efficacy and engineering goals (and subsequently persistence) [34], these studies may not highlight the important role of recognition by others. In our model, physics and math recognition have the largest direct effect on physics and math identity, respectively, and are therefore critically important for engineering. Although the importance of recognition has been cited in many qualitative studies of identity [17], [35], our work confirms its importance quantitatively. Furthermore, our work clarifies that performance/competence beliefs are not sufficient for identity development. In support of this finding, Marra et al. found that female engineering students in their study had positive shifts in self-efficacy while having negative shifts in feelings of inclusion [32].

Unlike the physics and math identity constructs, general science identity in our model did not include a significant direct path from science performance/competence to science identity. However, recognition and interest remain as mediating paths reaffirming their importance for identity development in all three cases. The mediating paths for recognition in the science identity block have lower path coefficients than the same mediating paths in math and physics identity development. These lower path coefficients may be due to the lower reliability of some of the measures for the recognition construct as mentioned above.

Engineering identity is strongly influenced by a student's developed physics identity (path coefficient of 0.815). This finding may not be surprising, but the relative influence of this path on engineering identity when compared to a general science (path coefficient of 0.722) or math identity (path coefficient of 0.537) is large. The larger effect of physics identity compared to math identity is somewhat surprising since the literature heavily documents the importance of mathematics outcomes to engineering performance and persistence with little reference to physics outcomes [36]. The stronger connection to physics is likely because engineering and physics content share a paradigm: heavily applying math with science. There are other parallels between engineering and physics as well – whether they are a consequence of similarities in the content, culture, or both is not yet clearly understood. For example, in terms of demographic considerations, females are under-represented in both engineering and physics at the undergraduate level whereas they are not in mathematics [37]. In addition, when students switch into or out of engineering, they often switch back or forth to the physical sciences; more often than in mathematics [38]. More broadly, however, this work shows that students' identity in physics, math, and science all contribute to an engineering identity. Finally, the path coefficient from engineering identity to the choice of an engineering major/career in college is 0.549. This loading illustrates that students' self-ascribed identity has a significant impact on their choice of engineering. Understanding these self-perceptions can help elucidate the transition between high school and college for students intending on majoring in engineering as well as allow us to account and control for these self-perceptions when examining how early college experiences in engineering might impact the choice of engineering sub-discipline and persistence.

These findings are important for the recruitment and retention of engineering students. Students attitudes about the subjects they take in high school are important and affect the career choices that they make as well as their persistence in those choices. Simply being "good" at these subjects is not enough for identity development. Students' attitudes and beliefs about their ability to perform subject-related work, the recognition of them as being good students in these areas by their peers, family and teachers, as well as an interest in the subject material are vital to engineering identity development. Additionally, professors who teach the pre-requisite or co-requisite classes of physics, math, and other important science courses for engineering majors may have an important influence on students' future engineering identities. The authoring of an engineering identity is not a one-time effort while pursuing a degree in engineering, but is a continual process [4]. A disruption of this process through poor classroom experiences in associated courses like physics, math, or other sciences can cause a decline in engineering identity and may change students' choice to pursue an engineering career in the future.

V. Conclusion

We found that students' physics, math, and general science identities are important factors for their engineering identity development. In our framework, students develop a multiplicity of identities which may interact to affect choice outcomes. Furthermore, subject-specific identities are moderated by beliefs about performance/competence, recognition, and interest. Perhaps surprisingly, performance/competence beliefs are not sufficient for identity development but require the mediation of recognition and interest beliefs to help actualize identities for students. For educators and administrators, this latter point is worth noting: there has been a historic focus emphasizing the importance of self-efficacy and related beliefs to student persistence, but this work highlights the fact that the development of students' recognition beliefs and interest may be just as critical as curricular objectives. Students who see their own identities lining up with specific disciplinary identities persist at a higher rate than those who do not [2]. For this reason, practitioners may consider fostering interest and recognizing students in their classrooms rather than simply emphasizing student acquisition of the technical skills needed to develop subject-related competencies. Developing interest and feeling recognized in a variety of subjects (math, physics, and science in general) is more important for the choice of engineering than feeling "good at" a variety of subjects. Furthermore, only developing beliefs about performance/competence in a subject area is detrimental to the formation of a subject-related identity and may decrease persistence in engineering. As we seek to increase the number and diversity of students in engineering, considering these findings is important not only for engineering education researchers, but also engineering administers and faculty. Our future work in this area will seek to incorporate into these models greater details about students' career outcome expectations and agency beliefs.

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Student Demographics and Outcomes in Electrical and Mechanical Engineering

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***Abstract*—Using longitudinal data from eleven institutions in the U.S., this study explores the persistence of students in the two largest engineering disciplines: Electrical (EE) and Mechanical (ME). These programs have large enrollments of students but small percentages of women. Despite these similarities, enrollment and persistence in these majors is qualitatively different. In this research, we adopt an intersectional framework and consider both race/ethnicity and gender. Our results show that ME attracts more White students while EE attracts more Black and Asian students. Hispanic men and women are attracted in similar numbers to EE and ME. Overall, ME has higher graduation rates than EE and women have higher rates than men in both disciplines. Transfer students of nearly all race/gender groups are more likely to persist to graduation than starters in the same disciplines. Black and Hispanic female transfer students are particularly successful in EE and ME, which suggests enhancing the transfer pathway as a strategy to improve diversity. The success of ME starters causes a shift in the demographic profile between starters and graduates. ME could learn from EE how to diversify its enrollment and EE could learn from ME strategies to retain its diverse students. These findings suggest that program factors affect each race-gender group differently. Therefore, the success of recruitment and retention strategies may depend on considering both the target population and the discipline.**

Keywords—electrical engineering; graduation rate; mechanical engineering; persistence; retention; stickiness; transfer students

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I. Introduction

A. *Understanding pathways in electrical and mechanical engineering education is vital to the profession.*

There have been numerous calls to diversify the engineering profession [1], [2]. Electrical Engineering (EE) is one of the oldest engineering disciplines, dating back to the 1880s [3], and also one of the largest. Mechanical Engineering (ME) also dates back to the 19th century and currently has the largest enrollments [4],[5]. Thus, students in EE and ME make up a large portion of the engineering population. What do these large fields have in common? How do they differ?

Enrollment and retention in engineering degree programs has been studied extensively, and more complete literature reviews are available elsewhere [6]. In a large multi-institution whole population study, no gender gap in persistence or graduation was found for engineering matriculants with all disciplines aggregated [7]. This study focuses on extending that work to explore two engineering disciplines that enroll many students, but that have a particularly male enrollment bias. Here, we briefly review important literature on student pathways for EE and ME as well as transfer students. Unlike most studies, we disaggregate by race/ethnicity, gender, and engineering discipline. In analyses of engineering persistence, it is important to adopt a critical race theory framework [8] and consider the intersectionality of race and gender [9]. For both EE and ME, we consider the race-gender of those who start in these majors, trajectories of students, six-year graduation rates, and "major stickiness" which is a ratio of the number of students who graduate in a major divided by the number of students who ever declared in that major. The stickiness metric permits consideration of transfer as well as first-time-in-college (FTIC) students [10]. This work presents a detailed description of students who major in EE and ME based on a large amount of data. These results are intended to speak to faculty, department heads and Deans.

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B. *Results of Prior Studies of Electrical Engineering Pathways.*

Despite having high enrollments of students, around the world EE has one of the lowest percentages of women students, including in the U.S.A. [5], Canada [11], and Israel [12]. Many studies of undergraduate student persistence aggregate all engineering disciplines [13][14][15][16][17]. This may often be a practical limitation imposed by the available data that results in small datasets when disaggregated by engineering discipline. There has been some work focused on EE. For example, Murphy[18] examined the paths of 34 EE majors at the Citadel and found that 44% graduated within five years in EE, 32% graduated in a discipline other than EE, and 24% did not graduate. York Young and Redlinger [19] analyzed the student flow for 23 EE matriculants at one institution over six years. They found that 14 (61%) of the EE matriculants graduated in six years. Six of these were in EE, three in Computer Science, and one each in five other majors. Humphreys and Freeland [20] found that 68% of 422 EECS matriculants at one institution were still in the major after four years. They note that women were a small fraction of the cohort, persisted in engineering at lower rates than men, and switched out of the major at higher rates than males. Lord, Layton, and Ohland studied the pathways of students in EE and computer engineering disaggregated by race/ethnicity and gender [21]. They found that although men consistently outnumber women in EE, the rates of matriculation and six-year graduation vary by race and gender. EE is the most popular choice for Asian and Black students (males and females) at matriculation, but while Asian students graduate at high rates, Black students (particularly males) are not retained. Graduation rates are lower than expected for Hispanic women in EE. By the third semester, some students of all races and genders have left their matriculation major, but others have migrated in from other majors, compensating for some of this loss. Trajectories of EE students are racialized and distinct.

C. *Results of Prior Studies of Mechanical Engineering Pathways.*

Despite the gender gap in enrollment, little research has been published on the pathways and persistence of women in ME. Only eleven of 412 articles in the International Journal of Mechanical Engineering Education use the words women, woman, gender, or female, and only seven were referring to students. One catalogued the accomplishments of outstanding women in ME [22], one explored motivating factors for women to study engineering in Ghana [23], and the rest mentioned women only in passing. Only four mentioned race, ethnic origin, or ethnicity in a relevant way. A search of conference proceedings of the American Society for Engineering Education and Frontiers in Education yielded a few single-institution studies. At Iowa State University, women's enrollment has increased from 7% to 10% since the launch of a student-run Women in Mechanical Engineering (WiME) program [24]. Tuskegee University reported a 48% six-year graduation rate in mechanical engineering for an 1991 cohort, although this number was based on enrollments rather than tracking of individual students [25]. Clearly there is a need for further discipline-specific research.

D. *Prior Studies of Transfer Students in Engineering*

Transfer students are a sizable, yet understudied, population with the potential to increase the engineering workforce and its diversity [26]. Many of these students transfer from community and other two-year colleges in which women, minorities, and economically disadvantaged students are over-represented. Community colleges enroll nearly half of U.S. undergraduates and large shares of women (58 percent of community college students), minority (45 percent), first generation (42 percent), and low-income (46 percent) students. These are the very groups that are under-represented among engineers in the U.S.—and a potential pool of recruits for engineering and other scientific fields [27]. Yet studies of engineering transfer students indicate that students who actually transfer to four-year institutions are demographically similar to those starting their academic careers at the four-year institutions, increasing the importance of understanding this population [28]. In the aggregate, engineering disciplines that do well in attracting and retaining first-time-in-college students also do well in attracting and retaining transfer students [10], but (as expected) race and gender play a role in the outcomes of transfer students [28]. Thus it is important to study the outcomes of transfer students disaggregated by race, gender, and discipline, and recent methodological developments facilitate the study of transfer students including comparisons with the first-time-in-college population [10].

II. METHODS

A. *The MIDFIELD Database and its Characteristics.*

This study uses the Multiple-Institution Database for Investigating Engineering Longitudinal Development [29], a dataset with 137,649 first-time-in-college (FTIC) students matriculating in engineering and 39,354 transfer students articulating in engineering at eleven U.S. institutions with nine of these in the Southeastern U.S. Of the U.S. engineering bachelor's degrees awarded in 2005, 1/10th were awarded by MIDFIELD institutions [30]. The MIDFIELD database includes seven of the 50 largest U.S. engineering institutions by engineering enrollment (institutions in which over 20 percent of students major in engineering, versus the nine percent national average) [31], and four of the top five producers of Black engineering graduates [30], including two that are historically Black colleges and universities (HBCUs) and two predominantly White institutions. By design, engineering students are overrepresented in MIDFIELD, which enables the analyses of subpopulations proposed in this research (by discipline, ethnicity, etc.). Students self-report gender and race, choosing among Asian, Black, Hispanic, Native American, and White (as well as Non-Resident Alien and Other, which are not included in this study). Results from the study of the MIDFIELD database are expected to generalize to the same type of institutions, large public universities with above average enrollment of engineering students, and therefore are relevant to institutions producing most engineering graduates nationally. All institutions offer degrees in Electrical and Mechanical Engineering. Since this dataset includes whole population data, statistical inference is unnecessary—all reported differences are true differences for the institutions and subpopulations studied for the time period.

B. The Population Studied in This Work.

Of the total MIDFIELD population, this work focuses on the 93,629 FTIC students and 26,350 transfer students with sufficient data to calculate six-year graduation rates during 1987-2010. MIDFIELD institutions offer several matriculation pathways [32],[33]. We study students in multiple pathways: FTIC who matriculate directly into EE and ME, students who choose these majors after completing a first-year engineering (FYE) program (where direct matriculation into specific engineering majors is not possible), FTIC students who matriculate in other majors and migrate into these majors, and transfer students who make their way into these majors.

Special methods are needed to include students in these diverse pathways in the same study. To include students enrolled in FYE programs as well as students who matriculate directly to specific engineering majors, we imputed the Semester 1 disciplinary enrollment at FYE schools. This imputed Semester 1 enrollment, Semester 1*, is calculated by allocating the total FYE matriculated population to specific majors at semester 1 in the same proportion as students choose each major after FYE. This assumes that the retention through the transition from FYE programs is the same for all engineering majors. For example, if 100 students matriculate to FYE programs, and 80 students declare a specific engineering major immediately after leaving FYE, then there is 80% retention. If 48 students declared EE after FYE, then we would impute 60 EE students at Semester 1* (48 / 80% = 60). The retention rates used in imputing Semester 1* enrollment are computed separately for each race-gender population. Throughout this paper, the term "starters" refers to the total of FTIC students who matriculated directly in a major and those imputed to start in that major. "Transfers" refers to students who earned credits at another institution before transferring to the MIDFIELD institution and were designated as transfer students by the participating institutions. Transfer students are assumed to begin in a particular semester, where for every 15 credits they transfer, their starting semester is increased by one.

In this paper, graduation is defined as having graduated by the sixth year from matriculation, following a standard of reporting by the Integrated Postsecondary Education Data System (IPEDS) [34]. The population at matriculation (Semester 1) is a useful referent and is needed for defining the persistence of the matriculating cohort. The population at Year 4 marks the point at which 90% of all students graduate, and has been used as a measure of success by Seymour and Hewitt [15] and others. Finally, graduation, as defined above, is labeled Year 6. It is important to include the Year 6 outcome in addition to the Year 4 outcome, because differences in the graduation rate beyond Year 4 have been observed when the data are disaggregated by race/ethnicity and gender [6].

To protect student confidentiality, a minimum cell size of 5 is common in practice. MIDFIELD research has generally excluded populations with fewer than 10 students from displays and analyses [35]. Although we have included Native Americans in prior work [6] [7], after disaggregating by discipline, there were not enough Native American women to include in this study. Since we could not include the women, we also excluded the Native American men.

III. Results and Analysis

A. Who enrolls in ME and EE?

Table I shows the number of starters in ME, EE, and Engineering (ENGR).

TABLE I. Number of Students Starting in ME, EE, and ENGR.

Race/Sex	ME starters	EE starters	ENGR starters
Asian Female	92	157	1124
Black Female	367	773	3555
Hispanic Female	49	51	531
White Female	1612	1020	13847
Asian Male	620	1048	4110
Black Male	1145	1823	6026
Hispanic Male	335	337	1937
White Male	12242	8942	59424
All Female	2120	2001	19057
All Male	14342	12151	71497
All students	16462	14151	90554

The ratio of the ME and EE starters in each race-gender group to all Engineering starters of the same race-gender group is shown in Figure 1, with the panels ordered by the median of the ME and EE values. For example, the top right panel of the figure shows that of all Black Males starting in Engineering, 19% start in ME and 30% start in EE.

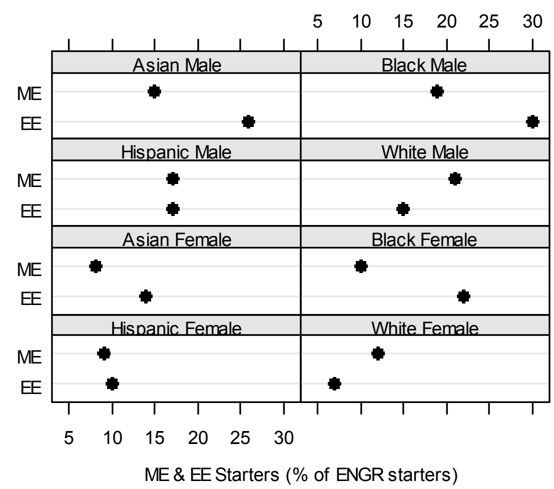

Fig. 1. Enrollment in EE and ME as percent of ENGR starters choosing the major disaggregated by race/ethnicity and gender.

As shown in our earlier work [21], Black engineering students, men and women, choose EE at the highest percentages of any group. For ME, White males choose it at the highest rate with Black males a close second. A higher percentage of White women choose ME than EE, although both percentages are below the aggregate percentage enrolling in those disciplines. In fact, White students prefer ME over EE but students in every other race/ethnic group prefer EE over ME. Asian men and women, particularly men, prefer ME over EE. The numbers and percentages for Hispanic students are very close for ME and EE. Since there are so many more White students, their story often dominates discussions.

B. Graduation Rates in ME and EE

Table II shows the numbers of starters in ME and EE remaining in the major through 6 years. With the starting numbers of Table 1, these values are used to compute the 6-year graduation rates shown in Figure 2, with the panels ordered by the median of the ME and EE values.

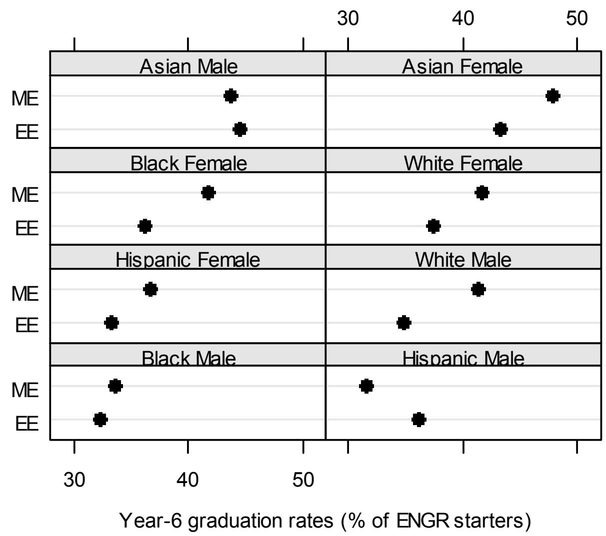

Fig. 2. Graduation rate disaggregated by race/ethnicity and gender for EE and ME starters.

Overall, students have higher graduation rates in ME than EE. This is true for all populations except Hispanic men where EE is higher and Asian men where the rates are nearly equal. The largest discrepancies are among White men and Black women; both groups have 6% higher graduation rates in ME than EE. Asian women have a 5% higher graduation rate in ME, while White and Hispanic women have a 4% higher rate in ME than EE. Black males in ME have a 2% higher rate than those in EE. In the aggregate, women have higher rates than men in both disciplines. The success of ME starters causes a shift in the demographic profile between starters (where EE has a notably higher fraction of Black females and males) and graduation rate (where ME graduates a notably higher fraction of Black females). Asian students have the highest graduation rates in both EE and ME with Asian women higher than Asian men for ME but lower than Asian men for EE.

TABLE II. NUMBER OF EE AND ME STARTERS WHO GRADUATE IN SIX-YEARS.

Race/Sex	ME Year 6	EE Year 6
Asian Female	44	68
Black Female	153	280
Hispanic Female	18	17
White Female	673	383
Asian Male	271	466
Black Male	386	588
Hispanic Male	106	122
White Male	5058	3114
All Female	888	748
All Male	5821	4290
All students	6709	5038

Note that these discussions of graduation rate are restricted to starters. These do not tell the complete story as will be shown later in this paper.

C. Trajectories of Students in ME and EE

Once students are enrolled in ME or EE, how do they fare? In Figures 3 and 4, the trajectory of students is shown for ME and EE starters and all ME and EE students. These figures are collections of time-series plots showing the number of students enrolled in EE or ME at matriculation (0), enrolled or graduated four years later (4), and graduated by six years later (6). Figure 3 shows starters only (direct matriculants in the discipline or those imputed to start in the discipline at FYE schools). Figure 4 shows the numbers of students in the major for all students, including starters, switchers, and transfers. The vertical scale (numbers of students) is logarithmic to include populations that differ by orders of magnitude. The horizontal scale (years after matriculation) is linear. In each panel, women are on the left and men on the right. Race/ethnicity is indicated by a letter. To illustrate, consider the leftmost column in Figure 3, "Women in ME (ME Students-Starters)". The lines labeled "B" and "W" indicate that in this category, White women outnumber Black women for each time period, starting at matriculation with approximately 400 Black and 1100 White women and ending at Year 6 with approximately 150 Black and 700 White women. The steeper the slope of the enrollment profile, the higher the loss of students from the discipline.

The trajectories for EE and ME starters shown in Figure 3 look similar to those for EE reported earlier [21]. Compared to EE, ME has more White and Hispanic students and fewer Asian and Black students, particularly Black women. All populations lose starters from matriculation until Year 6. Losses are rather steep from matriculation until Year 4. After Year 4, some populations level off, most noticeably Asian women and White students. Note that the steepest losses occur for Hispanic and Black students from Year 4 to Year 6. These steeper negative slopes indicate a faster attrition over this time period.

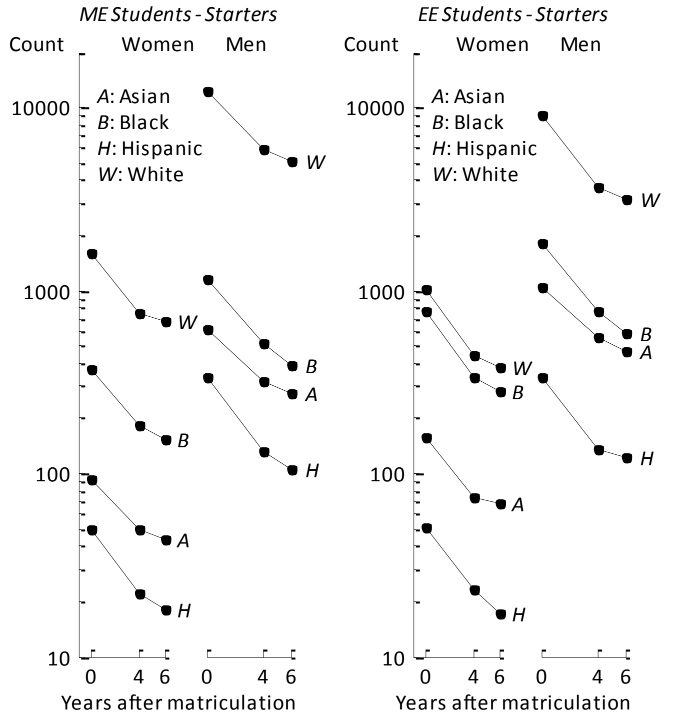

Fig. 3. Trajectory of starters in ME and EE.

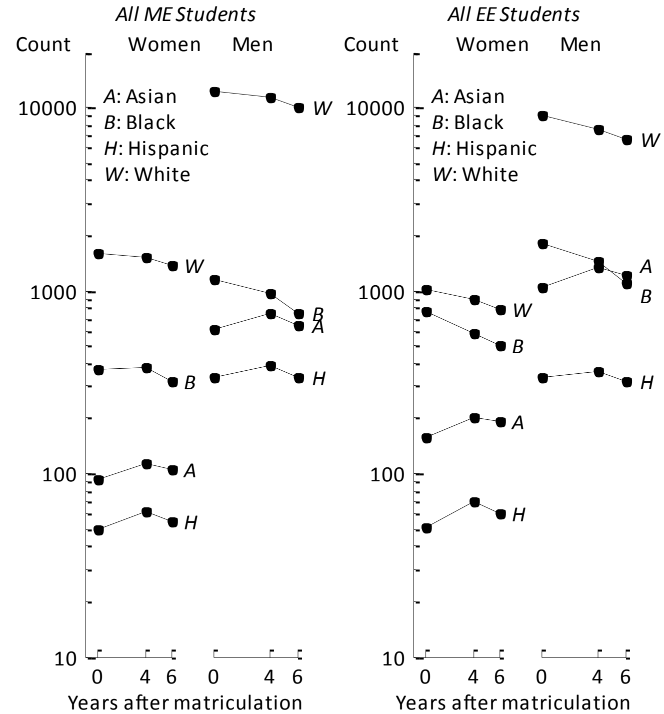

Fig. 4. Trajectory of all students in ME (left) and EE (right).

The shallower slopes of the curves in Figure 4 for all students, which include students matriculating in other majors and those who started at other institutions, show that students of each population are entering EE and ME, compensating for some of the starters who are leaving. Overall, the shapes of the trajectories for all students in EE and ME are similar. The most difference is seen for Black women. More Black women start in EE but low numbers at Years 4 and 6 suggest few transfer and switcher students. Fewer Black women start in ME but enough transfer or switch in by Year 4 to compensate for the losses of starters. Fewer White and Black students graduate in 6 years in ME and EE than started. The opposite is true for Asian students and Hispanic women suggesting the importance of transfer pathways for these populations. For Hispanic men in EE and ME, there are about the same number at matriculation as graduation.

D. Stickiness in ME and EE

Figure 5 shows the stickiness in the major for starters and transfers in ME and EE, disaggregated by race/ethnicity and gender, and ordered by the median of the values in each panel.

Starters and transfers are more likely to "stick" with ME than EE. Women show higher stickiness than their male counterparts for each race/ethnicity. White men and women have the most similar stickiness, underscoring the importance of disaggregating by race and gender so that the White population does not bias the discussion. Asian women have the highest stickiness in ME and the second highest in EE, close to the Asian men. The populations with the lowest stickiness are both men: Black and Hispanic.

Consistent with earlier work [10], transfer students tend to be more "sticky" than FTIC students. This is likely related to their having already successfully passed some engineering prerequisites and thus being more strongly committed to the major before entering our database. Transfers have higher stickiness in both ME and EE (in Figure 5, the open circles for transfer students are typically to the right of the closed circles for starters). Consistent with other studies [10], transfers in ME and EE also have much less variability across race-ethnicity and gender (the open circles are much-more aligned vertically). This is not surprising given how many sources of variance are matched among the transfer students in the study—even among the FTIC students, our sample includes students who all chose to enroll in higher education, selected one of the participating institutions, were admitted to do so, and selected engineering.

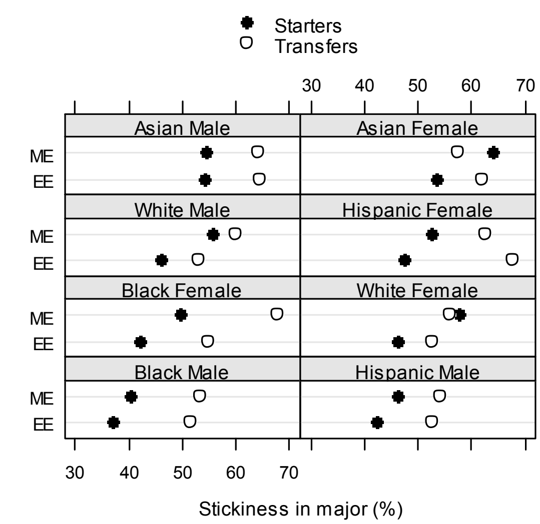

Fig. 5. Stickiness in Major of starters and transfers by race and gender.

The transfer students did all these things and additionally did so through a transfer pathway, so a reduction in variability in any outcome is predicted at least in part by the restriction of variability in the population.

Black and Hispanic women transfer students are notably successful. If transfer students have an experience similar to that of starters, we would expect populations with a high stickiness in the starter pathway to similarly have a high stickiness in the transfer pathway. Where this is not true, there is an interaction between discipline and transfer status. Hispanic female transfer students have the highest stickiness of all groups studied for EE (68%) and are second for ME (62.5%) where the Black female transfers have the highest stickiness of 68%. Success for Hispanic female transfers in engineering overall has been reported in previous research with MIDFIELD [36]. Black female transfer students in EE have a stickiness of 55%, still high but not as high as in ME. Asian transfer students continue to be successful. However, for transfers Asian men are stickier than Asian women.

IV. Discussion and Conclusions

The graduation rates studied here help understand the success of students in these disciplines, but the stickiness metric is particularly useful and facilitates the study of transfer students. Regardless of any of the challenges faced, transfer students of nearly all race/gender groups are more likely to persist to graduation than starters in the same disciplines, and some Black and Hispanic females find such success in the transfer pathway (in ME and EE respectively) as to suggest enhancing the transfer pathway as strategy to improve diversity. The emergence of these stories is a reminder to researchers and practitioners of the need to disaggregate by race/ethnicity and gender. In contrast, ME could learn from EE how to diversify its enrollment and EE could learn from ME strategies to retain its diverse students. Further work will extend this line of research to other disciplines.

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Student Perceptions of Andragogical Orientation and Student Learning

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***Abstract*— In order to develop critical thinkers and capable problem solvers it is important to understand the needs of today's engineering student and design instruction to meet those needs. An important component in that discussion is the degree to which students perceive themselves as adults versus child learners. The issue is important for educators; particularly those who teach senior-level courses, because research on adult learners points toward different classroom methods than those used for children. In this paper, we focus on capstone design - a course often structured to simulate a professional work experience to understand student beliefs regarding their self-perceived orientation as an adult learner and how those beliefs are related to a) their self-perceived learning outcomes and b) the value they place on forms and frequency of feedback. To examine this impact, we draw on the concept of "andragogy." This study utilizes student data from a 2011 survey of capstone students. The data includes student beliefs regarding the andragogical assumptions, self-reports of their learning, and perceptions of the capstone course. The findings support Knowles' andragogical assumptions and indicate that student learning in project-based courses have the potential to have higher andragogical orientations. These findings provide insight into the characteristics of the capstone student and provide opportunities for faculty to tailor teaching to meet student needs.**

Keywords—Andragogy, Adult Learning, Student characteristics, Design

I. INTRODUCTION

The ability to teach engineers who are capable of working effectively in a field or discipline relies on an education that is situated in a realistic and comparable environment commonly seen in project-based learning (PBL) courses [1]. A common example of these types of learning environments is representative in design courses, both at the first-year and senior levels. PBL approaches to teaching require students to exhibit a high level of motivation and advanced cognitive development, representative of an adult learner, in order to successful meet the requirements of the course.

One of the key types of teacher knowledge includes the knowledge of the student [2]. Felder and Brent [3] have acknowledged that in order to develop critical thinkers and capable problem solvers, teachers must understand the needs of today's engineering student and design instruction to meet those needs. In addition, engineering schools should attempt to improve the quality of their teaching, which in turn requires understanding the learning needs of today's engineering students and designing instruction to meet those needs. As such Felder and Brent [3] suggest the characterization of students as a promising area of study where learning style profiles, orientations to study, and levels of intellectual development of engineering students should be assessed and analyzed.

Knowles identified teachers as being critical to creating an environment supportive of adult needs. Several authors have noted that the facilitation of adult learning can be best achieved through a student-centered approach that, in a developmental manner, enhances the students self-concept and promotes autonomy, self-direction and critical thinking [4, 5]. In this sense, PBL has elements of andragogy within it and is representative of Knowles' andragogical framework [5, 6]. However the appropriate approach to teaching is dependent upon the state of the student [5].

In their work, Yoshimoto, Inenaga, and Yamada [7] identified that across three regions (Germany, United Kingdom, and Japan), more mature students preferred practical and independent learning with well-developed materials and provisions, whereas younger students preferred human contact and connection with teachers and classmates throughout the learning process. Another study indicated that age, when combined with acceptance of andragogical principles, was predictive of course satisfaction [8]; however, neither study identified how this impacted learning in the course. Overall, Clardy [9] notes that studies tend to show that andragogical approaches to adult learning and education do not perform as predicted due to a misunderstanding of the student perspective.

II. BACKGROUND

A. Knowles' Andragogy

Knowles [10] coined the term andragogy, meaning "the art and science of helping adults learn", whereas the traditional term of pedagogy is the, "art and science of teaching children" [11, 12]. Knowles approaches the concept of andragogy and pedagogy as a theory of practices that lie on a continuum, where pedagogy is at one extreme and andragogy at the other with defining assumptions for

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each (Table 1)[12]. The assumptions for the adult learner acknowledge that they are self-directed, have many life experiences, have learning needs closely associated with social roles, is problem-centered, is intrinsically motivated, and has a readiness to learn [10].

TABLE I. PEDAGOGICAL/ANDRAGOGIVCAL CONTINUUM [10, 12-14]

Pedagogy		Andragogy
Dependent on decision of teacher	–	Self-directed learner
Few life experiences	–	Many life experiences
Learning needs dictated by teacher	–	Learning needs related to social roles
Subject/content-centered	–	Problem-centered
Extrinsically motivated	–	Intrinsically motivated

The assumptions were developed from Knowles' recognition that the concept of the learner - life experience, readiness to learn, and orientation to learning - are different when comparing a child to an adult [10]. He acknowledges that through the process of maturation a person becomes increasingly self-directed, accumulates more life experiences that provide both content and context for learning, and views education as a process to develop competence in professional areas needed to achieve life goals.

B. Faculty Perspective

A prior study of faculty perspectives identified that a large percentage of faculty view their students as being more aligned with andragogical assumptions than pedagogical [12]. In addition, those faculty who view their students as adult learners utilized more student-centered tasks and assessments in engineering capstone design courses [12]. While no differences between faculty interactions and the mechanisms for feedback based on their perspective of the students exist, faculty who view their students as adults tended to use evaluations that included self-reflection papers and focus groups more than those who view their students as child learners. In addition, faculty who view their students as adult learners, typically view their role as a mentor to guide student learning, especially with emphasis on the student becoming a self-directed and taking responsibility for deadlines.

C. Research Questions

We use Knowles framework of andragogy in the capstone course because these courses are liminal spaces in which the students are at once still undergraduates in a course working for a grade, and practicing engineers addressing pressing, open-ended design challenges in their field. The degree to which student beliefs position them as either an adult or child learner (or both) significantly impacts the value they place on styles of teaching and their learning. Therefore we pose the following research questions:

RQ1.How do capstone students perceive their andragogical orientation?

RQ2.How does a student's andragogical perspective relate to self-perceptions of student learning in the capstone course?

RQ3.How does a student's andragogical perspective relate to their value of feedback and interactions with faculty in the capstone course?

RQ4.How do student andragogical perspectives align with faculty perspectives of the students' andragogical orientation?

III. METHODOLOGY

This study is part of a national examination of expert teaching in capstone design courses [12, 15-18]. The current analysis is a non-experimental quantitative design of student responses to a self-reported survey. Prior to the students' completion of the survey, their faculty, as well as other capstone faculty in ABET accredited program, completed a similar survey and interviews about their teaching. A review of the faculty survey and interviews can be found in [15-18].

A. Participants

The participants for this study were recruited from the faculty interviews in the first phase of the study. Overall, 20 faculty at different institutions distributed the survey to their capstone students in the last two weeks of the Spring 2011 academic term. The Spring term was chosen so that students would have a full capstone course experience to reflect on; whether it was one or two terms. Three weeks after the initial distribution, a request was sent to the faculty to remind their students about the survey. By the end of the term, 208 students had completed the survey. Due to the uncertainty of which faculty administered the survey it is difficult to determine the exact response rate.

B. Data Collection

The student survey included 99 self-reported items that were separated into three main sections: course logistics, capstone experiences, faculty interactions (instructor role, frequency and form of feedback and interactions, and benefit of interactions), and demographic information (years of education, sex, race).

The demographic information also included 5 items that addressed the students self-perceived andragogical orientation. A similar item was used in the faculty survey to identify andragogical and pedagogical differences [12]. The Student – Andragogical Perspective Measure (S-APM) consisted of 5 Likert style questions with answers ranging from strongly disagree (1) to strongly agree (5):

- I have an independent concept of myself and can direct my own learning
- I have accumulated a reservoir of life experiences that offers a rich resource for learning
- I have the ability to recognize my own learning needs

- I am problem-centered and interested in immediate application of knowledge
- I am motivated to learn by internal rather than external factors

A reliability analysis of the five items revealed that the Cronbach alpha was 0.784. When examined individually, the items had a minimum Cronbach alpha of .695 indicating acceptable reliability. Construct validity was confirmed through a principal component analysis of the item responses. The analysis indicated that S-APM was most likely a unidimensional measure of andragogical perspective as the five survey items explained 54% of the variation in the results.

C. Data Analysis

Using the five individual S-APM, a composite score called the Student – Andragogical Perspective Score (S - APS) was calculated by summing the individual items. The score ranged from 5 to 25. In order to determine perspectives based on the S-APS, the student responses were separated into two groups based on the standard deviation. Participants with an S-APS of more than one standard deviation below the mean were considered to have low S-APS and those with an S-APS of more than one standard deviation above the mean are considered to have a high S-APS.

Descriptive statistics were used to address the distribution of S-APS and faculty Andragogical Perspective Scores (APS) as required by RQ1 and RQ4. A Mann-Whitney U test was used to statistically compare the medians of the low and high S-APS with respect to learning outcomes and value of feedback and interactions (RQ2 and RQ3).

IV. FINDINGS

The data identifies a clear distinction between the value that high andragogical and low andragogical students place on interactions with and feedback from faculty and their self-perceived learning outcomes. In addition, the distribution of S-APS identifies inconsistencies between faculty and student perspectives.

A. Student - Andragogical Perspective Score (S-APS)and Alignment with Faculty Perspective

The student responses from the S-APM indicate, on a 25 point scale the average and median score is 20 with a right-shifted distribution of scores. The minimum score was 13 (2 participants) and 20 participants rated their APS as the maximum 25 (Figure 1). From this distribution of responses, 69% of the responses had an S_APS within one standard deviation of the mean. The high and low andragogical responses were determined as being one standard deviation outside the mean. Therefore, low S-APS respondents were grouped with scores 17 and less and high S-APS respondents with scores 24 and higher. These groups are used to compare the differences in value and self-perceived learning outcomes.

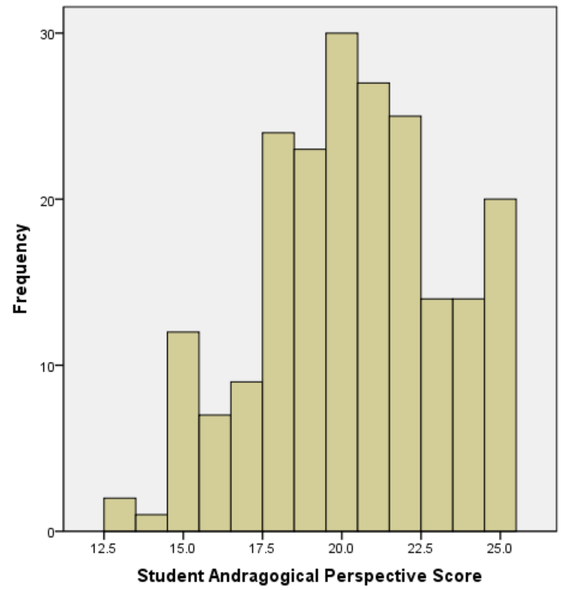

Fig. 1. Distribution of Stusdent - Andragogical Perspective Scores.

In comparison to the faculty responses identified in prior publications [12], the student andragogical perspective was higher than the faculty perception of student andragogical orientation (Table II). When examining the individual item responses, faculty and students were aligned with the student being problem-centered. The largest discrepancy between faculty and student occurred in the comparison of life experience. For this item, students considered their life experience much greater than the faculty perspective. The other items regarding the students' ability to direct own learning, recognizing learning needs, and intrinsic motivation saw less, but similar differences.

TABLE II. MEDIAN ITEM SCORES IN COMPARISON TO FACULTY PERSPECTIVE

APS Items	**Student Median**	**Faculty Difference**
Able to direct own learning	4	-1
Large amount of life experience	4	-1.5
Ability to recognize own learning needs	4	-1
Problem-centered	4	0
Intrinsically motivated	4	-1
S-APS	20	15.5

B. S-APS relation to Student Learning

The comparison of high and low S-APS respondents to their self-perceived learning outcomes indicates that students with high andragogical perspective rated their learning outcomes higher for all outcomes with the exception of written communication, concept generation, and communication with professionals (TABLE III). Where the high S-APS respondents had the greatest difference was in the learning outcomes of engineering ethics ($\Delta = 0.85$), creativity (Δ = 0.76), and responsibility for deadlines (Δ = 0.75).

TABLE III. COMPARISON OF LEARNING OUTCOMES AMONG LOW AND HIGH S-APS

Learning Outcomes	**Low S-APS Mean**	**High S-APS Mean**	
Written communication	2.97	3.50	
Oral communication	3.06	3.62	*
Project planning	3.32	3.82	*
Concept generation	3.45	3.74	
Analysis tools	3.10	3.65	*
Engineering ethics	2.35	3.21	**
Economics	2.68	3.41	*
Creativity	3.03	3.79	**
Design	3.39	4.09	**
Set goals	3.42	3.97	*
Responsibility for deadlines	3.48	4.24	**
Communicate with team	3.48	4.03	*
Communicate with professionals	3.52	3.59	
Stay engaged	3.39	4.00	*

$* p < .05$, $** p < .01$

C. Value of Feedback and Faculty Interactions

When examining the value that students place on the feedback given by faculty, the comparison of averages indicates that high S-APS respondents rated all forms of feedback statistically higher than low S-APS respondents (TABLE IV). While significant, the least difference was seen in the value that students place on electronic medium as a form of feedback. The greatest difference (Δ=.81) was seen in the value that that high S-APS respondents placed on feedback concerning their personal teamwork.

TABLE IV. COMPARISON OF VALUE OF FEEDBACK AMONG LOW AND HIGH S-APS

Value of Feedback	**Low S-APS Mean**	**High S-APS Mean**	
Written comments	3.95	4.57	*
Team technical content	3.91	4.55	**
Personal technical content	3.86	4.55	**
Team teamwork	3.77	4.37	*
Personal teamwork	3.67	4.48	**
Electronic medium	4.12	4.60	**

$* p < .05$, $** p < .01$

While feedback is clearly important to the success of capstone students, interactions with faculty encourage and facilitate the mentoring that supports student success [18]. In comparison to the large differences seen in learning outcomes and feedback, low and high S-APS respondents were similar with respect to scheduled meetings, and formal class times. In contrast, high S-APS respondents value informal interactions with faculty before and after class statistically significantly higher than low S-APS respondents. This higher value on informal interactions with faculty was also seen through a statistically higher rating of the value on electronic communication.

TABLE V. COMPARISON OF VALUE OF INTERACTIONS AMONG LOW AND HIGH S-APS

Value of Interactions	**Low S-APS Mean**	**High S-APS Mean**	
Formal class time	3.19	3.57	
Scheduled meetings	3.91	4.22	
Informal before/after class	3.14	3.97	*
Work spaces	3.20	3.82	
Large studio	3.00	3.68	
Electronic communication	3.72	4.34	*

$* p < .05$, $** p < .01$

V. CONCLUSIONS

While self-perceptions of learning outcomes and perspectives of value are limited in their effectiveness as an assessment, they provide an insight into the characteristics of the student as an adult learner. The results of this study identify the andragogical student as one who is secure in their learning and values one-one-one interaction with faculty. Their willingness to receive tailored feedback on their personal knowledge and skills supports the perspective that they exhibit a stronger sense of self-directed learning and intrinsic motivation that is characteristic of an andragogical learner.

Despite discrepancies with faculty perspective, students in their senior year place a high value on tailored instruction through feedback and interactions. From this perspective, they are open to and may excel through problem and project based learning that goes beyond the capstone course. Faculty can facilitate student learning in these environments by applying several mentoring functions [16-18]. An ability to develop interpersonal relationships and cultivate approachability with the student, *rapport*, provide students who desire one-on-one interaction the comfort to address learning needs with faculty. This rapport will yield opportunities for coaching of technical and professional engineering skills while giving faculty the opportunity to role model the attitudes and values associated with the field and key to the capstone outcomes.

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Quantitative Assessment of Student Motivation to Characterize Differences Between Engineering Majors

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***Abstract*—Student motivation is often undervalued in comparison to academic performance measures for evaluating changes in higher education. There is a need to consider the affective domain in reform, in addition to academic performance. The effect of student motivation toward short- and long-term goals on student actions is not well understood. To assess this need, two research questions are addressed: 1) What elements of a motivation instrument designed for first-year engineering students are valid for upper-level engineering students? 2) How do motivations differ for upper level students in different engineering majors? Students in their major-specific engineering courses were surveyed with the Motivation and Attitudes in Engineering (MAE) instrument, which assesses long-term goal related expectancy, and perceptions of present and future tasks/goals. Short-term task self-efficacy was assessed using items adapted from the Attitudes and Approaches to Problem Solving survey. Results based on comparisons between major, class, and grade point average (GPA) showed: 1) Higher GPA indicates significantly higher expectancies and self-efficacy; 2) Bioengineers have significantly higher expectancies than mechanical engineers; and 3) Juniors have significantly higher GPAs, expectancies, and more positive perceptions of the present than sophomores. Results indicate that students' motivations toward short- and long-term goals may influence actions toward learning.**

Keywords—attitudes; motivation; engineering disciplines

I. Introduction

Student motivation is often undervalued in comparison to quantitative student performance measures [1] in research that contributes to evidence-based curricular and programmatic changes in higher education. Evidence-based curricular changes in higher education have had limited effect on improving the state of higher education [2]. While lack of improvement in learning may be attributed to limited cognitive effects of the innovations being examined, it is more likely that these minimal learning gains are caused by ignoring students motivation [3]. Additionally, in engineering, these innovations often neglect the student-based [4] and cultural differences [5] between different majors. To enhance education there has been a call in the literature to consider the affective domain of students in addition to academic performance [1], [6]–[9]. One model for understanding how student motivation influences student learning is the Motivated Action Theory presented by DeShon and Gillespe [10]. This model posits that students are driven by goals to perform actions. In this model, student goals are situated in different levels or time scales, from goals that are more long-term and stable, to goals that are situated in the present and are temporary. The combinations of motivations toward short- and long-term goals prompt students to act. While Motivated Action Theory provides a map for student action it does not signify which paths are significant for actions that will improve student learning.

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To understand the significance of paths from long- to short-term goals we must first understand students' motivations at each proposed level. Students' motivations toward long-term goals can be evaluated through Expectancy x Value theory, the expectation of how one will perform on a task and how much one values a task or its outcomes [11]. Expectancy x Value theory posits that three main criteria must be met for motivated action: a) With enough effort, the performance can be achieved; b) If achieved, performance will lead to desired outcomes; and c) Those outcomes will lead to satisfaction [11]. Work in Expectancy x Value theory has shown that students who have higher expectations will have better academic performance [12], and those who see higher value for a task will persist longer [11]. Expectancy x Value theory has been developed to examine students' motivations toward long-term goals, such as major [11].

Despite development with long-term goals, Expectancy x Value theory does not provide express consideration of the variable time scales of students' long-term goals. Not considering the temporal space of students goals limits the way in which researchers and practitioners can understand how students' motivations influence action. Husman and Lens have examined students perceptions of the future and how the future relates to present tasks [7]. Future Time Perspective theory posits that the temporal distance of student goals, paired with the perceived instrumentality of a current task, will influence student actions in the present [7]. Husman and Lens have shown that students who have stronger academic motivations often have stronger or more detailed perceptions of the future, which correlates to improved persistence and performance on academic tasks [7]. While this framework explicitly examines students long-term goals, it has had limited application in engineering [13]–[15].

While the two frameworks mentioned above explicitly consider students' motivations toward long-term goals they have not been developed to work with motivations toward short-term goals. Bandura's work in self-efficacy has been developed

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to examine motivations toward short-term tasks [16]. Self-efficacy speaks to students specific perceptions on how they will perform on a task [17]. Self-efficacy has been shown to influence the use of learning strategies on tasks related to students' courses [18]. While self-efficacy and expectancy are correlated constructs when examining the same time scale of goals [12], self-efficacy was developed to examine short-term tasks that require a high level of granularity [19]. The granularity of self-efficacy makes it more useful for examining motivations toward short-term goals.

Different aspects of engineering student motivation will be addressed through two research questions: RQ1) What elements of an instrument designed for (and validated with) first-year engineering students are valid for assessing motivation of upper level engineering students? RQ2) How do motivations differ for upper level students in different engineering majors?

II. Methods

A. Theoretical Frameworks

Previous work with engineering students established three motivation factors related to their engineering major (long-term goal): students expectancies related to their major, perceptions of future goals and tasks, and perceptions of present goals and tasks [20]. These factors are based on two motivation theories: Expectancy based on Expectancy x Value theory [11], and perceptions of future (Future) and present (Present) explained by Future Time Perspective theory [7]. Results indicated that students with higher perceptions of the Future, or having a more positive outlook on their long-term goals, were more likely to persist in engineering than students with lower perceptions of the future [20]. In other work it has been shown that students with higher expectancies will perform better on academic tasks, and those who value tasks more will persist longer at those tasks [11]. Work in future time perspective has shown that students who have a time perspective (view of time) that is situated further in the future are more likely to persist on tasks that they are currently working on than students who have a view of time that is closer to the present [7].

In these prior studies, students' Expectancy, Present, and Future are evaluated in relation to their engineering major, and do not speak to students short-term motivations for classroom tasks such as problem solving. To better understand the different elements of student motivation we are adapting the above framework to include student motivations toward problem solving. A commonly used framework in student problem solving is expert-novice, comparing how students and experts (often faculty) solve problems [21]–[23]. This framework has been applied across many fields and has helped to elucidate the steps of problem solving that are important for success [22]. The expert novice framework was adapted into a survey and given to students to examine what parts of the problem solving process students would perform [24]. This survey administration, much like others, showed a difference between faculty and graduate students, with faculty more likely to perform expert tasks. However, this survey could not differentiate between successful and unsuccessful students due to the fact that students have yet to become experts during their time in the university system [25]. To assess student motivation in relation to problem solving, and examine the variability between students, the instrument developed by Mason and Singh was modified to examine student views of problem solving using a self-report rating of self-efficacy [19]. Confidence in problem-solving self-efficacy examined alongside motivation toward long-term goals can begin to elucidate the interactions of these two aspects of motivation.

B. Participants and Instruments

Students enrolled in major specific second year courses at a southeastern land-grant institution in fall 2012 participated in surveys assessing their views on motivation related to long-term goals and short-term goals. Bioengineering (BIOE) and Mechanical engineering (ME) students were selected for this study due to the similarities of some of the course content of the two majors yet dissimilar populations [26]. Students were given the Motivations and Attitudes in Engineering (MAE) survey, an instrument that assesses student perceptions of their Expectancy, Future, and Present [20]. This thirty-four question quantitative survey was developed and validated with first year students in a general engineering program at the southeastern land-grant institution. Examples of Expectancy items include, "I expect to do well in this engineering course" and, "I am confident I can do an excellent job on the assignments and tests in this engineering course". Present items included, "I will use the information I learn in this engineering course in the future" and, "What I learn in my engineering course will be important for my future occupational success". Future items included, "My interest in engineering outweighs any disadvantages I can think of", and "I want to be an engineer". Additional MAE items may be found in Benson et al. 2013 [20]. MAE items were anchored Likert-type items on a seven point scale from strongly disagree to strongly agree.

An additional set of twenty-three items pertaining to their problem solving self-efficacy were also developed. The problem solving items were adapted from the Attitudes and Approaches to Problem Solving survey [24], and placed on a scale from 0-100 [19]. This change allows us to examine motivation toward problem solving tasks (short-term tasks) that is distinct from motivation related to students goal of obtaining an engineering degree (long-term goals) [10]. Samples of problem solving self-efficacy items included "Drawing pictures or diagrams to answer multiple-choice engineering problems" and "Checking my work for errors when I have obtained an unreasonable solution," after being prompted with "Please rate how certain you are that you can do each of the things listed below". Additional sample items from this construct are found in Table III in the Appendix. These items were added to the end of the survey to not influence results of the original MAE items. Students were offered the opportunity to win a ten dollar gift card as incentive for participation. Extra credit was offered to BIOE students, but not to ME students due to departmental policies. A red herring item ("Please respond forty-two to this item.") was added to the self-efficacy section to determine if students were properly responding to survey items. Five students did not fill out the red herring item correctly and were excluded from analysis.

C. Analysis

All statistical analyses in this paper were completed using the software R [27]. An exploratory factor analysis (EFA) was conducted using the structural equation modeling (SEM) package to determine how the MAE survey would factor with a new student population and additional self-efficacy items. Promax rotation was used due to potential correlations of items, and a 0.4 was used as the minimum threshold. Confirmatory factor analysis was not conducted due to the novel population and insufficient sample size [28]. Internal reliability of the survey items was tested through the use of Cronbach's α [29]. Differences in motivation by major, academic class, grade point average (GPA), sex, ethnicity, and basic skills math test (BST) score were tested by using analysis of variance. The BST is an assessmentof students' pre-calculus abilities at this institution during the first two weeks of students first math class. Student scores from the BST were used due to the predictive nature of math preparation on student success [30]. Differences in GPA between majors were tested using Welchs t-test. Least squares means contrasts were run to examine the differences between juniors and sophomores and MEs and BIOEs, since these populations had sufficient numbers for standalone analysis. Least squares mean contrasts separate desired groups from an ANOVA population and test for differences while limiting the influence of the more complicated statistical model. BST score differences were analyzed for class and major using nominal logistic fit, which is used to make predictions with multiple categorical outcomes.

TABLE I. SIGNIFICANCE VALUES FOR MOTIVATION BY MAJOR, ACADEMIC CLASS, GPA, SEX, RACE, AND BST SCORE. $*\alpha<0.05$.

Motivation Factor	Expectancy	Present	Future	Problem Solving Self-Efficacy
Descriptor				
Major	0.08	0.17	0.48	0.45
Academic Class	0.02*	0.33	0.62	0.29
GPA	<0.01*	0.34	0.14	0.03*
Sex	0.32	0.99	0.94	0.65
Race	0.87	0.99	0.68	0.87
BST	0.08	0.95	0.84	0.61

TABLE II. MOTIVATION CONTRASTS BETWEEN BIOE AND ME STUDENTS AND JUNIOR AND SENIOR STUDENTS. $*\alpha<0.05$.

Motivation Factor	Expectancy	Present	Future	Problem Solving Self-Efficacy
Comparison				
BIOE v. ME	0.02*	0.43	0.98	0.15
Junior v. Sophomore	<0.01*	0.04*	0.31	0.10

III. RESULTS

Of the possible 331 students in the two courses there were 153 survey responses (46.22%), with 44 of the 195 ME students (22.56%) and 79 of the 88 BIOE students (89.77%) responding. Of the total respondents, 32.03% were female (40.5% of BIOE students and 15.91% of ME students). The sample was composed of 85.62% White Non-Hispanic, 3.27% Black or African American, 2.61% Asian, 1.31% Hispanic, 5.88% other, and 1.31% non-responding about their ethnicity. The sample had one freshman, one hundred sophomores, forty-five juniors, six seniors, and one graduate student. EFA results for this population indicated that factors of the MAE were similar to previous administrations with first year engineering students [20]. Three items within Expectancy ("I am certain I can understand the most difficult material presented in the readings for this engineering course", "The course work in engineering classes is easy", and "I am having to work harder than many of the other students in my classes"), four items within Present ("I am having fun in my major", "I get satisfaction from my coursework", "I am encouraged and supported in my studies by the engineering faculty", and "My overall attitude about my engineering department is positive") and six items within Future ("I like the professionalism that goes with being an engineer", "I feel pride when I tell others that I am an engineering major", "I must pass my engineering course in order to reach my academic goals", "Engineers are respected by society", "I have an understanding of professional and ethical responsibility", and "The grade I get in this engineering course will affect my future") did not factor in this analysis and were dropped from subsequent analysis. Self-efficacy items factored into a single construct, showing that students view the different aspects of problem solving as one process. One item from the problem solving self-efficacy section of the survey did not factor ("Handling the mathematics involved with solving engineering problems") and was excluded from the analysis. Cronbach's α were 0.93, 0.86, 0.90, and 0.95 for Expectancy, Present, Future, and Problem Solving Self-Efficacy, respectively. For each construct, items were averaged and this average score was used for subsequent analysis. A non-weighted average was used due to the imposed cutoff when conducting an EFA and the weights possibly giving rise to overvaluing remaining items. ANOVA results showed that students in different academic classes have significantly different expectancies (Table I). Students with higher GPAs also have significantly higher expectancies and problem-solving self-efficacy. No significant differences were seen based on major, sex, ethnicity, and BST both for motivation constructs and GPA.

Due to confounding from limited numbers of students in academic classes (senior, freshman, and graduate) and majors (non-BIOE/ME), least square means contrasts were run to compare MEs and BIOEs as well as sophomores and juniors (Table II). On a scale of 1 – 7, BIOEs have significantly higher expectancies (5.28) than MEs (4.83). Juniors showed significantly higher expectancies (5.53) and perceptions of the present (5.94) than sophomores (4.91, 5.61 respectively). There are differences in GPA based on academic class (p=0.04), with juniors (3.51) having a significantly higher GPA than sophomores (3.34).

IV. DISCUSSION

EFA results have shown that the MAE can be used with upper-level students with minimal modification. The results of the EFA are similar to previous administrations where the factors were Present, Future, and Expectancy [20]. Cronbach's α's for this study are all within the good to excellent ranges, indicating internal consistency of the items [29]. Problem solving self-efficacy broke out as its own factor, indicating that students view it separately from long-term goals, such as major related expectancy which has been shown to be correlated to major related self-efficacy [12]. Problem solving self-efficacy as a single factor may indicate that students view problem solving as one step or hurdle instead of a series of subcomponents. Given students prior experiences with problem solving they may be chunking the steps of solving a problem together [21], [22]. Additionally, students may be viewing the short-term task of problem solving as one hurdle instead of a series of barriers due to having time perspective set in the future [7]. Results have indicated differences between academic classes on expectancy and perceptions of the present. Differences in self-efficacy and expectancy were noted for students with higher GPAs. The influence of self-efficacy and expectancy on GPA mirrors the work of Jones and colleagues that showed that both factors are predictive of GPA [12]. While self-efficacy and expectancy have been shown to be correlated in previous work [12], these factors are potentially viewed as unique by students due to different time scales of motivations toward obtaining a degree and motivations toward solving a problem [7]. This interpretation is further supported by our comparison of junior and sophomore students: despite juniors having significantly higher GPAs than sophomores there is not a significant difference in their problem solving self-efficacy. Students with higher problem solving self-efficacy may have had more instances of mastering problem solving in the past [31]. Students with higher GPAs may have had more recognition of their mastery of problem solving, thus their higher self-efficacy. Higher perceptions of the present may indicate that students have a better developed time perspective and value their course materials more [7]. More positive perceptions of the present may also speak to increased persistence within the major and tasks related to the major [20].

Differences in present and future perceptions for all academic majors are potentially masked due to limited numbers of students in majors outside of BIOE and ME. Lack of differences between sexes and ethnicities may indicate that students who make it to major specific courses have similar motivation profiles. BST scores while predictive of student performance are not predictive of differences in student motivation for this population. The lack of differences between sexes may indicate that the instrument measures presented here are separate from other pieces of motivation such as intrinsic and extrinsic motivation which have indicated sex-based differences in other work [32] or that students who have progressed this far in their academic careers possess similar motivational profiles regardless of sex, the same explanation also applies for the lack of differences between races. The MAE survey used in this study has demonstrated that students who persist in engineering possess similar motivation profiles when compared to those who leave engineering [20]. The lack of sex differences reported here are also in contrast with results presented by Hutchinson-Green and colleagues that have indicated that females have lower self-efficacy than males in general engineering courses [31]. This difference may be due to the major-specific context in which students were surveyed influencing results. Items in the context of a students major may better relate to their long-term goals which may lead to better performance on tasks and increased self-efficacy [7], [31]. The increased time of enrollment may also allow students to develop an understanding of what their abilities are and what they are truly capable of doing.

The results of this work support the theory of DeShon and Gillespe, showing that students motivations toward multiple goals are at play. A student's goal of being a high performer, manifested through a strong GPA, may be influencing their expectations toward their major and their problem-solving self-efficacy. The group of students who have higher GPAs are also likely to be juniors who see more usefulness for their current courses in terms of reaching their goals. The interplay of motivations related to long- and short-term goals is displayed through the multiple motivations that students possess toward different tasks. These results support the Motivated Action Theory's idea of multiple levels of motivations playing into student action.

Previous work in motivation has demonstrated that students' motivational states can be influenced through instruction [6], [7], [33]. Despite the fact that these motivational states have been produced in laboratory environments, they have been shown to lead to improved learning strategy use [34] and knowledge transfer [6]. While motivation cannot be entirely influenced by instruction [10], the ability to lead students into positive motivational states could result in student actions that are more beneficial to their learning. Additionally, these results indicate that students' motivations toward short- and long-term goals/tasks are at play concurrently and may be driving student actions.

V. Conclusions

Results of this work show that the Motivations and Attitudes in Engineering Survey can be applied to student populations who have advanced beyond the first-year of their studies and can be used for differentiating student groups. Results indicate that students' perceptions of the present, perceptions of the future, major-related expectancies, and problem-solving self-efficacy are distinct pieces of students motivations. These four aspects of motivations examine student perceptions of long- and short-term tasks/goals. Students who have progressed further toward completion of their major show higher expectancies than students who have made less progress despite being in the same required courses. Additionally, juniors have shown higher perceptions of the present, potentially indicating better understanding of what they want to do, compared to sophomores. Students with higher GPAs also possess significantly higher expectancies and problem-solving self-efficacy. BIOE students have also been shown to have higher expectancies than ME students. Understanding these differences in student motivations, despite the similar entry requirements for students, can help better direct instructional change that can help motivate students in ways that are more beneficial for learning.

VI. Future Work

Results from this work only speak to a small set of motivational features that can drive students to perform. As such, future work must consider additional frameworks to describe the motivation of students pursuing engineering degrees and solving engineering problems. While we have a better understanding of how different student characteristics influence student motivation, we have yet to connect these motivations to students actions toward learning. Here students have considered their ability to perform during the different steps of a problem as one motivational construct. The types of problems and key features of the problem solving process as viewed by students were not clearly understood, as indicated by the single problem solving self-efficacy factor. Understanding the types of problems and problem features that students notice under the influence of different motivation profiles is not well understood. To gain further understanding of students' motivations toward problem solving (short-term tasks) and major (long-term goals), the results of this work will be used to group students based on motivational profiles through cluster analysis. These groups will be used to purposefully select students for interviews. These interviews will qualitatively examine students motivations toward long-term goals (major and future careers), short-term tasks (problem solving situations), and how the interactions of these two motivations influence student action (knowledge transfer). An understanding of how motivations influence student action will allow for the creation of interventions that can influence student motivations related to the learning, retaining, and using information presented in the learning environment.

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VII. Appendix

TABLE III. Problem solving self-efficacy items displayed below were on a scale from 0-100. Prior to answering these items students were prompted with, "For the following items, please rate how certain you are that you can do each of the thingsbelow by writing the appropriate number." Additional examples of MAE items can be found in Benson et al. 2013 [20].

Item
Work through an engineering problem with a peer, when having difficulty solving it alone.
Go to see a teacher or TA to get help when I am not sure how to start a problem.
Check my work for errors when I have obtained an unreasonable solution.
Handle the mathematics involved with solving engineering problems.
Draw pictures and/or diagrams even if there is no partial credit for drawing them.
Determine what may be wrong with a problem solution if the answer seems unreasonable.
After solving engineering problems in which the same principle is applied in different contexts, apply that principle in other situations.
Identify the engineering principles in the problem before looking for corresponding equations.
Determine when my answer and/or work is wrong.
Think about how each term in an equation relates to the an engineering problem I have not seen before.
Solve challenging engineering problems.
Reflect on engineering principles that may apply when unsure of the correct approach to solve the problem.
Solve an engineering problem symbolically before plugging in the numbers.
Determine which approach is more reasonable, if two approaches to solve an engineering problem gave different answers.
Explicitly think about the concepts that underlie the engineering problems I solve.
Draw pictures and/or diagrams to represent the situations described in engineering problems.
Solve a multiple-choice engineering problem by drawing a picture and/or diagram.
Learn from the problem solution after I solve each engineering homework problem.
Keep working on an engineering problem even if I havent been able to solve it after 10 minutes.
Learn enough from my mistakes on tests and homework such that I do not repeat those same mistakes.
Use different approaches to solve an engineering problem when one does not work.
Solve an engineering problem with numbers instead of symbols.
Learn by solving a few difficult problems using a systematic approach.

Engineering Person-Thing Orientation: Comparisons between first-year students and practicing engineers with implications for retention and professional placement

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Abstract— **Academics, industrial leaders, and policy makers seem to agree that the United States can improve its ability to attract and retain engineering talent. Efforts aimed at addressing this need vary broadly from increasing the public's awareness of the problem, to re-framing the identity of engineering, de-emphasizing its less glamorous aspects, and orienting engineering's future toward solving the world's greatest problems facing humanity. In doing so, it is suggested that engineering would be a more appealing profession to groups that are historically under-represented. The fundamental assumption of these efforts is that an improved image of engineering as a socially engaged helper of humanity will result in greater initial and prolonged interest in engineering. Research investigating engineering as a profession has found few examples of specific engineering disciplines considered socially sensitive. This may suggest engineering is a career choice better aligned with individuals who prefer working with things rather than people. This exploratory study will utilize the Graziano, Habashi, & Woodcock (2011) Person and Thing Orientation Scale to examine how these things versus person tendencies appear in engineering college students and practicing engineers. It aims to identify potential sources of differentiation for these preferences within and across the sample populations.**

Keywords—person-thing orientation (PO-TO); student retention; engineering profession; engineering identity; engineering disciplines; industry; practicing engineers

I. Introduction

The Engineer of 2020 (National Academy of Engineering, 2004), and Rising above the Gathering Storm (National Research Council, 2007) raise a sense of urgency for engineering educators to better understand industry's need for greater numbers of engineers and to elevate filling these shortages as critical for the United States economic stability. Other initiatives appear to take an adjacent tact, emphasizing the benefits of becoming an engineer rather than sounding a siren song among the profession. The Grand Challenges effort (National Academy of Engineering, 2012) portrays engineering as a vibrant discipline capable of solving the world's biggest problems, particularly those associated with improving quality of life for people.

This shift in portrayal of engineering could be important when considering how to attract greater numbers of females (and other under-represented populations) into the profession. Currently the number of females obtaining engineering degrees is virtually steady (National Science Foundation Division of Science Resources Statistics, 2011) while at the same time women receive over half of degrees issued from universities and colleges, a number that continues to grow (ASEE, 2012). In spite of efforts to reframe engineering in a more exciting and female friendly way (Giddens, et al., 2008), studies investigating females' interest in science and medicine over engineering often cite a preference among females for occupations that are helping in nature (Miller, Rosser, Benigno, & Zieseniss, 2000). In particular, these studies note a distinct preference toward occupations that engage people rather than related mechanical artifacts (Miller, et al., 2000). Interestingly at the university level, industrial engineering of all engineering disciplines is noted to attract disproportionate numbers of females, frequently for socially oriented reasons (Brawner, Camacho, Lord, Long, & Ohland, 2012).

According to Little (1968) people selectively orient to environments that are congruent with their interests and occupy that niche. Just as we can parse human interests into people and things we can parse the environment the same way. We expect people to choose environments that are congruent with their interests. This is particularly true in the United States where interests are primary motives for career choice. Science, Technology, Engineering, and Mathematics (STEM) fields are perceived as very thing oriented, so we expect that people high in Thing Orientation are attracted to STEM. In particular, engineering is commonly typified as a discipline that primarily deals with the creation and manipulation of objects as opposed to a discipline centered on interpersonal interaction or data manipulation. Based on the work by Graziano and colleagues (Graziano, Habashi, & Woodcock, 2011) an individual's

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preference between people oriented (PO) events and activities versus thing orientations (TO) can be established. Further, in a related study (Graziano, Habashi, Evangelou, & Ngambeki, 2012), gender differences in educational major choices were highly correlated to the person and thing dimension. In addition, they found that Person Orientation may push people towards person oriented careers and drive people away from thing oriented careers, while alternatively, Thing Orientation was found to move people toward thing oriented careers while being unrelated to selection of person oriented careers. Finally, the study found that women and men high in Thing Orientation expressed more interest in thing oriented careers, an effect particularly pronounced for women (Graziano, et al., 2012). With these findings in mind, interests are therefore an important determinant of career choice when women consider entering careers that are not gender role congruent.

II. STUDY DEVELOPMENT

The goal of this study is to examine the following research questions:

1. Do first year engineering students and practicing engineers share a homogeneous PO-TO profile?

2. If different, in what ways are they differentiated?

3. Can demographic influencers (including gender) associated with PO-TO scores be observed and confirmed across both populations?

4. Are there industry sectors or engineering disciplines that demonstrate stronger orientations toward persons versus things?

5. Is there an indication that somehow the workplace creates a transformative environment for ones PO-TO profile?

Using the Graziano et. al. PO-TO instrument, this exploratory quantitative survey study will examine the interest in people and things of 400 first-year engineering students and over 150 industry professionals. The participants for this study are from two distinct pools – first-year engineering students and practicing engineers from industry, both of whom were accessed for this study through convenience sampling.

Analysis for this study will include both demographic and ANOVA statistics. ANOVA mean value comparisons across the two populations will be looking at gender, generation, and ethnicity for possible sources of person versus thing score differentiation. Within the population of engineers in practice, this study will examine the central tendency PO-TO profiles by specific engineering disciplines and industry sectors.

We predict that analysis will demonstrate more thing orientation than person orientation across both sample populations overall. In addition, we predict that within both populations, male participants will have a greater thing orientation than female participants corroborating prior research. We do not however anticipate PO-TO differentiation by ethnicity. Further, we anticipate that when compared to the professional engineers, the student engineers will display a slightly greater tendency toward thing orientation, indifferent to gender. Finally, we predict that for the practicing engineering population, PO-TO mean scores will be differentiated by industry sector, but will display no mean differences across engineering discipline.

III. DISCUSSION

Currently, our research is in the analysis and interpretation stage. Data was collected from both target populations as part of two separate research studies, and initial mean scores and demographics have been developed for each. Next steps will include the merging of individual data sets to complete the ANOVA comparisons, and begin interpretation of the results.

The value of this work for engineering educators and the professional community is three-fold. First, for researchers focused on issues surrounding retention and under-represented populations in engineering, it may illuminate another aspect of student preference attributable to their choice of engineering as a career choice. Going further, if PO-TO preferences are found to shift once engineers reach the workplace, this may help to explain why some graduates who successfully navigate and complete a rigorous traditional engineering education fail to remain in the profession long term.

Second, for those engaged in student advising and coaching in engineering education pathways, the findings of this study could encourage the use of the PO-TO instrument as another predictive tool for academic persistence. This would occur by determining alignment/misalignment between the student and the engineering profession's cultural orientation.

Finally, by investigating and developing a PO-TO profile for engineering professionals across industry sectors and disciplines, we can begin to explore how the cultural context of practice may be influencing an individual engineer's interest in people and things. Implications for this possibility could influence career placement activities for both novice and expert engineers, as research has suggested that alignment between personal and professional identity is important in the profession of engineering (Downey & Lucena, 2004). Further, understanding the person or thing orientation of an industry sector or specific engineering discipline could assist engineers of all education/experience levels make improved job selection decisions by aligning their PO-TO profile with that of potential employers. Prior to being in the position of job selection, students attempting to determine their discipline specific engineering pathway could use PO-TO profiles of engineering disciplines to inform their educational choices.

IV. CONCLUSIONS

Although the results of this study are still unfolding, the potential benefits to engineering education and the profession on whole offer significant promise. Using the PO-TO scale (Graziano, et al., 2011) across a diverse engineering population hopes to add insights related to individual preference between person oriented events and activities versus thing orientations in different contexts. Further, determination will be made as to the level of influence demographic aspects such as gender, ethnicity, industry sector and engineering discipline play.

Student engineers and engineers in general are thought to be drawn to engaging things, yet data to corroborate this persistent image is absent. Reviewing the literature for the importance of thing orientation to chose and persist in engineering, it would be beneficial to examine if engineering thing orientation can be corroborated, is constant, or changes over time. Such a finding could eventually uncover additional insights into contributing factors for why some graduate engineers never choose to engage in engineering related careers.

An understanding of such relationships could also provide opportunities for engineering educators to influence the messages and regulate/support outreach and college activities taking advantage of thing orientation to increase engineering persistence for groups that are historically under-represented including women.

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Exploring the Student Experience in Low-cost Intrinsic Motivation Course Conversions

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***Abstract*—The low-cost intrinsic motivation (IM) course conversion project aims to promote the adoption of education innovations, lowering the costs of these innovations by promoting students' intrinsic motivation to learn and to invest in their own education. We have piloted and scaled the IM course conversion of a large enrollment, sophomore-level engineering course. As part of a broader evaluation, we interviewed 31 students to better understand how the IM course conversion affected students' motivations to learn. During these interviews, students described their experiences in the course as a story from the beginning to the end of the semester. Interviews were transcribed and analyzed with an open coding scheme focused on motivational and affective statements. Preliminary analysis indicates that strategic choices, positive team dynamics, and productive failures in the learning process all contribute to promoting students' intrinsic motivation to learn in both pilot and full scale IM course conversions.**

Keywords—intrinsic motivation, low cost, Self-Determination Theory, undergraduate, large enrollment, student interviews, course conversion

I. Introduction

The low-cost intrinsic motivation (IM) course conversion project aims to redesign core engineering courses so that they primarily focus on promoting students' intrinsic motivation to learn. These converted courses would require low investments of time and money for instructors to teach. Because the traditional design of engineering courses focused on teaching the "right things" or perhaps even the "right way," previous reform efforts focused on getting students to learn the course content better by changing instructors' approaches to teaching. Although a focus on instructors' teaching methods can be beneficial, we believe that it may fail to prepare students to be life-long learners who are passionate and excited to become engineers. In contrast, the IM course conversion project focuses reform on methods to promote students' IM to learn with the belief that motivated, excited learners will ultimately learn more and persist longer in their learning.

In this paper, we report on the qualitative evaluation of the pilot and full scale versions of the IM course conversion. We interviewed 31 students who had experienced the IM course conversion to understand how the course affected their motivation to learn and their interest in the course content. We are using a grounded-theory-based analysis method informed by motivation theories with the goal of developing a finer-grained theory for describing what happens inside or outside the classroom to promote students' intrinsic motivation to learn, and how different course structures change students' motivational orientations.

II. Methods

A. IM Course Conversion

Using Self-Determination Theory (SDT) as the foundational decision-making framework, we make all IM course conversion decisions to promote students' sense of *purpose*, *autonomy*, *relatedness*, and *competence* for learning the material [1][2]. We ask instructors to identify a narrow strategic core for their course content so that their courses have a stronger sense of purpose and to give students a degree of autonomy to direct their own learning. With these guiding principles, in Fall 2011 and Spring 2012, we piloted IM course conversions with a subset of students (fewer than 50 students) from a large enrollment (more than 200 students) sophomore-level core computer engineering course. In Fall 2012, we scaled this IM course conversion to engage all students in the same course. In this IM converted course, all students crafted three learning agreements in which they could choose how they would practice the course content and demonstrate their mastery of the course content. They could even choose elective topics to study. Our previous quantitative research found that students in the IM courses achieved learning gains that were comparable to students who were in collaborative problem solving courses, but IM students expressed a greater sense of ownership and support for their learning [3].

B. Interviews

After completion of the course, we asked students to share their individual experiences by participating in interviews. A total of 14 students who had experienced the pilot conversions and 17 students who had experienced the full scale conversion volunteered for interviews. We used a semi-structured interview protocol and asked students to walk us through a timeline of their experiences in the course. We analyzed the interview transcripts without an a priori coding scheme, because we found no prior studies that indicated what we might expect to find. Our open coding process focused on students' motivational and affective statements. We created, reduced, and synthesized codes with a four step process: 1) individual open coding, 2) collaborative code reduction, 3) individual re-coding based on the reduced code set, and 4) theme development. So far, we have completed the analysis of the eight interviews from the first pilot IM course conversion.

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III. Preliminary Results

Thematic analysis resulted in four main themes which mapped to four of the motivational orientations described in SDT [4]: 1) no motivation or disengagement, which mapped to *amotivation* (AM); 2) motivation by grades or requirements, which mapped to *external regulation* (ER); 3) motivation by career or bettering oneself, which mapped to *identified regulation* (IR); and 4) motivation by learning, excitement, interest, or fun, which mapped to *intrinsic motivation* (IM). We found that strategic choices, positive team dynamics, and productive failures in the learning process commonly marked movement from AM, ER, or IR to IM throughout the students' experiences. The following quotations are from the first pilot IM course conversion only and are annotated with the motivational orientations assigned to individual phrases in braces (e.g., {IM}).

Students were identified as IM oriented when they made statements about interest in learning or enjoyment of the experience. A representative IM quotation is shown below.

> Please don't take up spots in the [pilot] by saying you want an easy A. And **those who in the past have wanted to learn more than what's in the class, who want to learn what's real life, then definitely, definitely do this {IM}**. I wish all classes were like this. (emphasis added)

Students became more intrinsically motivated to learn when working within a positive team dynamic, when given opportunities to make strategic choices about their learning, and when failures early in the course led to productive decisions later on. Selected quotations from students who started out AM, ER, or IR oriented and moved toward IM oriented are discussed below.

Positive team dynamics (*relatedness*) resulted in mutual support, greater perseverance, and increased excitement for the course. Students who described positive experiences with other team members made more IM oriented statements about the course than those who reported either neutral or negative experiences.

> We had a good group…. We split up work evenly, everyone got their work done and then we all got together and put our parts together {ER}. The only problem was when you're transferring ... files to one computer ... we all sat there and we're trying to figure out what was going on, so I think that was a good team building thing even though it kind of stunk {IR/IM}.

> Being with other people and working with other people who were also really excited about it makes me more excited {IM}.

Students were given the opportunity to choose how they would demonstrate their mastery of the course content (*autonomy*). When students based their initial choices on "getting an easy A," the final products were low quality and received negative feedback from instructors. These early failures "woke students up" and caused them to rethink their choices (*purpose*). The students' later choices centered on learning gains rather than grades and received positive feedback from instructors (*competence*).

> [At] the end of the first learning contract, we got stuck because we got very low grades {ER} ... We were very upset and we were thinking 'should we drop out of this section or not? {AM}' But then we kind of came out of that. **We shouldn't just give up {IM}** ... (emphasis added)

> Right after that exam it sorta just tanked {ER} and then just realized, "Okay. You know what? Time for the second learning contract. The second exam is something we can do, we can actually make an impact on." {IR/IM}

> But after the first one when we were designing the questions, we decided to do a design thing more, to **get more out of the course {IM}** ...The project aspect, trying to design something that really works well. To design things that work efficiently as much as a [sophomore] could probably do {IM}. (emphasis added)

We hope to elucidate these aspects of students' experiences with future analysis of the other 23 interviews.

IV. Future Directions

We are currently analyzing the second pilot and the full scale IM course conversion interviews. Future work will include qualitative results from all 31 interviews as well as classroom and team meeting observations. We will triangulate these qualitative results with quantitative surveys of both autonomy support and achieved learning gains for both the pilot and full scale conversions. We will also compare the pilot and full scale conversions.

We are studying the outcomes of IM course conversions in one large enrollment course in computer engineering for sophomores. We hope to expand the study to include conversions of courses at different levels and within different engineering disciplines in future semesters. Collaborations with chemical engineering and bioengineering are currently underway. Interest in IM course conversions has spread beyond engineering as well, with education and psychology instructors taking notice and adapting the method to their own classrooms.

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Bring Best of Two Worlds in a Software Engineering Class, Student Outcomes of Accreditation Board of Engineering and Technology (ABET) and Information Literacy Standards of Association of College & Research Libraries (ACRL)

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***Abstract*— In this collaborative project with librarians, the faculty members of Nelson College of Engineering, West Virginia University Institute of Technology (WVU Tech) identify the importance of information literacy (IL) in accreditation documents and then leverage accreditation guidelines from Accreditation Board of Engineering and Technology (ABET) student outcomes to integrate IL skills from standards of the Science and Technology Section (STS) of the Association of College and Research Libraries (ACRL) into an existing software engineering course. This project was sponsored by West Virginia University Information Literacy Course Enhancement Grant. We included the full range of the university libraries' resources, expertise, and services in course planning and delivery by incorporating different IL units: an introductory talk, special workshops, library sessions and consultations with the librarian throughout the semester. As conducting researches, designing projects, and writing reports are most effective vehicles for students' learning of strategic and rigorous information retrieval and management, the class includes a group software-development project and an individual paper-writing project. We included different data collection and evaluation methods distributed throughout the semester, including Standardized Assessment of Information Literacy Skills (SAILS), a web-based tool to document IL skill levels and to pinpoint areas for improvement.**

Keywords—Information Literacy, Software Engineering, ABET outcome, ACRL Standards

I. INTRODUCTION

According to the National Forum on Information Literacy "information literacy (IL) is the ability to know when there is a need for information, to be able to identify, locate, evaluate, and effectively use that information for the issue or problem at hand" [4]. This paper describes a collaborative project between engineering faculty members of Nelson College of Engineering, West Virginia University Institute of Technology (WVU Tech) with university librarians to identify the importance of IL literacy in accreditation documents and then to leverage accreditation guidelines from Accreditation Board of Engineering and Technology (ABET) student outcomes to integrate IL skills from standards of the Association of College and Research Libraries (ACRL) into an existing software engineering course. This project was funded by West Virginia University Information Literacy Course Enhancement Grant.

In this project, we offer pedagogical innovations through unique combination of different methods of instruction delivery and class assignments. Along with traditional lectures, we offer workshops (on IL, technical writing, professional presentation, CASE Tools) and special library sessions (on orientation, search strategy, citation analysis). We also included special sessions on ethics and contemporary issues (watching related video, discussion on engineering ethics standards, intellectual property, copyright law etc). In addition to regular tests, the class includes a semester long group project, formal presentations, paper writing and multiple active learning exercises. In a group environment the students build their own software project over the semester by applying the software engineering process, methods and tools. The whole semester is divided into four phases "Communication and Planning", "Modeling", "Construction" and "Deployment". As the semester goes through each of these phases, the students gain theoretical knowledge from lecture contents, related hands-on experience from their own projects and share their experience through formal presentations. The class also has an individual project in which each student perform research on a current software engineering topic to prepare a formal report. Students work with librarians to research background material, formatting requirements and referencing others. This class allows us to compare the efficacy of design engineering projects with that of engineering reports as alternative vehicles for information literacy. While integrating the ACRL standards and ABET outcomes, we emphasized more on the professional skills including communication (oral presentation and writing), teamwork, ethics and lifelong learning. Rather than just letting them work in a team, we guide our students in group development, consensus-building, resolving-conflict, and team-leadership. Finally we demonstrate how students can become a lifelong learner by becoming proficient in broad spectrum of professional skills.

Our greatest strength is our extensive assessment effort through the whole semester. On top of regular grading through scoring rubrics and peer evaluation (on teamwork), we are performing multiple survey/tests including pre and post

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survey, assignments on citation analysis, search strategy, plagiarism and a test called Currency, Relevance, Authority, Accuracy, Purpose (CRAAP) test [8]. We are also conducting external evaluation through Standardized Assessment of Information Literacy Skills (SAILS) test [10].

The rest of the paper will include following sections. In section II, after describing information environment in ABET's nine general outcomes for computing programs and ACRL's five standards for science and technology, we will try to relate both options. In section III we will explain the background of this project. Our efforts around five professional skills communication, teamwork, impacts of computing, ethics and lifelong learning will be narrated in section IV. Before we draw our conclusions, our different implementation and assessment strategies are described in sections V and VI respectively.

II. ABET AND ACRL

In following subsections, after briefly describing ABET's outcomes for computing programs and ACRL's standards for science and technology section, we will try to identify the relationship between these two skill sets.

A. ABET Student Outcomes for Computing Program

The Accreditation Board for Engineering and Technology (ABET) is recognized as the worldwide leader in assuring quality and stimulating innovation in applied science, computing, engineering, and engineering technology education. ABET student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program [3]. Criterion 3 of computing programs includes a set of nine general outcomes that all computing baccalaureate graduates should possess. The nine general student outcomes of computing programs are listed in Table 1. One aspect of the enhanced ABET criteria (2000), particularly relevant to engineering and technology is "an understanding of professional responsibility". In section IV we will walk through ABET's five professional skills communication, teamwork, impacts of computing, ethics and professional development (also known as lifelong learning).

B. Standards of ACRL's Science and Technology Section

The Association of College and Research Libraries (ACRL), a division of the American Library Association, is a professional association of academic librarians and other interested individuals [4]. It is dedicated to enhancing the ability of academic library and information professionals to serve the information needs of the higher education community and to improve learning, teaching, and research. In order to identify the 21st century information environment in computer science or more generally in engineering education, let us look at the simpler versions of information literacy standards (also described in details in Table 1) specific to science, engineering, and technology defined by the Science and Technology Section (STS) of the Association of College & Research Libraries. Here, we will also identify ways to accomplish these standards in our software engineering class.

1) Determine the nature and extent of the information

In corporate world, engineers need to find critical information from databases, technical journals, handbooks, and product catalogs to solve the problems. Defining the problem and identifying what they need to know are critical first steps that engineering students tackle. As the students themselves seem to be most receptive to IL when they are engaged in creative projects, inclusion of a workshop on IL before projects are being assigned will be very beneficial.

2) Acquire information effectively and efficiently

Engineering students (also professionals) often do their research only with the internet and overestimate their abilities in searching the internet for information. Most of them are unaware of subject-specific databases that could be better sources for more detailed information on a topic with a clearly-defined subject area. The guidance of the librarian on what other tools are available and when they are useful for a specific information need will help students to expand their skills in finding web sites, books, and journal articles via the use of a web search engine, the library catalog, and a research database.

3) Critically evaluates the procured information

A quick search of any technical topic will yield a sea of user-created information content of varying quality. The necessity of being able to correctly select, interpret, and measure the "goodness" of the information, and therefore how much it should be relied upon, becomes more and more critical. As engineering students typically value accessibility over quality when choosing information sources, it is very important to teach them how to critically evaluate material.

4) Use information effectively and ethically

Engineering ethics is one of the crucial areas in engineering education. Using media information (Report on Bhopal or Columbia shuttle incident) to discuss about ethical principles and our responsibilities to the society is a very effective technique.

5) Understand IL as a component of lifelong learning

The goal of engineering programs is to educate competent engineers. Because the working environments and experiences of engineering students will differ greatly after graduation, engineering programs aspire to teach a set of skills that will be of value in different working environments and also encourage them to engage in a life of continuing pursuit of knowledge using IL.

When we consider the implications of the IL standards, identify the information applicable to the problem at hand, find the appropriate sources, evaluate the quality of the information, apply it ethically and engage in a lifelong learning, we can see that IL is the very *essence* of engineering education and it must be incorporated in our curriculum to meet the future professional needs and success of our students.

C. The Relationship

Although ABET outcomes criteria do not explicitly mention information literacy, it is apparent that students cannot achieve many of the ABET outcomes without developing information literacy skills [5]. Some IL standards clearly overlap with ABET outcomes in communication, teamwork, impacts of computing, ethics and lifelong learning. However it is still not a common practice for the IL skills to be assessed as part of ABET outcomes assessment. As we wanted to integrate these two skill sets, identifying their relationship is crucial for our project. After carefully analyzing the skills in both sets, one can identify that these two actually can complement each other. While ACRL standards are designed around the conception that the engineers are only the consumer of the information, ABET is placing the engineers as the sole producers of information. ABET's outcomes assumes that the engineers work with data which are only generated through their own experimentation. They do not encounter the need to account for information gathered in other ways, particularly through existing information resources [5].

We identify a symbiotic relationship between these two sets. We are hoping that if the engineering faculty and librarians work together to design and develop different types of instruction methods to deliver these skills and assessment tools to evaluate, like a true symbiotic relationship, both skill sets will nourish each other. The success of these efforts will not only be the summation of both, it will be a success of multiplying factors. We strongly believe that integrating ABET outcomes with IL together can achieve far more than either can individually. In TABLE 1, we put the related ABET's outcome and ACRL's standards side by side.

III. BACKGROUND

In this section, we describe our process in integrating our IL criteria with our ABET assessment process. We will also make the case for utilizing the same class which is currently being used for assessing ABETs outcomes for a project funded by a course enhancement grant to incorporate IL skills.

A. The Development Process

In Computer Science and Information System department of Nelson College of Engineering of WVU Tech, as part of a department wide effort, we are currently preparing for application for ABET accreditation on 2014. At the beginning, we performed curriculum mapping process, where we were trying to identify core courses for performing the documented and effective process for the periodic review and revision of the student outcomes. During this process, along with our senior project capstone class (CS 461), our sophomore level software engineering class (CS 222) has been selected as a natural candidate to measure the fulfillment of a large numbers of the ABET outcomes. In early spring 2012 when the university library has announced a course enhancement grant to incorporate IL in an existing course; this software engineering class seems like a perfect candidate. Because we are already committed our time and resources to ABET preparation, we desired to integrate efforts for including information literacy standards with those of ABET in this class. After successfully securing the grant, we approached our librarians with ideas and suggestions of IL based instructional issues particularly relevant to our software engineering course. As the librarians have been providing essential instruction in IL for many years, they can assist us (software engineering faculty) in adjusting to the emerging standards by incorporating lessons of IL responsibility into an existing curriculum. Our librarians worked amongst themselves to ascertain the specific incremental instruction components that can be integrated into this particular course and provided us concrete suggestions that can be a basis for to documenting IL instructions, which in turn can facilitate documentation for accreditation reports. This collaboration between software engineering faculty and librarians has so far been a great experience in exploring the effective intersection of ABET outcomes and IL competencies, in the context of incorporation into an existing course.

Several works can be found in literature which mapped IL criteria to ABET outcomes [5, 6, 7]. Most of these work [6, 7] place IL in the "lifelong learning" (also known as continuing professional development) category of ABET outcome. We have chosen to broaden this mapping outside of lifelong learning because we believe IL skills are developed across several professional outcomes including communication, teamwork, impacts of computing and ethics. In our work, we tried to bring the bests of both worlds of ABET and ACRL by not only mapping them together, but also reviewing these skills with an emphasis on how they can be taught together. In this project, software engineering faculty and librarians are working together to develop creative ways to combine these skills. During our work we survey the literature to identify successful and promising examples of implementation of IL and successful assessment mechanisms to evaluate ABET outcomes in a class. Because each institution develops their own set of mechanisms, we did not simply adopt another's mechanism but developed our own implementations of instruction delivery and assessment tools based on our own programs need. In Table 1, along with grouping related ABET outcomes and ACRL standards together, we are also identifying our instruction implementation components and assessment tool for the related skill.

B. The Reasons to Select this Course

There are three major approaches in which IL can be incorporated into education: full curriculum reform, dedicated courses, and inclusion in existing courses. As our department is currently preparing for ABET accreditation, finding faculty time to plan and implement full curriculum change would be too ambitious for us. While the second approach seems very appealing, the pressure exerted by state legislatures and university administrators to reduce the number of hours in engineering programs, makes adding any course to the existing program an impossible solution. Hence we have chosen the third approach which can be accomplished by making changes to existing courses, a practical solution for our programs.

To identifying courses more suitable candidate for introducing IL, we performed a literature survey to see what other school are doing. Some universities reported the difficulty with introducing in-depth information literacy primarily at the freshman level. The report showed that engineering students are not, at that point, yet knowledgeable enough about their prospective fields to be able to appreciate technical literature available necessary to the successful practice of the profession. On the other hand another school reported that after using the senior project class to incorporate IL, a frequent comment from students to the faculty was "Why didn't we learn this earlier?" After careful considerations, we selected CS 222 Introduction to Software Engineering to embed IL units. We strongly believe that this sophomore level class is a natural candidate for introducing IL. The class enrollment is between 14-18 students. The class is required for computer science, computer engineering and information systems majors. The class is the pre-requisite for CS 322 System Analysis and Design Methodology which is prerequisite for CS 461 Senior Project capstone class.

IV. Professional Skills

Since the founding of the ASEE in 1893, we have witnessed the engineering education to collectively shift the focus from course content to the development of students as emerging professionals. More recently, the last two decades have paved the way for including the professional skills as learning outcomes [1]. In ABET outcomes for computing, outcomes "d – h" are identified as "professional" skills. Shuman [1] have conducted comprehensive survey on how these professional skills can be taught, or more correctly learned, and the difficult issue of assessing these skills and recognize that there is considerable research that remains to be done. In this section of our paper we will concentrate on these five professional skills, map them in ACRL standards and identify our ways to implement these in our own software engineering course.

A. Communications

The proceedings of both the Frontiers in Education conferences and the annual conferences of the American Society of Engineering Education are replete with examples of ways to integrate communication into the core of engineering education [1]. In our class we are going through the phases of software development cycle, with a concentration on oral, visual and writing communication skills. At the end of each phase, the student groups are making power point presentations to the class on their experience during the corresponding phase. In the class, each student is also working in an individual project in which each student perform research on a current software engineering topic to prepare a formal report. During the whole semester, along with traditional lectures, we offer workshops (on technical writing, professional presentation, CASE Tools) and special library sessions (on search strategy, citation analysis). Students are getting the first hand opportunity to work with librarians to develop their research skills. We believe that placing communication components to express their recently gained experience will be a good way of approaching ABET's criteria for communications in a course with significant technical content.

B. Teamwork

This team based project driven class provides our students with the opportunity to experience the dynamics of team design work from idea development to completion. During the semester, the engineering faculty member and the librarians are working closely with the students as their team members. We are hoping that our teamwork development strategies will teach our students the skills necessary to work effectively in teams like: demonstrating positive interaction, good listening skills, understanding of team roles, sharing responsibilities, helping others, soliciting member input, resolving conflict etc. For each of the four phases in the semester, students are evaluated by their own team members.

C. Ethics and Local/Global Impacts of Computing

The true test of engineering ethics education is how graduates behave in the workplace during their careers, certainly a difficult outcome to measure *a priori* [11]. Stephan [11], in questioning whether or not engineering ethics can be taught, quotes philosopher Michael Davis in giving four good things that can result if successful: students can become more aware of the ethical implications of their work, they can learn ethical standards, they can become better judges of ethical conduct, and they can become more willing to put their ethical knowledge into action. Although there is no debate about importance of ethics and contemporary issues in engineering curriculum and because of ABET requirements, much attention has focused on how engineering students perceive, articulate, and resolve ethical dilemmas in their professional life, our existence in this "Information Age" puts us in further challenges. According to Wikipedia "The Information Age, also commonly known as the Computer Age or Digital Age, is an idea that the current age will be characterized by the ability of individuals to transfer information freely, and to have instant access to information that would have been difficult or impossible to find previously." Through the internet, we are developing a new world of human knowledge and information, which has no geographical, political, social, or generational boundaries. This new world is accessible to anyone who wants, from the scientist in developed world, to the farmer in rural areas of an underdeveloped country. This new world engenders new forms of ethical issues for which old solutions to past ethical problems cannot be merely exported and mechanically re-applied. Hundreds of years of research on ethics have helped us understand how ethical ideology is related to our life when more traditional ethical quandaries are encountered. However, whether conclusions regarding traditional ethical issues apply to IT-related behaviors is unknown.

Both ABET and ACRL, criteria call for ensuring *understanding* rather than *demonstrating* that graduates are ethical [9]. Education researchers [1, 9] emphasize on evaluating students on knowledge and skills, not values and beliefs. Our librarians and engineering faculty members have worked together to develop (researched and written) pedagogical tools (for both instruction and assessment) to teach not only engineering design, but engineering ethics to expose the students to realistic situations involving unstructured problems with multiple possible answers and trade-offs. We are hoping that these will foster the development of higher-level cognitive skills in students, by enabling them to address problems that require analysis, judgment, independent thought, and critical thinking.

D. *Life Long Learning*

"It has been said that the "half-life" of engineering knowledge--the time in which half of what an engineer knows becomes obsolete--is in the range of two to eight years." [2]. In Criterion 3 of ABET's computing programs we can see "lifelong learning" as professional development (outcome "h"). Whereas for ACRL, we see lifelong learning as an integral part as standard 5, "The information literate student understands that information literacy is an ongoing process and an important component of lifelong learning and recognizes the need to keep current regarding new developments in his or her field". Although most literature [6, 7] placed IL primarily in the realm of life-long learning, we disagree. According to Shuman [1], "One will become a proficient lifelong learner as one becomes proficient in the broad spectrum of professional skills". We also believe that as students acquire all these skills in ABET outcome and ACRL standards, they will, in fact, acquire the ability to do lifelong learning.

V. Implementation

The professional skills can be incorporated into this existing course at many levels, and ways. In the initial draft we identify the opportunities to incorporate different IL units: an introductory talk at the start of the course, a special workshop and consultations with the librarians throughout the semester. During our collaboration we designed effective ways to deliver our instructions to offer the best of both worlds, ABET's outcomes and ACRL's standards.

A. ***Semester long Group Project***

Literature shows that design projects are the most effective vehicles for students' learning of strategic and rigorous information retrieval and management. The software engineering class has a group project in which the students will build their own software project over the semester by applying the software engineering process, methods and tools. This group project is two-fold: Project building and Project Demonstration. The whole semester will be divided into four phases; (1) Phase I: Communication and Planning, (2) Phase II: Modeling, (3) Phase III: Construction and (4) Phase IV: Deployment. As the semester will go through each of these phases, the students will gain theoretical knowledge from the lecture contents and related practical (hands on) experience from their own projects.

B. *Group Presentation*

At the end of each phase, the groups will make power point presentation on their experience as they went through the phase. They will also demonstrate the work products related to corresponding phase as follows: (1) Phase I: list of stake holders, question sets, list of objects, list of constraints etc, (2) Phase II: use case, use case diagrams, analysis diagram, CRC card, behavioral diagrams, design models, component diagrams, architectural diagrams, deployment diagrams, (3) Phase III: first iteration of the software, test cases and test results, (4) Phase IV: final iteration of the software.

C. *Special Workshops and Sessions*

In the class special workshops are conducted on "professional presentation", "technical writing", "UML Visual Paradigm", "information literacy". During the semester, librarians will conduct special sessions on "search strategy", "citation analysis", "software testing". The class will also include video sessions (report on bhopal or columbia shuttle incident) and active learning assignments (working in an Agile software development environment).

D. *Enterprise Architecture and Project Management Case Research (Individual assignment)*

The class also has an individual project in which each student perform research on a current software engineering research topic or software engineering process standards to prepare a formal report. Making accommodations for the students to work with a librarian to research background material for the written report will be a perfect situation. Through this assignment, the students will be graded on the quality of their research and the variety and appropriateness of the selected resources. This will also provide the students to introduce to specific journal search in on-line library catalogs and formatting requirements (like IEEE template).

VI. Assessment

Our goal is not only integrating ABET's outcomes and ACRL's standards in an existing class, but also to design an assessment plan to evaluate both. Our strength is our extensive assessment efforts which are described below.

A. ***Scoring Rubrics with Performance Indicators***

We implemented performance indicators to measure ABET's outcomes and ACRL's standards fulfillment. Then we developed rubrics with performance indicators to measure every outcome and standard addressed in this individual course. At the end of every semester engineering faculty members will evaluate program outcomes and they will also evaluate the IL standards in conjunction with the librarians. Librarians and engineering faculty both need to be prepared to make adjustments based upon results found within the cycle of assessment.

Although we are analyzing data for all outcomes and standards, because of space limitations, we are displaying our results only for presentation skills. Fig. 1 shows the percentage improvement in student's overall presentation skill from Phase I to Phase II. Here, we are analyzing the presentation skill as a team in five different criteria.

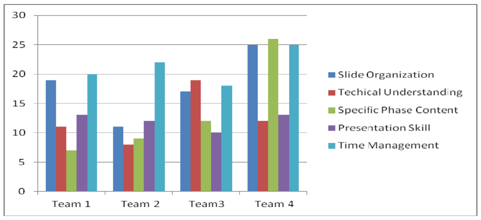

Fig. 1. Percentage improvement in student's overall presentation skills from Phase I to Phase II

B. *SAILS Test*

The SAILS test is a nationally-recognized assessment of information literacy skills [10]. The test is a knowledge test based on the ACRL information literacy competency standards for higher education. Analyzing our pre and post score demonstrate an average 17% improvement. Using the SAILS test allowed us to identify strengths and weaknesses of our students' IL skills. Although some student's achievement is quite significant, for others it was not as we expected. We are hoping this first time experience with SAILS testing will provide us direction for our course in order to better develop the IL skills of the students of our future software engineering classes.

C. *General Survey/Test on IL*

We are performing multiple survey/tests on IL including pre and post survey, assignments on citation-analysis, search-strategy, plagiarism. As an internal evaluation option (where as SAILS is the external option) we have designed pre-testing and post-testing. Because the test measures overall information literacy, pre and post testing have been conducted after a long interval of twelve weeks and demonstrated an average 31% improvement.

D. *Student Peer Evaluation*

After the presentation of each phase, the students are asked to grade their team members on demonstrating positive action, good listening skills, understanding team roles and sharing responsibility. In fig. 2 we show the improvement in teamwork skills for individual student (12 students) according to our instructor's evaluation and student peer evaluation approach. From the figure, we can see that there is significant improvement in teamwork skills for all of our twelve students.

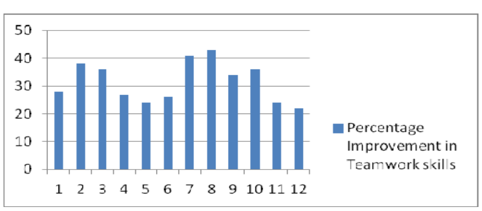

Fig. 2. Percentage improvement in teamwork from Phase I to Phase II

E. *CRAAP Test*

The CRAAP Test [8] is a useful guide to evaluating resources used by our librarians for ACRL STS standard 3. In our software engineering class, they help students to take the CRAAP test to make a case for the importance of critically evaluate the authenticity of an information source.

VII. CONCLUSIONS

In this paper we describe our experience in preparation for ABET assessment process while integrating information literacy with ABET student outcomes in a sophomore level class. This project was collaboration between software engineering faculty members with the librarians. This collaboration enabled us to deliver IL contents throughout the semester rather than in one discrete lecture and to facilitate the development of a realistic assessment plan. Unlike others work in literature [6, 7], where ABET and ACRL outcomes mapping is mostly on life-long-learning, we also dealt with other ABET professional skills like teamwork, communication and ethics. We also identified the different points of view of ABET and ACRL regarding the relationship of the engineers with the data they work with.

This project is a win-win-win situation for the students, for the librarians and for the department. With this embedded IL approach, the students will achieve an improvement not only in their perceptions of IL skills but also an improvement in their actual skills. By evaluating student IL skills, the library team can modify the existing IL instruction to focus more on identified weaknesses. At the same time, by introducing IL in our software engineering class, we get the opportunity to develop a curriculum with a stronger foundation.

ACKNOWLEDGMENT

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TABLE 1. Mapping of ABET Outcomes, ACRL Standards along with our Implementation and Assessment Strategies

ABET Outcomes	ACRL Standards	Our Practices		
		Implementation		*Assessment*
		Role of Engineering Faculty	***Role of Librarians***	
Outcome (b) An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution	**Standard 1** The information literate student determines the nature and extent of the information needed.	Assign a project to each team. Conduct *Active Learning Sessions* so the students can ✓ analyze the assigned problem ✓ identify and define the computing requirements ✓ determine the nature and extent of the information needed	Conduct General Library Session at the beginning of the semester on ✓ Available resources – Databases, Card catalog, Types of sources ✓ Non Available resources - Interlibrary loans ✓ Searching tools and techniques Special one-to-one sessions with each team	Group Project Grading Rubrics
Outcome (a) An ability to apply knowledge of computing and mathematics appropriate to the discipline **Outcome (c)** An ability to design, implement, and evaluate a computer based system, process, component, or program to meet desired needs **Outcome (i)** An ability to use current techniques, skills, and tools necessary for computing practice	**Standard 2** The information literate student acquires needed information effectively and efficiently. **Standard 3** The information literate student critically evaluates the procured information and its sources, and as a result, decides whether or not to modify the initial query and/or seek additional sources and whether to develop a new research process.	1. Introduce students to new knowledge of computing and guide them to apply this knowledge in the project 2. Work with the students during: ✓ two week long Communication and Planning phase ✓ four week long Modeling (design) phase of their project ✓ two week long Implementation phase of their project ✓ two week long Testing phase of their project 3. Conduct workshop to train students on UML Visual Paradigm 8.3 Tools 4. Work with students to develop work products including USE case, UML Diagrams, CRC Models, Analysis model and Design Model, Architecture Design, Component design	Specific Library Sessions during the semester ✓ Guide to find sample work products ✓ Guide to find standard software testing suits ✓ Recommended readings Continuing search strategy assignments Continuing one-to-one session with teams	Group Project Grading Rubrics CRAAP Test Quizzes SAILS Test
Outcome (f) An ability to communicate effectively with a range of audiences	**Standard 4.3:** Acknowledges the use of information sources in communicating the product or performance **Standard 4.6:** Communicates the product or performance effectively to others.	Conduct workshop on Professional presentation Conduct workshop on Technical Writing Develop Rubrics Provide detailed instructions with grading policy	Conduct library session on Citation Analysis Go through IEEE Template General Instruction on formatting	Presentation Grading Rubrics Research Paper Grade
Outcome (d) An ability to function effectively on teams to accomplish a common goal	**Standard 3.5:** Validates understanding and interpretation of the information through discourse with other individuals, small groups or teams,	Provide guidance in ✓ group development, consensus building, resolving conflict, and team leadership. ✓ After each phase conduct peer evaluation among team members	✓ Work as a team member to find related information ✓ Solicit input	Peer Evaluation
Outcome (e) An understanding of professional, ethical, legal, security and social issues and responsibilities **Outcome (g)** An ability to analyze the local and global impact of computing on individuals, organizations, and society	**Standard 4:** The information literate student understands the economic, ethical, legal, and social issues surrounding the use of information and its technologies and either as an individual or as a member of a group, uses information effectively, ethically, and legally to accomplish a specific purpose.	Conduct Special sessions Play video on explosion of the Challenger, the Three Mile Island Nuclear Power Plant accident, Bhopal, Chernobyl and the Ford Pinto incidents Engineering Ethics Standards Conduct discussion on Engineering Ethics	Conduct Special sessions on Intellectual property, Copyright law Plagiarism	Library work on Search Strategy, Plagiarism Citation Analysis

A taxonomy of exercises to support individual learning paths in initial programming learning

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***Abstract* – Initial programming learning is known to be difficult to many students. To improve this situation it is necessary to support students learning effectively. This means that learning activities should be adapted to each student learning pace and specific needs. This is difficult considering that classes often have a large number of students. The definition of individual learning paths adaptable according to the student performance might help to improve the situation. To support the definition of learning paths it is useful to have a large set of exercises, organized according to a taxonomy that includes different dimensions and parameters relevant to the choice of appropriate exercises at any moment. To present this taxonomy is the main objective of this paper.**

Keywords – Programming education; Taxonomy; Learning paths; Programming learning difficulties.

I. INTRODUCTION

Introductory programming learning causes difficulties to many students worldwide. Various reasons have been identified [1], [2], [3], [4], [5] and several proposals have been put forward in the literature to minimize those difficulties [1], [4], [6]. However, high dropout and failure rates in introductory programming courses continue to be reported in many higher education institutions.

The heterogeneous nature of most classes is often mentioned as a cause for difficulties. It is common to find students with very different levels of knowledge, motivation, commitment and learning rhythm. Therefore, it is difficult for the teacher to follow an approach suitable for every individual student. In an attempt to reach all students, teachers often design lectures and activities to the "average student", who may not even exist in the class. To improve this situation personalized support and guidance is necessary, so that individual needs and difficulties can be addressed. However, considering the number of students that classes commonly have, it is not easy for a teacher to deal with the diversity of student's levels and needs at each moment.

To allow a personalized support to a large number of students there is a need to systematize the learning process. This systematization must take into account the individual needs and learning pace of each student, but also the main objective that the student must reach a certain level of programming proficiency.

To be successful in introductory programming courses the student must learn a set of basic concepts, the syntax of a programming language, and develop problem-solving skills using the programming language to express solutions. The introduction of the basic concepts and the language syntax is often made in lectures where a teacher presents them to a large number of students. Although this model is cost effective, it is far from ideal from a pedagogical point of view. All students receive the same information in the same format, not taking into consideration individual differences. It is usually accepted that students often have different motivation, learning strategies and learning styles [6], [7], [8], [9]. So, it is important to consider those differences when designing learning experiences. For example, some students would learn easier if there is an initial and generic presentation of the various contents, accompanied by small examples, while others would learn better if each topic is addressed separately and more profoundly, practicing it through a wide range of exercises.

The development of programming problem solving skills is the more complex aspect for novices. It demands an intensive programming experience and it is necessary to define adequate exercises at each stage. The sequence of exercises shouldn't be predefined and the same for all students. It should be adapted for each student needs and current level of knowledge. Activities that are too easy in a particular moment don't give a good contribution to the student cognitive development, but if they are too difficult for the student they may cause frustration, demotivation and dropout. In our view, it is important to propose to each student activities that create some difficulty, but that they may be able to solve, at least partially. This can contribute to raise the student motivation and self-confidence, making him/her believe that it is possible to be successful, and that solving problems is an effective way to learn.

Motivation can also be improved if the student feels improvement in his/her abilities. A possible strategy when a student is not able to solve a problem is to divide it in sub problems and propose some of them to the student. When he/she solves the sub problems the original problem can be proposed again, hoping that the student has progressed and is now able to produce a better solution. If this happens the student will notice the improvement.

To support this individualized learning experience, which implies the dynamic definition of learning paths, it would be useful to have an automatic system that may propose exercises to the student. This system would need to use a large set of exercises that should be classified in several dimensions to support the process of choosing the next exercise to a particular student, under the pedagogical principles described above. In other words we felt the need for a taxonomy to classify common programming exercises, taking into consideration the pedagogical objectives of our work. To present that taxonomy is the main objective of this paper.

In the following sections we briefly present some taxonomy proposals found in the literature, describe and fundament the taxonomy we propose, and present some preliminary evaluation of its utilization in the definition of individual learning paths.

II. RELATED WORK

Taxonomies of educational objectives are used worldwide to describe learning outcomes and assessment results, reflecting a student learning stage. Usually authors divide educational objectives into three domains: cognitive, affective and psychomotor. As described in Fuller et al. [10], some, such as Bloom's taxonomy [11], treat each of these as a one-dimensional continuum, others, like the revised Bloom's taxonomy [12] describe the cognitive domain using a matrix. Yet others, like the SOLO taxonomy [13], use a set of categories that describe a mixture of quantitative and qualitative differences between student performances. There are also taxonomies that use all three domains equally. However, existing research on the use of learning taxonomies in computer science focuses on the cognitive domain.

A very well-known taxonomy is the original Bloom's taxonomy [11]. It is a classification of the different objectives and skills that educators set for students. Skills in the cognitive domain are divided in six levels. Starting from the lowest order processes to the highest: Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation.

The Knowledge level consists in activities that demand recognizing or recalling information. Referring to the case of introductory programming, Lister and Leaney [14] report that questions on Java programming appropriate to the Knowledge level would be for example: "List the three types of repetitive structures that exist in Java." or "What kind of repetitive structures in Java are executed at least once?"

Activities in Comprehension Level consist in demonstrate sufficient understanding to organize and arrange information mentally on a given subject. At this level, the student understands what is being communicated without necessarily relate it to other issues or view their full implications. Lister and Leaney [14] report that a question about Java programming appropriate to the Comprehension level could be the translation to Java of a very specific instruction described in a textual or pseudocode format. For example, "Write a Java statement that declares a variable *x* that can contain integer values".

Activities in the Application level consist in constructing an answer through the application the previously learned information. Lister and Leaney [14] report that many traditional tasks of programming are on the application level, since they are completely specified. According to these authors a question about Java programming appropriate to the application level would be to ask students to write a class, whose characteristics are specified in detail. The specification should include the attributes and the headers of the methods. The code of each method should not be long (e.g. less than 20 lines) or algorithmically complex.

Analysis level includes questions requiring critical and detailed thinking. Bloom states that the level of analysis emphasizes the partitioning of the subject into its constituent parts, as well as the detection of relationships between them and how they are organized. Lister and Leaney [14] report that an appropriate Java programming task appropriate to the analysis level could, for example, consist in providing to the student some code that implements the standard programming Model-View-Control, and ask student to identify the pieces of code that implement the model, the view and the controller.

Synthesis level includes questions requiring the execution of creative and original thinking. It consist in join all the parts into the whole. In the case of Java programming Lister and Leaney [14] suggest that a typical exercise suitable for this level would be to decompose a problem into classes and determine the most appropriate methods for each class.

Evaluation level includes open-ended questions that allow multiple answers or solutions. According to Lister and Leaney [15] this level of the taxonomy is perfectly suited to the teaching of programming, because aspects such as clear, concise and efficient code should be valued. The authors mention that a Java programming task appropriate to the Evaluation level could consist on peer evaluation of code in terms of its effectiveness.

Bloom's taxonomy has been revised [12]. The authors changed the nouns listed in Bloom's model into verbs, to correspond with the ways learning objectives are typically described.

The SOLO (Structure of the Observed Learning Outcome) taxonomy [13] makes no reference to the learner performance cognitive characteristics or to the affective dimension. It focuses on the content of the learner's response to what is being assessed. It aims to identify the nature of that content and the structural relationships within it. The content could be designed to assess knowledge, cognitive skills or underlying values. The taxonomy can be used to establish the expected relationships between these different types of content.

The levels of the SOLO taxonomy are: Pre-structural, Uni-structural, Multi-structural, Relational and Abstract. The Pre-structural level is the least sophisticated type of response that a student can give. Reveals insufficient knowledge about a subject or little interrelated knowledge. Lister et al. [16] report that a student giving a pre-structural response to a question demanding the interpretation of a piece of code demonstrates a significant misunderstanding (misconception) concerning the topic in question or uses a previous concept irrelevant to the subject. The Uni-structural level includes answers where the student expresses a certain understanding or a minimum knowledge about some but not all aspects of a given problem. The student understands certain simple meanings, revealing a partial understanding of a particular problem within a more complex case. Usually the response of the student focuses only on one important aspect of the task to be solved. The Multi-level structure includes responses where the student expresses an understanding of several or all parts of the problem, but without an awareness of the relationships between them, treating them independently. The Relational level includes answers where the student demonstrates a level of understanding that integrates the parts of the problem in a coherent structure, using this framework to solve a given task. The student is able to use concepts that integrate a given data set comprising its application to familiar problems. The Abstract level includes answers where the student shows a level of understanding that allows the relationship between reflection and questioning the existing principles and acquaintances, so that he/she can deal with new problems [13], [17].

Fuller et al. [10] propose a new taxonomy (The Matrix Taxonomy) considered particularly useful for evaluating the learning of programming. The inspiration for this taxonomy resided in research conducted by Winslow [3] and Lister et al. [18] that indicates that the ability to understand the code of a program and the ability to produce code are two semi-independent skills. Students who can interpret programs may not necessarily be able to write their own programs. Also the ability to write code does not necessarily imply the ability to correct errors. The authors considered that Bloom's Taxonomy would be a good basis for their taxonomy that would use a two-dimensional array. The dimensions of the matrix represent the two scales of skills separately, including the ability to understand and interpret a program and the ability to design and build a new one. The levels that reference the understanding and interpretation of code are placed on the horizontal axis (Remember, Understand, Analyze and Evaluate). The levels concerning code generation are placed on the vertical axis (None, Apply, Create), both with lower levels in the lower left corner. The authors consider that, according to this taxonomy, a student may not have any skills to create code (None). Through the vertical axis we can comprehend that students cross each line through a strict sequence. For example, a student could not be able to synthesize (Create) without a certain degree of competence at the application level (Apply). This taxonomy can be especially useful for educators who need a grid to classify their students. It also illustrates the different learning paths that students can follow, as shown in a study conducted by Lahtinen [19].

However we agree with Raymond Lister when he says that "specific to the teaching of elementary programming: the lower two levels should emphasize the skill of reading and comprehending code, the intermediate two levels should emphasize the writing of small fragments of code, but within a well-defined context, and the upper two levels should emphasize the writing of complete non-trivial programs" and that "students should first be taught to read programs before they write programs" [20].

III. TAXONOMY OF EXERCISES

Our research group is involved in the development of a platform that may support novice-programming student's autonomous work. It includes several tools, such as automatic diagnosis of the student's difficulties based on the problems he/she was able to solve previously and the errors made, feedback on the current assignment, and definition of individualized learning paths based on the student's past performance. These learning paths are sequences of exercises to be proposed to the student, in order to develop his/her programming skills. Its definition is dynamic, considering the difficulties shown in each exercise by the student. To support this approach we created a database of common introductory programming assignments classified according to a taxonomy we created. It allows the selection of the next exercise to propose to a student considering his/her current level.

The taxonomy we developed maps each programming exercise in one or more dimensions, taking into consideration different aspects that we consider relevant to the classification of exercises. Some of the dimensions used were: the levels of Bloom's Taxonomy; the mathematical knowledge necessary to solve the exercise; the complexity of the control structures involved in the solution; the complexity of the exercise description and the algorithmic complexity.

A. General aspects

The definition of a taxonomy of exercises has the intent to allow an adequate classification of introductory programming exercises. This should facilitate the selection of an appropriate exercise to be proposed to a particular student in a specific moment. This is central to our objective of supporting the definition of individual learning paths for any student.

The taxonomy allowed us to structure a database of exercises that is continually evolving with the inclusion of more exercises. The work of defining the taxonomy and classifying the exercises was based on an already existing set of exercises, which was used in introductory programming courses at our department. Those exercises were structured in worksheets, each of them addressing a topic (variables and operators, conditional structures, repetition structures, functions, arrays, strings, …). In each worksheet, the exercises were organized according to the sequence they are presented and solved in lab classes. Each worksheet also included exercises proposed for the student's individual work.

We can't expect students to solve all the problems included in the worksheets, and that isn't necessary for most of them. Also, it is not feasible to create a shorter list of problems adequate for all students as their needs normally differ strongly. An exercise that is suitable for a student may be too difficult or too simple for other students. We agree with the principle of "small steps" mentioned by Hofuku et al. [21] as a way to consolidate the programming learning process. When choosing an exercise it is important to consider its cognitive requirements and compare them with the student current situation to avoid the creation of "gaps" that may hinder learning. A classification of exercises is necessary, so that it is possible to choose the right one for each student in a particular moment. That was the main objective of the definition of the taxonomy we describe in the next section.

B. Dimensions

Our classification proposal includes three dimensions in which it is possible to classify any exercise. Those dimensions are presented in the next three subsections.

1) Topics

In this dimension exercises are classified considering the programming structures necessary for their solution. The possible values in this dimension correspond to the common topics in an introductory programming course based on an imperative language, "variables and operators", "conditional structures", "repetition structures", "functions", "vectors", "arrays", "strings" and "files". This list is not closed and can be adapted to the specific strategy of any course (for example if it uses object oriented programming). An exercise may belong to more than one topic, as it should be classified in all topics necessary for its solution (for example "variables and operators", "conditional structures" and "repetition structures" if all of them are necessary to solve the problem). The topics dimension does not assume any relationship between exercises classified in the same topic in terms of complexity or relative order between them. For example, an exercise involving nested loops is normally more complex than another that uses only a simple loop, but they would both be classified in "repetition structures".

2) Complexity

In this dimension exercises can be classified considering its complexity in several parameters that may be configured by the teacher. In our work "algorithm complexity", "code complexity", "math complexity" and "cognitive effort" are considered. The first two deal with the complexity of the solution algorithm and the code that needs to be written. We decided to include the "math complexity" parameter because we often observed that student's difficulties were caused by the mathematical knowledge involved in the solution, and not in the algorithm itself [22]. The "cognitive effort" parameter aims to measure the overall difficulty of a problem, including its description complexity (in our experience sometimes students don't even understand what the problem is about). This dimension allows sorting exercises that belong to the same topic regarding its complexity in the above-defined criteria.

As our objective is essentially practical, the complexity of an exercise on any parameter is always defined in relative terms – a new exercise will be compared with one or more exercises already defined in the same parameter.

3) Levels

This dimension was thought to help in the classification of exercises by levels, following existing models. At the moment this dimension has two parameters, "Bloom's taxonomy" and "exercise level". The first allows the classification of an exercise in one of the levels of Bloom´s taxonomy, as it may be useful to use Bloom's taxonomy to set the next exercise to propose to a student and also to follow his/her evolution using this taxonomy levels. The "exercise level" parameter is intended to classify the exercise considering the type of student it addresses: beginner, intermediate or advanced (in the context of the level demanded in the course).

Fig. 1 shows the different classification that can be attributed to a particular exercise. It can be included in one or more topics, and classified in any of the complexity and levels parameters.

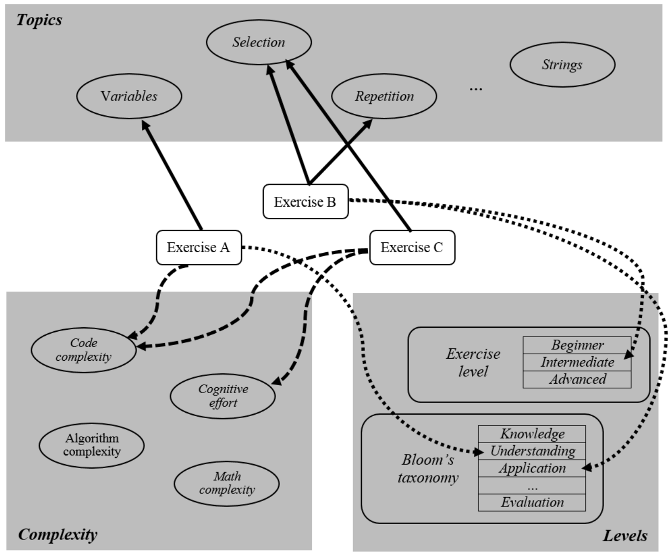

Fig. 1. Classification of exercises

C. Graph of exercises

The use of weights is very important in our approach, as they play a central role is establishing relations between exercises and in determining which one should be proposed next. The relation between exercises in a particular parameter is represented by a comparison-weighted graph.

The assignment of weights is made in comparison with the exercises previously classified and already present in the graph. When adding a new exercise to the graph it is not necessary to compare and classify it with all other exercises already present, but only to set a weight in comparison to an already existing exercise. The weight can be any integer value, positive or negative. A positive value represents that considering the represented parameter the exercise will be more difficult. A negative value represents an easier exercise, concerning the parameter in analysis. For example, considering the graph of Fig. 2, exercise A is easier than exercise B and exercise C is much more difficult than exercise B.

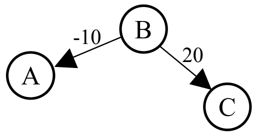

Fig. 2. Graph example

The edges are unidirectional and are defined taking into account the introduction order of the exercise. If exercise B already exists and we introduce exercise A, related with B, the direction is from B to A. In the example the weights used were multiples of 10, but other values may be used. The idea was to create a "gap" that allows posterior introduction of other exercises that are relatively easier or slightly more difficult -

for example we can use +5 or -5 to represent an exercise which is a little harder or a little easier, respectively.

Currently the assignment of weights is done manually. However we intend to create a semi-automatic mechanism that allows the assignment of weights to new exercises that are added to the graph. This tool is under development considering the "code complexity" parameter. The calculation of weight is made in two steps. First an absolute complexity score is calculated. Then the system looks in the graph for an exercise classified in the same topics having a score as close as possible. The new exercise is inserted in its neighborhood and the difference in scores is recorded. The calculation of the absolute complexity score is based on a solution for the problem introduced in the system. The code is analyzed and its data and control structures are identified. Each of them contributes to the exercise complexity score, taking into consideration its context. For example, a conditional structure may have a certain weight, but if it is inside a repetition structure its weight will be higher due to the added difficulty that this situation creates. To clarify, we may use the code in Fig. 3 as an example.

```
1:  if (x>10)
2:    x=10;
3:  for(i=0;i<10;i++)
4:    if (i>x)
5:      x=x+1;
```

Fig. 3. Code example

Considering that conditional structures have a difficulty of 5 and repetition structures a difficulty of 10, the exercise would receive 5 points for the condition in line 1 and 10 points for the repetition structure that begins in line 3. The conditional structure in line 4 receives a higher score, because it is located inside the loop. The value is calculated by multiplying a fraction of the weight of the repetition by the conditional value (5). Through a recursive mechanism it is possible to calculate a value that reflects the difficulty of each exercise.

IV. Taxonomy Application

As mentioned before, the overall objective of this work is to support the definition of individual learning paths, which might effectively help students to develop their programming skills. Of course learning depends on several factors, some of them difficult to control by the teacher. However, we think that to propose the right activities to the students in each moment is fundamental. This is especially true when students feel difficulties and it is necessary to give them other exercises, eventually slightly easier, but involving the same concepts. If there is a good set of exercises classified according to the taxonomy we propose this selection is easier and can even be automatic. In the above case, the new exercise should have been classified in the same topics, but having a lower score in some of the complexity parameters. If the student is able to define an appropriate algorithm but he/she is experiencing coding difficulties, the teacher (or an automatic system) can suggest an exercise that has a lower "coding complexity" score and identical scores in the remaining parameters.

Another approach that may be pedagogically interesting when a student feels difficulties with an exercise is to give him/her new exercises that are sub tasks of the original. If the student is able to solve them it is a good moment to stress the importance of proper planning and division of a problem in sub problems that might be easier to solve.

To test some of these ideas we designed an experiment that involved 44 students from the second programming course of the Computer Science degree of the Engineering Institute of Coimbra. During the first semester the students attended an introductory programming course, where they should have developed basic programming skills using the C programming language. In the experiment participated 13 students that didn't get approved in the first course. The degree regulations allow that students can attend the second programming course without having success in the first one. Although it is not very frequent sometimes some of these students manage to recover and get approved in the second course. Another 13 students in our sample were repeaters who had already get approved in the introductory programming course during the previous year.

The experiment consisted in proposing an exercise with some algorithmic complexity to the students. They were informed that there were several approaches and possible ways to solve the problem. They were also informed that the solution would not be given during the class, so they should try to solve the problem individually or in pairs. Teacher support would be available for doubts and difficulties they might experience. This recommendation tried to avoid a common student behavior: have a passive attitude in classes and just wait that the teacher gives the solution to pass it to their notebooks, many times without even understanding what they are writing.

The proposed exercise was:

It is intended to reduce an image to one quarter of its original size. The initial image is a two dimensional array with M × M integer values where each pixel can take a value between 0 and 9 (shades of gray). The reduced image is stored in a two dimensional array with M/2 × M/2 real values where each element (pixel) corresponds to the average of the 4 elements it replaces. For a better understanding of the statement see the example shown in Fig. 4 (in this case, for M=8):

Original matrix

0	4	9	3	6	7	2	9
9	4	7	8	3	4	7	2
5	1	2	6	3	8	6	2
7	1	4	8	7	2	0	7
4	9	3	5	2	1	5	7
5	3	4	7	8	9	1	0
2	3	5	6	7	9	2	4
2	3	4	5	6	7	8	9

Reduced matrix

4.25	6.75	5.00	5.00
3.50	5.00	5.00	3.75
5.25	4.75	5.00	3.25
2.50	5.0	7.25	5.75

Fig. 4. Matrix reduction

Write a C function to perform this operation. The function should take three arguments: address of the first element of the original array, address of the first element of the reduced array and the value M.

After the students had access to the exercise the teacher gave a generic explanation on the objectives of the exercise. Some time was given for students to start solving the problem, but only the best students were able to start doing it. The remaining students simply weren't able to try any possible way to reach a solution.

After about 10 minutes the teacher made an intervention. The students who were already solving the exercise were encouraged to continue their work in the same line. The other students received a sequence of simpler exercises where each was an evolution of the previous one. The goal was that, at the end of this sequence, the students would reach the solution of the original exercise.

The exercises / steps were:

1) Print all values in the array, row by row and column by column. For the example given, the sequence would be 0 4 9 3 6 7 2 9 9 4 7 8 3 4 7 2 5 1 2 6 3 5 6 7 8 ... 9

2) For the previous sequence, print only the values in the even rows and columns, one per line. For the example the sequence would be 0 9 6 2 ....

3) Note that the values printed in the previous step are the first element of each sample of the original exercise. Now print also the remaining values of each sample. For example: 0494 9378 67...

4) Add to the end of each line the average value of its values. For example: 0494 4,25 ...

5) Store each average value in the reduced matrix.

Although the students could initially solve the problem considering the dimension 8 (M = 8), the final solution should support any size of the original matrix. This was similar to previous class exercises where students had to create functions capable of processing arrays of different sizes. Students had the notion that they should index values using pointers to the first element of the matrices associated with an offset calculated based on the row number, column number and the number of columns per row.

The students didn't show any special difficulty solving the first step. A similar exercise had already been done before and they were able to do what was asked. Of course, each student progressed at his/her own pace, but they were all successful in this first step. All the students chose to use 2 nested loops, with two control variables ('i' and 'j'), and, inside them, a *printf* statement to print each value.

In the second step, every student immediately identified the need to increase the control variable of each loop by two. Here we noticed some problems related with the codification of the algorithm. The students that chose to implement using two 'for' structures only changed the third parameter, from something like 'i++' to 'i+2'. The teacher didn't tell what the error was. Instead, he asked each student to also print the value of the control variable. Students easily realized that the value was always the same, and that the increment statement was not doing what they expected. After this they changed the statement to something like "i=i+2" ("i += 2", "i++, i++", …).

Once again, in the third step, each student reached the solution at his/her own pace. The main difficulties were related with the need to index other values, applying some offset to the control variables without changing their values. Nevertheless, students were able to identify the necessary offsets ([i][j],[i][j+1],[i+1][j] and [i+1][j+1]). They needed some time to transform the identified offsets in a pointer arithmetic statement but didn't ask for help in this task.

The fourth step was completed with no student asking for any help. They were able to calculate the average and show the value.

The fifth step had the difficulty of identifying and calculating the coordinates in the reduced matrix. Some students realized that it was possible to increment the reduced matrix pointer. Other students needed some help to identify that a possible solution was to divide the indexers of the original matrix by 2. After this they concluded the exercise without problems.

In the end most students had the initial exercise solved and functioning as expected.

The few students who failed to solve the complete exercise were mostly those who previously lacked the minimum skills, students who had failed in the first introductory programming course, and were alone in the classroom (not in pairs). Although they were able to solve some steps within the time given, they were not able to complete all the tasks and, consequently, they were not able to solve the original exercise.

V. CONCLUSIONS

Learning to program is not an easy task for many students. It is not uncommon to find high dropout and failure rates in introductory programming courses. Although many reasons can contribute to this situation, we still believe that most students will be able to learn if an adequate support is provided.

The support necessary varies from student to student. Any experienced teacher has probably met students that learn programming easily, while others show deep difficulties even when they work and try to learn. Each student has his/her own learning rhythm and it is not wise to expect that all keep the same pace. This causes many difficulties to the teachers that have to deal with this heterogeneity in the context of large classes. In this situation it would be helpful to have a tool that might help to individualize the support given to a particular student. The work presented in this paper aims to be a contribution to the development of that tool.

A taxonomy of common introductory programming exercises is essential to the definition of individual learning paths. The classification of exercises under several perspectives allows a more adequate reaction in function of each student specific difficulties. More than insisting that the student should solve some problem or giving him/her the solution for it, it is more effective to propose different exercises, a little easier in some perspective, so that the student can improve skills and then be able to solve the original exercise.

Although we didn't mention the good students too often, the taxonomy can also help to define faster learning paths for those students, avoiding the boredom of being asked to solve many exercises that are too easy for their level.

This taxonomy can also help to promote student motivation creating an adequate balance between successes ("motivational stimulus") and failures ("positive errors") essential to a consolidated learning.

We are aware that the taxonomy will be more useful if there is a tool that uses it to automatically propose exercises to students. To have a more extensive set of exercises we are also considering following the technic used in *problets* [23], defining templates from which we can generate "new" and different exercises. That tool is currently under development at our research group.

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An Exploratory Survey on the Use of Computation in Undergraduate Engineering Education

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***Abstract*—Advances in computing contribute to science and engineering discovery, innovation, and education by facilitating representations, processing, storage, analysis, simulation, and visualization of unprecedented amounts of experimental and observational data to address problems that affect health, energy, environment, security, and quality of life. In spite of the emerging importance of the role of computing in engineering, a well-recognized shortage of scientists and engineers who are adequately prepared to take advantage of, or contribute to, such highly interdisciplinary, highly computational scientific challenges is evident. This exploratory study identifies how computation is integrated in the engineering disciplines at the undergraduate level. The research question is: *How engineering professors integrate computation as part of their disciplinary undergraduate courses?* This study reports anonymous survey responses of thirty-nine engineering and engineering technology faculty members who identified themselves as integrating computation as part of their undergraduate courses. Results indicate that most of the faculty members used computation for the solution of complex calculations, for conducting simulations, and for design purposes. Further research is required in order to identify and validate appropriated pedagogical practices to integrate computation as part of disciplinary courses.**

Keywords—computation, pedagogical methods, undergraduate education.

I. INTRODUCTION

Advances in computing contribute to science and engineering discovery, innovation, and education by facilitating representations, processing, storage, analysis, simulation, and visualization of unprecedented amounts of experimental and observational data to address problems that affect health, energy, environment, security, and quality of life. Therefore, promoting computing as both a fundamental knowledge and a technical skill becomes necessary in order to develop a workforce that identifies and implements optimal solutions and rapidly adapt in order to compete in our fast-changing, global society. [1-3]. In spite of the emerging importance of the role of computing in engineering, the well-recognized shortage of scientists and engineers adequately prepared to understand and contribute towards solutions that decidedly require computationally complex and interdisciplinary efforts is evident [4-6].

Professionals within the disciplines of science and engineering have emphasized the need for a new and modern approach to educating and training the next generation of researchers that will effectively complement experimental and theoretical approaches to address problems in science and engineering [e.g., 7-9]. Computational thinking, the problem solving method that engages solutions via computing techniques, is seen as a necessary companion to the approach. Computational thinking [10] integrates disciplinary knowledge with fundamental analytical skills needed by individuals entering the workforce to meet the increasing technologically driven demands.[11]. To address these challenges, we need to integrate computation in the curriculum sooner and often.

Computing contains various sub-disciplines such as computer science, computer engineering, software engineering, information systems, computer systems, and domain-specific applications [12]. This project focuses on the latter of these, namely domain-specific applications or discipline-based computing as we will refer to it here on forward. We define discipline-based computing as an interdisciplinary approach that integrates computational methods (e.g., numerical methods such as Euler and Krylov methods), tools (e.g., MATLAB, Mathematica, Mathcad, MapleSim), and practices (e.g., modeling and simulation) of computational science and engineering with disciplinary knowledge to (a) comprehend the behavior of complex systems or (b) to predict the behavior of new designs [13]. This exploratory study identifies how computation is integrated in the engineering disciplines at the undergraduate level. The research question is: *How engineering professors integrate computation as part of their disciplinary undergraduate courses?*

This study reports survey responses of thirty-nine engineering and engineering technology faculty members who identified themselves as integrating computation as part of their undergraduate courses.

II. THEORETICAL FRAMEWORK

Pedagogical Content Knowledge (PCK), first presented by Shulman (1986), is the theoretical framework that guided this investigation. PCK is a framework that describes how teachers transform their content knowledge into a structured knowledge to then be learned by their students. Such content knowledge is blended with pedagogical methods for learning purposes [14]. Several categories of teacher knowledge are derived from this framework, including Pedagogical Knowledge, Content Knowledge, and Pedagogical Content Knowledge.

Pedagogical Knowledge (PK) refers to knowledge about teaching methods and pedagogical strategies. Content Knowledge (CK) refers to concepts, procedures, and principles that belong to a specific subject. Finally, Pedagogical Content Knowledge (PCK) refers to "an amalgam of content and pedagogy unique to a subject matter teacher. The blending of content and pedagogy into an understanding that allows the teacher to more thoroughly understand how to present a topic" [14, 15]. The relevance of PCK lies in the ability of teachers or

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instructors to mix specific content with an adequate pedagogy for effective teaching. Some authors point out that a direct relationship exists between good teaching and good PCK [14].

To make PCK suitable for this context, the adaptation proposed by [16] was employed. This adaptation consisted of mapping how the assumptions about teacher knowledge can be adapted to expert (faculty) knowledge. Since PCK was originally designed to be used in science education, and as the respondents for this study were undergraduate engineering faculty members – as opposed to science teachers –, they can be described as content experts who do not necessarily have any pedagogical preparation. The second adaptation consisted of our own interpretation of each of the PCK constructs as applied to this specific context. CK was interpreted as the common types of disciplinary problems that faculty pose to students to solve using computation, and the software they use to attain this goal. PK was interpreted as the pedagogical and teaching methods used to introduce computation and the frequency of computation usage in the classroom. PCK was conceived as faculty descriptions of the role of computation into their engineering classroom and the most common learning outcomes instructors try to accomplish in their courses by means of computation.

Specifically in the context of engineering classrooms we have also investigated what are engineering instructors' Technological Pedagogical Content Knowledge (TPCK) for introducing computation and computational tools [17]. This research identified that participating instructors incorporated computation or computational tools for conceptual understanding while others integrated it with the goal of providing their students with computational techniques. Other instructors used a combination of both. We have also identified instructors' specific intended learning outcomes of using computation and computational tools in engineering contexts [18]. The following learning outcomes were identified: (a) To increase awareness of the potential role of computation in a particular field of science or engineering; (b) To measure materials or devices by collecting data as in a laboratory experiment; (c) To explain the cause-effect relationship of a given underlying model; (d) To test the accuracy of a given model and/or its computational implementation; (e) To validate the results or performance of the product of a design task; (f) To implement computational techniques/ methods in a modeling task. (g) To predict the results of an experiment in a design task. (h) To discriminate between different models/methods to represent a given physical phenomenon. These studies are useful because they can guide the design of learning objectives that can be turned into learning experiences

In this study we utilize PCK together with our own preliminary work on instructors' intended learning outcomes as a framework to identify how and for what purposes computation is being introduced into the undergraduate engineering classrooms.

III. METHODS

Baxter and Lederman [19] advocate multiple data collection techniques such as interviews and observation techniques, convergent and inferential techniques, visualization techniques and multi-method evaluation as effective data collection methods for identifying PCK constructs. We select a multiple-choice survey approach coupled with open ended questions to explore common approaches for integrating computation at the undergraduate level.

A. Participants, Procedures and Data Collection Method

Recruitment of participants was conducted through two different mechanisms: (1) the mailing list of the ASEE Engineering Technology Division with approximately 4000 members and (2) the mailing list of the ASEE Educational Research Methods Division with approximately 1300 members. An invitation announcement was conducted one single time through each of the above mentioned vehicles inviting faculty to participate.

A description of the purpose of the study was communicated followed by an invitation to participate in an online survey and asked to respond to a combination of nine multiple choice and open-ended questions. The URL to the survey was included and which is hosted on an online survey server. Once on the survey server, participants were provided instructions to the survey and reminded of the voluntariness and anonymous nature of the study. Then, participants were provided with the following definition of computation:

> *"Computation refers to the execution of an algorithm. Specifically in engineering computation may refer to the integration of computing algorithms and methods (e.g., numerical methods such as Euler and Krylov methods), tools (e.g., MATLAB, Mathematica, Mathcad, MapleSim), and practices (e.g., modeling and simulation) of computational science and engineering with disciplinary knowledge to (a) comprehend the behavior of complex systems or (b) predict the behavior of new designs.*

Then, participants responded the following questions:

1. Please give us a brief description of the engineering or engineering technology courses you teach at the undergraduate level in which you actually use computation. [Open-ended question]
2. What role does computation play in your teaching as part of the undergraduate courses you have described above? [Open-ended question].
3. What kind of computation software do you use in your teaching? [Options: MATLAB/Simulink, Mathematica, MapleSim, Mathcad, and Others].
4. In what form do you actually integrate computation into your undergraduate teaching? [Options: lectures, projects, homework assignments, laboratory practice, other].
5. How often do you use computation to accomplish the following learning outcomes in your undergraduate teaching? [Options: the eight proposed learning outcomes from [18] listed above].
6. How often do you have your students use computation to solve the following kinds of problems? [Options: never, rarely, occasionally, every once in a while, frequently]. (a)Satisfaction of constraints problems; (b) Minimization or optimization problems; (c) Mean-field or particle-based

dynamic systems; (d) Time-independent 1D spatial varying system; (e) Diffusion/ Electric field problems.

7. What are other typical engineering or engineering technology problems that you commonly couple with computation? [open-ended question]

8. Are there any other ideas or comments you would like to share with us about the role of computation in your teaching? [open-ended question]

Options of the multiple choice questions were derived from literature or through personal communications with four experts in computational science and engineering from materials, mechanical, civil, and electrical engineering disciplines.

Thirty nine engineering faculty voluntarily responded the full anonymous survey. Participants are from different universities and have taught at least one course in engineering or engineering technology at the undergraduate level. Most of them have experience teaching electrical, computer or mechanical engineering courses. Figure 1 shows the percentage for each disciplinary area of the courses in which participants integrated computation.

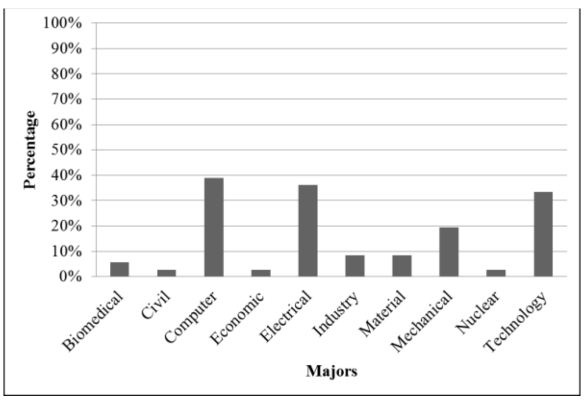

Fig. 1. Percentage of computation integrated in a course by participants vs course discipline

B. Scoring and Data Analysis.

We coupled qualitative with quantitative methods of inquiry for analyzing the data as follows.

Qualitative Data Analysis: The analysis of the open-ended questions was approached using a categorical analysis. To categorize the responses we used two main techniques called open-coding and axial-coding. During open-coding we conducted an initial level of abstraction in conceptualizing major ideas. Inter-rater reliability was conducted throughout the study. First, three researchers individually analyzed the responses to each question and then came together as a group to discuss findings. During axial-coding, we reconstructed the data to identify their explanations and relationships. This step consisted of organizing the categories and trying to find similarities. Finally, the number of occurrences for each category was counted.

Quantitative Data Analysis: Multiple choice questions related to employed pedagogical methods and software were normalized to describe the percentage for each option. Questions related to common learning outcomes and frequency of use of computation, were scored using a five-level Likert-scale. We denote the range from 0 to 4 to be the frequency of using computation. The corresponding five levels are: "never," "rarely (once or twice per semester)," "occasionally (once or twice per month)," "every once in a while (once or twice every other week)," and "frequently (more than once or twice a week)".

IV. Results

Here we present the analysis and results for each individual question. Our theoretical framework, PCK, is then reintroduced in the discussion section to facilitate the identification of themes.

A. How faculty identified the role of computation as part of their teaching of undergraduate courses?

Two themes were identified from the responses: “Activities” for integrating computation and “Learning Outcomes” associated with integrating computation.

Activities. Activities refer to actions or tasks carried out using computation through the learning process. Within this theme, the most popular role (n=19, 33.93%) was to solve complex calculations. Some of the statements that respondents used to justify its use were: *"Makes complex computations manageable"* or *"Simplification of calculations required to resolve voltages & currents in complex circuits"*

The next most commonly used activity among instructors’ responses was to represent phenomena (n= 9, 16.07%). The use of simulation tools into the classroom to represent real phenomena was broadly discussed both as an activity and as a learning outcome: *"I use these simulations to illustrate the effect of changing parameter values"*

Another use was to implement algorithms (n=8, 14.28%). Some examples of the algorithms or activities they performed when implementing algorithms include MATLAB use to execute Taylor or Newton Raphson algorithms as follows:

> *"We use MATLAB to execute algorithms such as Taylor series to estimate the sin or cos of an angle, Newton Raphson algorithm to solve a single equation in a single variable, and numerical estimates for derivatives and integrals based on sets of data such as estimating the velocity of an object based on position data"*

The fourth activity with high relevance for the respondents was the use of computation to support analysis processes (n=7, 12.50%). This activity is supported by comments whereby computation is used towards computer-aided analysis, automation of data analysis, and circuit analysis. Sample quotes include: *"Freshman level: computation to analyze data, compute statistics, perform least squares curve fit "*

The last two categories for activities identified were to solve real world problems (n=4, 7.14%) and to measure variables (n=3, 5.35%). Examples of quotes are: *"Students use MATLAB to write programs for solving the mechanical engineering problems"* and *“Students are shown the ways in which real engineers do their daily computation and documentation of it.”*

Learning Outcomes. Learning outcomes refer to learning performances that faculty members expect their students to learn or perform when using computation. This theme included five different categories. The most commonly mentioned learning outcomes were "to understand and create artifacts through the design process for specific problems" (n=10, 38.46%) and "to understand the behavior of the system by variation the parameters" (n=10, 38.46%). The first one is related to the design process. Some examples of how the respondents described this category are: *"Provides tools for upper level undergraduate studies and design work."* And *"students perform computation to automate design and analysis processes"* The second one is related to the use of simulation to understand how a phenomenon works. Some of the responses were: *"It is also used so that they can understand behavior by allowing them to change inputs and quickly see how outputs vary"* and *"Helps students understand behavior of systems."*

The next category is "to formulate, build and understand models" (n=3, 11.54%). The use of the word model/modeling was recurrent in responses like: *"I feel it is important to introduce the senior-level undergraduates to some computational modeling."* and *"I can show them how to work with each other in data gathering, data analysis, model building, and output analysis."*

The two remaining categories are, "to comprehend how computation can support time and money saving through automation and optimization" (n=2, 7.69%), and "to read and interpret a graph" (n=1, 3.85%): *"They learn how computation can save time and money and make the process of design easier, faster and more efficient."*

Finally, some of the respondents described the role of computation in terms of the relevance they perceive. Most of the respondents (n=9, 69.23%) believed that computation has a *central role* in their courses. Some others (n=3, 23.08%) gave it a *medium supporting role*, while one of them (n=1, 7.69%) thought that computation has a minor role when it is used to introduce senior-level undergraduates to some computational modeling.

B. *What are common learning outcomes associated with the use of computation for teaching and learning?*

Table I displays a descriptive analysis of a set of learning outcomes associated with the use of computation for teaching and learning. The results indicate that a small portion of the participants used learning outcomes different to those that were presented in the given options, but the variations for the frequencies of using computation are relatively large. Moreover, the most and least used learning outcomes are "to discriminate the differences between models and methods" and "to increase awareness of the potential role of computation in a particular field of science or engineering". As part of the "other" category, few respondents stated that they used computation software to introduce novice students to fundamental programming concepts and logical thinking.

C. *Which software do instructors use to introduce computation into their disciplinary courses?*

The options for the multiple choice question included MATLAB/Simulink, Mathematica, MapleSim and Mathcad. Almost fifty percent of the participants used MATLAB/Simulink as the computation software in their teaching. In addition, many respondents selected the "other" choice wherein they were additionally provided the opportunity to type in the tool name. Tools mentioned in this category included R, C++, Excel, Labview, Multisim, and calculator. Figure 2 presents the percentages of responses as related to software used by participants in their respective class (es).

TABLE I. FREQUENCY OF USE OF RELATED LEARNING OUTCOMES ASSOCIATED WITH COMPUTATION

Learning Outcome	**Never**	**Rarely**	**Occasionally**	**Once in a while**	**Frequently**
To increase awareness of the potential role of computation in a particular field of science or engineering (N=39)	n=20 51.28%	n=11 28.21%	n=5 12.82%	n=2 5.13%	n=1 2.56%
To measure materials or devices by collecting data as in a laboratory experiment (N=38)	n=6 15.79%	n=11 28.95%	n=7 18.42%	n=9 23.68%	n=5 13.16%
To explain the cause-effect relationship of a given underlying model (N=39)	n=10 25.64%	n=13 33.33%	n=11 28.21%	n=3 7.69%	n=2 5.13%
To test the accuracy of a given model and/or its computational implementation (N=39)	n=8 20.51%	n=11 28.21%	n=9 23.08%	n=9 23.08%	n=2 5.13%
To validate the results or performance of the product of a design task (N=38)	n=9 23.68%	n=9 23.68%	n=10 26.32%	n=4 10.53%	n=6 15.79%
To implement computational techniques/ methods in a modeling task (N=38)	n=8 21.05%	n=15 39.47%	n=4 10.53%	n=5 13.16%	n=6 15.79%
To predict the results of an experiment in a design task (N=39)	n=6 15.38%	n=9 23.08%	n=10 25.64%	n=8 20.51%	n=6 15.38%
To discriminate between different models/methods to represent a given physical phenomenon (N=37)	n=7 18.92%	n=8 21.62%	n=7 18.92%	n=6 16.22%	n=9 24.32%
Others (N=8)	n=2 25%	n=0 0%	n=1 12.5%	n=0 0%	n=5 62.5%

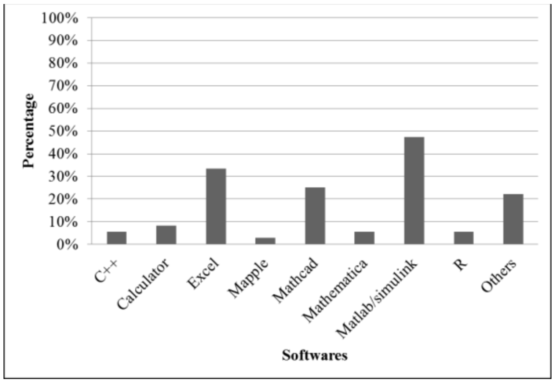

Fig. 2. Percentagesof a given software used by participants in their class(es)

D. What pedagogical methods and delivery mechanisms do participants integrate when teaching?

In Figure 3, the frequencies of the most common pedagogical methods and delivery mechanisms are shown. Lecture, projects, homework assignments and laboratory practice were most commonly used ways to introduce computation within disciplinary courses. In addition, homework assignments were the most commonly used form of integrating computation. Other forms including laboratory reports, exams and class demonstrations were also mentioned in the "other" category.

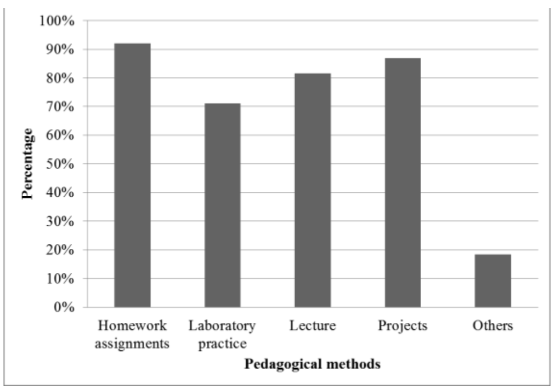

Fig. 3. Percentage of various pedagogical methods and delivery mechanisms employed by the collective set of participants

E. What is the frequency of use of computation in related assignments?

Table II demonstrates the frequency of use of computation in related assignments. It illustrates that computation was usually used in solving mean-field or particle-based dynamic systems, diffusion/electric field problems, and time-independent 1D spatial varying system problems. Problems such as energy and efficiency, physical construction, circuit analysis/design were also mentioned in the "other" category.

F. What are the most common types of engineering problems that can be solved with computation?

In examining the participants' responses, three themes emerged and are classified as: (1) Specific Application; (2) Specific Approach; and (3) Context.

Specific Application. Specific application can be defined as specific problem areas instructors focused on to solve with computation. Within the identified categories the most recurrent problem was described in multiple contexts of engineering design (n=12, 42.86%). Design of steel, concrete, wood, amplifiers, and circuits represented the most commonly used problems for this theme.

TABLE II. FREQUENCY OF USE OF COMPUTATION RELATED ASSIGNMENTS

Related Assignment	Never	Rarely	Occasionally	Once in a while	Frequently
Satisfaction of constraints problems (either chemical or mechanical) (N=38)	n=8 21.05 %	n=9 23.68 %	n=4 10.53%	n=8 21.05%	n=9 23.68%
Minimization or optimization problems (N=38)	n=3 7.89%	n=10 26.32 %	n=6 15.79%	n=10 26.32%	n=9 23.68%
Mean-field or particle-based dynamic systems (N=38)	n=2 5.26%	n=3 7.89%	n=2 5.26%	n=5 13.16%	n=26 68.42%
Time-independent 1D spatial varying system (N=38)	n=2 5.26%	n=5 13.16 %	n=7 18.42%	n=7 18.42%	n=17 44.74%
Diffusion/ Electric field problems (N=37)	n=2 5.41%	n=6 16.22 %	n=3 8.11%	n=3 8.11%	n=23 62.16%
Others (N=16)	n=5 31.25 %	n=5 31.25 %	n=1 6.25%	n=0 0%	n=5 31.25%

The next most common type of problem is automatic control (n=5, 17.86%). Some of the related responses are: "*project control problems*", "*control systems*" or "*automatic control theory*". The remaining categories are mostly broad, focusing on topics such as: statics (n=3, 10.71%); dynamics (n=2, 7.14%); strength of materials (n=2, 7.14%); electronic (n=2, 7.14%); mechatronics (n=1, 3.57%); and nuclear reactor theory (n=1, 3.57%).

Specific Approach. Specific approach refers to problems viewed as specific task to be accomplished by students using computation. The most commonly used approaches were to do simulations (n=6, 35.29%) and to solve calculations (n=3, 17.65%). They were described in statements like: *"Finding roots of equation having orders higher than 2. Laplace transform and analyzing system's behavior to a particular input signal."*

Data representation (n=2, 11.76%) was also highlighted as an important approach. Samples of quotes include: *"Plotting of experimental data vs. prediction equation"* or *"curve fitting, interpolation, presenting data graphically."* The rest of the categories were for programming (n=1, 5.88%), data collection (n=1, 5.88%), calibration of instruments (n=1, 5.88%), iterative design/analysis (n=1, 5.88%), and error analysis (n=1, 5.88%).

Context. Context can be defined as the situation of the problem in a given setting, time or space. Three categories were identified within this theme. The most common context for the problems was referred to as "real world problems" (n=6, 66.67%). Samples of responses into this category were:

"Problems that come up from their work place." Some other respondents mentioned other types of contexts for the problems such as capstone courses (n=2, 22.22%) and senior projects (n=1, 11.11%).

G. Additional Comments

We also invited the participants to offer any additional ideas or comments. Highlights from these include some of the already described uses for computation (e.g., solve calculations and do simulation), statements that emphasize the relevancy of computation, and descriptions of the difficulty of coupling disciplinary content with programming.

> *"Many of our students express being overwhelmed with the learning curve involved with learning to program...so, some students complain that they are being forced into a comp. sci. role, but their major is m.e., b.m.e., m.j.e., etc. They don't realize that all engineers may be expected to do programming at some time or another."* And *"Programming is a difficult topic to teach freshmen but I believe they benefit from the experience. It is one of their first steps toward becoming problem solvers."*

V. Discussion

In this section we discuss each question under the three categories of the Pedagogical Content Knowledge framework.

A. Pedagogical Knowledge

The main themes that emerged from the responses related to PK were: pedagogical methods, delivery mechanisms, and frequency of use in related assignments in which computation was used. The most common ways for having students apply computation were in homework assignments, project development, and laboratory practice. These results suggest a predominance of computation performed by the student was during independent work. The use of lectures and class demonstrations was the most commonly used way for presenting computation. The most frequently used computation related assignment type involved contextualizing problems in dynamic systems whereby students used simulation tools to inform the solution to their problem.

Additionally, most of the identified types of problems (e.g., minimization or optimization problems) showed an average frequency of use higher than 50% and only a small portion of the faculty members never use them. This suggests that all these related assignments are relevant for their disciplines. However, it is not easy to make a distinction for frequency of use due to the high difference among such frequencies.

B. Content Knowledge

Design process applied to real world settings appears to be the most common approach for integrating computation into disciplinary courses. These processes typically involve solving complex calculations and the use of simulations. Among these types of assignments the most commonly used software packages were MATLAB/Simulink and Mathcad. This finding can be compared with the described activities and frequent problems and contexts identified. These tools seem to be appropriate for representation, simulation purposes, and for the solution of complex calculations.

C. Pedagogical Content Knowledge

The identified PCK can be associated with participants' descriptions of the role of computation in disciplinary courses in terms of the activities they implemented. Within the identified activities, it is important to highlight that most of the described activities were related to either tasks that can help students make efficient use of their time and make complex systems manageable. For instance, solving complex equations through computation instead of solving them manually was frequently described as one way to save time. Many respondents also expressed used computation to teach students about programming or supporting computer-aided analysis. Alternatively, some of the instructors used these activities in an integrative way – an inquiry process of several stages: data collection, data analysis, modeling and validation.

The learning outcomes identified can be roughly aligned with learning categories depicted in the Revised Bloom's Taxonomy [20]. As explained in Magana et al., [18], the mapping of the intended learning outcomes indicated on how far engineering instructors wanted their students to achieve certain learning outcomes. For example, both "to understand and create artifacts through the design process for specific problems" and "to understand the behavior of a system by variation of parameters" can be equally balanced between the Conceptual and the Procedural Knowledge within the Knowledge Dimension of Bloom's Taxonomy. In this context, students may not only have to understand how something works (either design process or phenomenon) but they may have to interact at some level with it. The difference between these two learning objectives can be established at the level of interaction. While the one objective is related to the use of simulation for understanding given phenomena (Understand Level in Bloom's Taxonomy), the learning outcome related to the design process actually expects students to create a design or an artifact (Create Level in Bloom's Taxonomy).

VI. Implications for Instruction

Disciplines wherein respondents suggested they readily integrated computation are Computer Engineering, Electrical Engineering, and various Engineering Technology disciplines. Results suggest most common applications for integrating computation include automating solving complex calculations to arrive at a solution faster and more accurately, for conducting modeling and simulation, and for design purposes. Although respondents established a central role for computation into their courses, there was no strong evidence to suggest any use of computation at a deeper level or in alternative meaningful contexts such as inquiry learning or design. Considering the most frequent pedagogical methods identified, it seems students primarily engage in computing assignments as part of individual work. This process of individual work may be overwhelming for students. This is consistent with findings from Magana et al., [13] where they found that coupling computation with disciplinary knowledge is challenging for students.

Pedagogies that support a smooth integration of computation with disciplinary knowledge from a learning standpoint include implementing inverted classroom pedagogies. For example, a student comes to class having already watched the online lecture, which is available for them to watch at their convenience. During class, informed by their understanding and reflection of the lecture, perform computation in the classroom having the added benefit of learning deeper understanding from faculty and teaching assistants as well as their peers when working on group projects. Pair programming [21] is another viable pedagogy shown to have multiple benefits such as greater likelihood of students' success at course completion, their increased confidence in programming abilities, and increased participation of female and minority students when applied to computing courses [21,22].

We also advocate the use of online scaffolding to support individual work. For instance, the use of worked examples has been commonly used in the field of computer science. Worked examples are composed by a problem statement, a sequence of steps to solution and a given solution. These set of tools, usually given with a similar problem statement, allow decreasing the cognitive load by facilitating the acquisition of a certain cognitive skill [23].

VII. Conclusions and Future Work

Computation is a required skill in modern engineering; however, integrating computation with disciplinary knowledge may pose some challenges for instructors and students. Progress is being made by integrating software for scientific computation that can facilitate the solution of complex calculations, the design of processes or artifacts and understanding of complex phenomena. Suggested pedagogical methods and strategies that can support the integration of computation for teaching and learning include flipped classroom, paired programming and worked examples.

The limitations of the study relate to the small sample size. We do not know if participants who chose not to respond did so because either they decided not to participate (among many reasons) or because they are not integrating computation at the undergraduate level. However, we believe that identifying, describing and documenting how other instructors are integrating computation can be an initial fruitful endeavor to identify benefits and challenges for integrating computation with disciplinary knowledge and potential ways to overcome the latter one. Therefore, future work will consists of conducting in-depth case studies that can bring more light into the ways computation can be integrated more effectively at the undergraduate level, challenges that instructors and students face and the effectiveness of the suggested pedagogical strategies in facilitating and supporting this integration.

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An Empirical Study on the Estimation of Software Development Effort with Use Case Points

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***Abstract*—Empirical studies are important in software engineering to evaluate new tools, techniques, methods and technologies in a structured way before they are introduced in the industrial (real) software process. Perform empirical studies in a real context is very difficult due to various obstacles, so, we intend to create a stable environment that allows us to perform reliably empirical studies with students. This paper describes a case study with 104 students grouped in seven teams that developed a software system (Web application) for a real costumer. In this study we used a model based on Use Case Points (UCP) to estimate the resources needed to develop a software system.**

Keywords—empirical studies; software engineering management; software engineering process; software quality; use case models; use case points.

I. INTRODUCTION

Empirical studies in software engineering have had a significant role in the evaluation of tools, techniques, methods and technologies before they introduced in industrial software. In the early nineties, Basili introduced, for the first time, the concept of *experience factory* [1]. These authors developed an organizational schema for collecting experiences on reuse of empirical results, for analysing them and generalizing the knowledge contained [2]. This scheme was designed based on many years of the Software Engineering Laboratory (SEL) work. Empirical studies developed within the SEL involved students from different USA universities and industry partners.

With our approach we do not intend to create a new SEL. Instead, we intend to create a space (virtual or physical) that allows us to conduct empirical studies in the software engineering area by involving students that are enrolled in our current software engineering courses (both at undergraduate and postgraduate university programmes).

To ensure compliance, in terms of cost, schedule and quality of an IT (Information and Technology) project is important to estimate the total amount of resources early in developing process. Currently, there are several methods to estimate the resources needed to develop a software system. For this propose, in our research we find *Function Points* (FP) [3], *Use Case Points* (UCP) [4] and LOC (*Lines of Code*) methods.

In our empirical study we used graduate and undergraduate students that were randomized grouped in seven teams to develop a software system. We applied the original UCP method for estimate the effort needed to develop the software system of each one teams.

Our final goal of carrying out empirical studies with students is to understand its validity when compared with the corresponding studies in real industrial settings. We intend to answer if it is adequate to use students as subjects in empirical studies? What is the better way to involve students as subjects in order to obtain valid results? Can we use the results with student in real context?

In this paper, a description of Empirical Software Engineering (ESE) using students versus professionals as subject is presented in Section 2. Section 3 describes related work with *Function Points*, *Use Case Points* and LOC (*Lines of Code*) methods. In Section 4, we present in detail the original *Use Case Points* method that we use in the next section. In section 5 we briefly describe the case study we have developed to initially assess the effectiveness of using UCP method in educational context. Finally, in Section 6 we present the conclusions and future work.

II. ESE USING STUDENTS VERSUS PROFESSIONALS

In this section, based on literature review we describe the strengths/weaknesses of using students versus professionals in the empirical software engineering context.

In the survey conducted in [5], a total of 5,488 subjects took part in the 113 experiments investigated, eighty-seven percent were students and nine percent were professionals. This survey demonstrates the importance of using students in this context.

In many studies, students are used instead of professional software developers, although the objective is to draw conclusions valid for professional software developers. The differences are only minor, and it is concluded that software engineering students may be used instead of professional software developers under certain conditions. Höst et al. have a paper where the performance of software engineering students in empirical studies is discussed and evaluated [6]. The authors emphasize two main reasons for performing this kind of studies. First, it may serve as a measure of the quality of education. A large difference in performance between professional software developers in industry and students in their last year at the university may imply that the persons leaving the university need experience and training before they are able to fully contribute. A second reason for studying the differences between students and professionals is that many empirical studies in software engineering research rely on students as subjects, although attempting to generalize the findings to professional software developers [6]. Höst et al. argue that the main reason to use students as subjects is often that they are available at universities and they are willing to participate in studies as part of courses they attend. In many cases, it is possible to combine the learning objectives of the courses with the research objectives of the studies.

Tichy refer that software graduate students are so close to professional status that the differences are marginal. The author also refer that this students are technically more up to date than the "average" software developer who may not even have a degree in computing. About software professionals, Ticky refers that they may be better prepared in the application domain and may have learnt to deal with systems and organizations of larger scale than a student. The author also argues that a theory is provisionally accepted only if it has been tested in at least two experiments by independent groups and the empirical work have a main role in this issue [7]. In educational context, we can do empirical work with students from different courses, schools and regions. Later, if possible, we can reply these experiments in industrial context.

Sjøberg et al. argue that the main reason of most subjects in software engineering experiments are students is that they are more accessible and easier to organize, and hiring them is generally inexpensive. Consequently, it is easier to run an experiment with students than with professionals and the risks are low. However, authors refer that the discussion in the software engineering community about students versus professionals seems over-simplified [8].

Jaccheri et al. refer that empirical studies are often carried out with students because they are viewed as inexpensive subjects for pilot studies. The authors also argue that, at any rate, the final goal of carrying out empirical studies with students is performing empirical studies in industrial organizations and establishing collaborations with them [9].

Svahnberg et al. refer that the students are readily available, often willing to participate, and require no or little compensation. They conducted a study where they found out that students are able to both have a personal view and express their opinion about the way it works in industry. This study was about requirement selection task where students must select which requirement that should go into a specific release of a system [10].

Carver et al. have developed a checklist that provides guidance for researchers and educators when planning and conducting studies in university courses. Initially, the authors identified the requirements that research and pedagogy place on a valid empirical study with students and after, they used this information as the basis for develop that checklist [11].

III. EFFORT ESTIMATION METHODS

There are great efforts and contributions to measure the size of a software system and estimate the effort needed to develop it. Measuring the size of a software system is different to estimate the effort needed to develop it. The first is an activity that estimates a probability of a software system size in a measurement unit while the second estimates the effort required to developing it. The relationship between the size of a software system and effort required to develop it is given by the productivity of the software development team.

Metrics are measurement methodologies whose main objective is to estimate the size of software system and assist, as an indicator, the project management of software system development. The estimated size is one of the most commonly used metrics for software size, since has direct impact on development effort and project management. It is an indicator of the amount of work to be performed and this kind of knowledge can be used to help us to estimate the cost and the lead time for the project [4]. According to Pressman, measurement enables managers to plan, monitor, improve and enhance the software process development [12].

Estimating the size of a software system is a critical development process activity. Not only does size impact the technical solution; it also impacts the project management solution [13].

The size of the software system means the amount of work to be performed in a project development. Each project can be estimated according to the physical size (which is measured through the requirements specification, analysis, construction and testing); based on the functions that the user gets, in the complexity of the problem that the software system will solve and in the reusability of the project, which measures how much the product will be copied or modified from another existing product [14] [15].

Currently, there are several metrics of size estimation and it is difficult to select the most appropriate for the size of a software project in an organization. The main metrics were developed based on the software functions such as: *Function Points* [16], *Bang* [17], *Feature Points* [18], *Boeing' s 3D Function Points* [19], *Mark II* [20], *Use Case Points* [4], *COSMIC Full Function Points* [21].

A. LOC (Lines of Code)

The first metrics of software size estimation emerged in mid-1960's, although the first dedicated book on software metrics was not published until 1976 [22]. These metrics were based on the physical size of *Lines of Code* (LOC) and were used as the basis for "measuring programming productivity and effort" [14]. This metric considers the software from the perspective of the internal structure and is applied in the final stages of the software project [23].

Ross highlights two advantages of using LOC method: 1) the possibility to estimate automatically, and 2) the ease of using historical data because most of the existing data about estimation were measured by LOC method. The disadvantages are related to ambiguity, because the metric becomes ambiguous when dealing with non-textual abstractions and the lack of significance of the measure to the end user (costumer) [13]. Besides these disadvantages Fenton and Pfleeger note that a count in LOC depends on the degree of code reusing and the programming language and can be five times higher than another estimate, due to differences in techniques of measurement of blank lines, comment lines, data declaration and statements [15]. The authors also emphasize that the LOC method penalizes small and well-designed programs, it is not adequate to non-procedural programming languages and is difficult to obtain in the early planning stages of development of a software system [15].

LOC method was a metric widely used until mid-1970. From there emerged various programming languages and consequently the need for other ways to estimate the size of software.

B. Function Points

The *Function Points* (FP) is one of the first metrics to measure the size of software with some precision. It is the most used in the industry and became an international standard in 2002 through the ISO/IEC 20926 [24]. Currently, the mapping of the *Function Points* method to estimate object oriented software projects has been widely discussed in the literature.

Function Points method was developed in the mid 70's and published in 1979 by Allan Albrecht in an attempt to minimize the difficulties associated with lines of code as a measure of software size, and to assist in generating a mechanism that could predict the effort associated with software development [3, 25]. The first version of *Function Points* aimed to be applied early in the software development process, to be related to economic productivity and to be independent of the source code or programming language.

In 1984, Allan Albrecht refined this version and later, with the increased use of the *Function Points* method, it became necessary to define a guide to interpret the original rules for new environments. Due to this need, in 1986 was created the *International Function Point Users Group* (IFPUG) [26]. From this date, the IFPUG became responsible for defining the counting rules, the training and certification of professionals interested in the application of this metric and dissemination of several historical databases of productivity of software development in industry, provided by various agencies, including the *International Software Benchmarking Group* [27]. This information enables the estimation of development time for new software projects and team productivity based on previous estimates made by the *Function Points* method [25, 28]. The *Function Points* has become the most widely used and studied metric in the history of software engineering and in late 1993 had groups of users in 18 countries [29].

The *Function Points* method aims to establish a measure of "size" of software in function points (unit of measure for software as well as the hour is unit of measurement for time), by quantifying the functions implemented from the point of view of user in a business focus and not in technical focus [25]. As the basic principle, this metric focus on requirements specification to obtain estimates of time, cost, effort and resources in early phase of software development process independently of the technology used for their implementation [30]. It provides a count indicative early in software development process without knowing details of the data model. Later in the software development process, this count becomes more accurate estimate of the complexity of functions and, at the end of software development (in the implementation phase), a detailed count is performed, obtained from the degree of complexity of the functions raised in the functional process, data model, description of the screens and reports [25, 26].

In general, organizations apply the *Function Points* as "a method for determining the size of the software package purchased; to support the analysis of productivity and quality; to estimate the costs, resources and efforts of development projects and maintenance of software" [28]. In addition to these purposes, Longstreet highlights other utilities of *Function Points* method: "define when and where to make reengineering; estimate test cases; understand the increase of scope; assist in contract negotiations; develop a standard set of metrics; and make benchmark of software" [25].

C. Use Case Points

The *Use Case Points* (UCP) metric was defined to estimate Object Oriented (OO) projects based on the same philosophy of *Function Points* and in the process "*Objectory*", where the use case concept was developed. Later, Ivar Jacobson developed "*Object-Oriented Software Engineering (OOSE)*", methodology based in use cases, a technique widely used in industry to describe and collect the functional requirements of the software. Considering that the use cases model was developed to collect the requirements based on use and users vision, it makes sense to base the estimation of size and resources of software projects in use cases [31].

Since the UCP method was selected to perform the empirical study with the students, next we present the relevant characteristics and the counting process of this method.

IV. USE CASE POINTS METHOD

The first description of the method was published by Gustav Karner [4] with the aim of creating a model that would allow estimating the resources required to develop a software system under *Objectory AB* (later acquired by Rational Software). Its influences came from the classic

Function Point method. However, after the original work, the author has not done any further publication or justified aspects of the conception of the method, thus it was being applied and adapted according to the circumstances. The method consists in calculating a metric called *Use Case Points* that give us an estimation of the size and complexity of a software project. If we know the development team productivity (to be obtained based on previous projects), we can derive an estimate of the effort required to develop the software project.

The UCPs are related to functional, technical and environmental complexity of the software project, namely the following aspects:

- The number and complexity of the actors and use cases in the system;
- Several non-functional requirements with impact on the project (e.g. performance, usability, reliability, etc.);
- The impact of the environment where the project is developed.

When applying the method, we must first calculate the complexity of actors and use cases in the system to quantify the variables *Unadjusted Actor Weight* (UAW) and *Unadjusted Use Case Weight* (UUCW), respectively. When combined with their weight, we obtain an inadequate measure of the size and complexity of the system called *Unadjusted called Use Case Points* (UUCP). The next step is to adjust this measure with a number of technical factors and environmental factors given by *Technical Complexity factor* (TCF) and *Environmental Factor* (EF) variables, respectively. These factors combined with the UUCP variable will produce the effective number of UCPs that reflect the size and complexity of the software project. In the following subsections we detail the steps needed to calculate the UCPs.

A. Unadjusted Actor Weight (UAW)

An actor is an entity that interacts with the system to achieve its goals: a person, a machine, a software application, etc. Thus, to capture these differences, each actor is classified as *simple*, *average* or *complex* and each actor type is associated with a weight as shown in Table I.

TABLE I. COMPLEXITY OF ACTORS

Category	Example	Weight
Simple	An external system through an API (Application Programming Interface)	1
Average	A user who interacts with the system through a command line	2
Complex	A user who interacts with the system through a Graphical User Interface (GUI)	3

Although we believe that a GUI is more complex than a command line or API, there are no published studies that justify this aspect [32]. The complexity of the actors in the system is given by the *Unadjusted Actor Weight* (UAW) variable, and is calculated by the sum of the products between the actors in each category with their associated weights.

B. Unadjusted Use Case Weight (UUCW)

A use case is a story about how users interact with the system to achieve their goals. There are several ways to write a use case, however, to avoid that the measurement of the number of UCPs of the software project is not affected, all use cases of the system must be written with the same level of detail. The user-objectives oriented approach described in [33] is suitable for apply the method.

Such as actors are classified according to their complexity, the use cases are also classified as *simple*, *average* or *complex* through the number of transactions containing the main course of success and alternative courses, as shown in Table II.

TABLE II. COMPLEXITY OF USE CASES

Category	Number of transactions	Weight
Simple	3 or less	5
Average	4 to 7	10
Complex	More than 7	15

It is noted that a transaction cannot be a step in the courses of use cases. Ivar Jacobson (the use cases author) defines a transaction as an action triggered by the user to which the system reacts and presents the results of its processing [34].

To calculate the *Unadjusted Use Case Weight* (UUCW) variable, each use case must be classified according to its category and the corresponding weight must be multiplied by the number of use cases the systems possesses of each category.

C. Unadjusted Use Case Points (UUCP)

After calculating the complexity of actors and use cases of the system, the respective variables must be combined to determine an estimation of the *Unadjusted Use Case Points* (UUCP). UUCP is considered an unadjusted estimation because it will be adjusted by a set of technical and environmental factors to calculate the effective value of the UCPs of the software project. The calculation of UUCP uses the following equation:

$$UUCP = UAW + UUCW \qquad (1)$$

D. Technical Complexity Factor (TCF)

The size of the software system does not depend only on its functions and the users it serves. It also depends on the quality characteristics of the system. Therefore, there is a number of technical or non-functional factors that must be considered to measure the size of the system based on what was agreed between the costumer and the supplier. A list describing all technical factors proposed by Karner is shown in Table III [4].

The impact of each factor within the project is rated on a scale 0, 1, 2, 3, 4 and 5, where 0 means that it is irrelevant and 5 means it is essential. If the factor is neither important nor irrelevant it must be rated with the value of 3. The rate of the factor must be multiplied by the associated weight as shown in Table III. The sum of all the products calculates the

TFactor value, which is used to calculate the *Technical Complexity Factor* (TCF):

$$TCF = 0.6 + (0.01 \text{ x } TFactor) \quad (2)$$

Karner based the constants 0.6 and 0.01 on the adjustment factors of *Function Points* created by Albrecht [3]. For example, for a given system with a *TFactor* equal to 42, the TCF is:

$$TCF = 0.6 + (0.01 \text{ x } 42) = 1.02 \quad (3)$$

TABLE III. *TECHNICAL FACTORS* CONTRIBUTING TO COMPLEXITY

Factor	Description	Weight
T1	Distributed systems	2
T2	Performance	2
T3	Efficiency	1
T4	Complex internal processing	1
T5	Code reusability	1
T6	Installation ease	0.5
T7	Usability	0.5
T8	Portability	2
T9	Changeability	1
T10	Concurrency	1
T11	Security	1
T12	Accessibility of others	1
T13	Training	1

E. Environmental Factor (EF)

The characterization of the software development teams is also important to obtain a measure of the size and complexity of the software project; thus there is a set of aspects related to the development environment that must be weighed. The levels of the motivation of the team or the familiarity with the software process development adopted are examples of environmental factors that must be taken into account on the calculation of the UCP value. A list describing all environmental factors proposed by Karner is shown in Table IV [4].

The impact of each factor within the project is rated on a scale 0, 1, 2, 3, 4 and 5, where 0 means that it is irrelevant and 5 means it is essential. If the factor is neither important nor irrelevant it must be rated with the value of 3. The rate of the factor must be multiplied by the associated weight as shown in Table IV. The sum of all the products calculates the *EFactor* value, which is used to calculate the *Environmental Factor* (EF):

$$EF = 1.4 + (-0.03 \text{ x } EFactor) \quad (4)$$

TABLE IV. *ENVIRONMENTAL FACTORS* CONTRIBUTING TO EFFICIENCY

Factor	Description	Weight
E1	Experience with a software development process	1.5
E2	Development experience with similar projects	0.5
E3	Experience with OOP	1
E4	Maturity in OO analysis	0.5
E5	Motivation	1
E6	Stability of requirements	2
E7	Part time workers	-1
E8	Experience with technologies adopted	-1

For example, for a given system with an *EFactor* equal to 17.5, the EF is:

$$EF = 1.4 + (-0.03 \text{ x } 17.5) = 1.+ (-0.51) = 0.89 \quad (5)$$

F. Use Case Points (UCP)

Finally, after calculating the above variables shown in the previous subsections, the last step is to calculate the effective number of UCPs of the system using the following equation:

$$UCP = UUCP \text{ x } TCF \text{ x } EF \quad (6)$$

If the team productivity is known, the UCP value can be used to estimate the effort required to develop a software system. According to Karner, each UCP corresponds to 20 hours of work [4].

V. CASE STUDY

Based on the previously described approach for calculating the UCP, a case study was developed to determine the productivity of some student software development teams.

The teams were constituted by second year students of the course 8604N5 Software System Development (SSD) from the undergraduate degree in Information Systems and Technology in University of XXX (the first University to offer in XXXX DEng, MSc and PhD degrees in Computing). The teams had between 10 and 17 people (1 team with 10, 1 team with 14, 1 team with 15, 3 teams with 16 and 1 with 17). Each team receives an sequential identification number (Team 1, Team 2, .., Team 7) and the description of the customer problem.

The teams developed a software project of medium complexity, using the *Unified Modeling Language* (UML) notation encompassed in an iterative and incremental software development process, in this case, the *Rational Unified Process* (RUP). The teams followed the guidelines established by the RUP reduced model [35, 36], executing the phases of inception, elaboration and construction according to the best practices suggested by CMMI-DEV v1.2 ML2. The project lasted 3 months. This software project was to develop a Web solution using object-oriented technologies and relational databases, to support the information system of one local costumer that provided all the information about the organization and interacted directly with the teams.

The main goal of case study was to calculate the productivity of the teams in hours/man per UCP, based on the size of each software project and in effort reported by each team. To determine the teams productivity, we have used the following equation:

$$Productivity = Effort[h] / Size[UCP] \quad (7)$$

The measurement of the functional size expressed by UUCP metric was based on the latest version of the use case model that developed by each team. Each team has chosen a different number of components to develop. The quality attributes and restrictions were also different for each team. These differences had considerable impact on the calculation of the TCF. For reasons of space is not shown the table with the weights of technical factors assigned to each of the teams. Table V presents the weight of environmental factors across all teams.

To calculate the team' s productivity we have used the real effort that each team reported to develop the software system. This effort involved hours spent within the project, as well as attending lectures related with the SSD course.

TABLE V. WEIGHT OF ENVIRONMENTAL FACTORS ON TEAMS

Description	Weight
Experience with RUP	3
Development experience with similar projects	0
Experience with OOP	3
Maturity in OO analysis	1
Motivation	3
Stability of requirements	3
Part time workers	1
Experience with technologies	3

Table VI presents the metrics collected from each development team. From this table we can conclude that the productivity factors of the teams vary between 5,6 hours to 12,2 hours per UCP. On average, the productivity factor per team is 9,36 hours per UCP. These results are directly related to the total effort accomplished in hours and the size of projects measured in UCPs.

In general, teams with more elements reported more effort. Normally, we tend to assume that the size of projects in UCPs is proportional to the functional size. However, this did not happen to all teams, as seen in Fig. 1.

This discrepancy occurs primarily for two reasons. The first indicates that the teams with more members (and reporting more effort) give more emphasis on documentation tasks (mainly the writing of reports). The other reason is due to the quality of artifacts (mainly the use case models) that are limited by the reduced experience of the teams in requirements specification. We could observe in all teams, use cases with poor quality, leading to a subjective interpretation to identify transactions in the main and alternative courses. Additionally, the majority of the use cases were classified as *simple* according the UCP method because it had few transactions.

Based on the costumer assessment, the teams with the highest software project size in UCPs had the best results, especially teams Team4, Team3 and Team7 (with the exception of the Team6). Finally, it was also found that the use case models of these teams were superior to the others.

VI. CONCLUSIONS

In the empirical study, the average productivity of the teams was based on the size of the software projects in UCPs and in total effort made throughout the all phases of the software project development. We believe that the average productivity could be used in future situations: (1) in the business planning phase of the project within the Software Process and Methodologies (SPM) course (first semester) to estimate the development effort of the project to implement in the SSD course (second semester); (2) during the implementation phase for control purposes, to calibrate the effort of every moment of the project. The results could also be packaged in database (repositories) with historical data with projects information. This data can include all measurements obtained in all project of the teams.

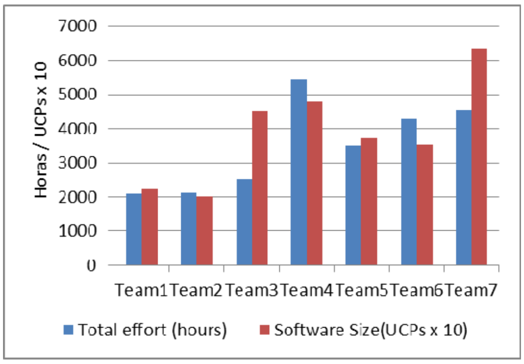

Fig. 1. Comparison between total effort and software size per team

After application of the UCP method in three real projects, Karner found that it takes 20 man hours to complete one UCP [4]. This factor has been accepted as an historically collected figure representing productivity [31, 37]. The teams involved in the case study presented coefficients of productivity more generous. This does not mean that they are super teams, but means that further research is needed to find the reason of this discrepancy. However, we believe that empirical studies involving students on these subjects are important for the scientific community and the industry.

Considering also that productivity is directly related to the effort made and with the functional size per UCP, we suggest for future editions of the SMP and SSD courses that all teams use a development tool, for example *Teamwork Project Manager* [38], in order to accurately determine the effective involved effort. We intent to assess the influence of this tool in the teams performance. As future work, the determination of the productivity of each element according the role of the RUP that he/she assumes is also an interesting experiment.

TABLE VI. RESULTS OF THE SOFTWARE DEVELOPMENT TEAMS

Description	Team1	Team2	Team3	Team4	Team5	Team6	Team7
Number of elements	10	15	16	17	16	16	14
Total effort [hours]	2094	2118	2511	5467,5	3517,5	4287	4548
Unadjusted Actor Weight (UAW)	36	27	45	42	30	21	87
Unadjusted Use Case Weight (UUCW)	170	165	365	400	300	305	570
Unadjusted Use Case Points (UUCP)	206	192	410	442	330	326	657
Technical Complexity Factor (TCF)	1,075	1,045	1,095	1,075	1,115	1,075	0,955
Environmental Factor(EF)	1,01	1,01	1,01	1,01	1,01	1,01	1,01
Software size	221,45	206,4	448,95	475,15	367,95	350,45	627,44
Use Case Points (UCP)	224	203	453	480	372	354	634
Productivity [hours / UCP]	9,36	10,45	5,54	11,39	9,47	12,11	7,18

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Method for Teaching Parallelism on Heterogeneous Many-Core Processors Using Research Projects

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Abstract—**Parallel programming and parallel architectures are necessary to achieve scalability and performance. It is difficult to evaluate when to teach parallelism and how to change the paradigm from serial to parallel algorithm in traditional curricula. Currently, there are efforts to introduce parallel programming since there are multi-core processors. However, there is a new chip generation called many-core processor. For instance, one processor chip can be built with 1,000 processing cores. Moreover, this type of processor is designed to achieve scalability and performance based on heterogeneous cores. How to teach parallelism to undergraduate and graduate students? Human resources are necessary to design and program parallel architectures based on this next generation of many-core processor. Therefore, the main goal of this paper is to show an experience based on research projects. The idea is to join students from different courses and levels, e.g. Computer Science, Information Systems, Computer Engineering, and Graduate in Informatics. All of them working together in order to understand all characteristics of heterogeneous many-core processors based on integrated environment composed of computer clusters and simulation. The proposed method focuses on projects convergence to teach how to extract characteristics from benchmark traces in order to simulate many-core processors based on Networks-on-Chip. Consequently, students can understand parallel heterogeneous architectures and how to program them. Main results present the number of students interested in this research field along last three years and several scientific papers published. It is important to highlight that papers have students' participation and two papers are related to education. Results reinforce the contribution of the proposed method since we have several benefits including continuous and cooperative work along more years.**

Keywords-Computer Engineering; Parallel Architecture and Programming; Heterogeneous Many-Core Processors; Education

I. INTRODUCTION

A 1,000-core processor depends on semiconductor technology and strategies to reduce power consumption [1]. It is a matter of time. The architectural challenge was the first step, and several proposals to interconnect many cores are presented by literature, mainly Networks-on-Chip (NoCs) [2, 3, 4]. Therefore, we can easily link hardware and architecture, but software [5] is also an important issue related to this new era of many-core processors [6]. There is no "dark side of the force", but what/how/where is the type of software developed to 1,000-core processor? In order to exploit many cores, software must be parallel. However, it does not make sense to run the same code of computer networks (based on complex protocols) on a small chip where resources are constraints. We have to exploit space to place processing cores or memories. On-chip interconnection is necessary for scalability; it needs to be small, simple, since it is not more important than cores (to process data) or memories (to store data). Therefore, we need to design software based on different parameters from different architectures, such as GPPs (General-Purpose Processors), ASIPs (Application Specific Instruction Set Processor), and GPUs (Graphic Processor Units). All of them can compose a unique chip called many-core, e.g. 1000-core processor. This way, parallel software [7, 8, 9] for many-core processors must be analyzed on environments composed of parallel machines (multi-core workstations, GPUs, computer clusters, etc.). Moreover, it is important to simulate and evaluate the impact of Networks-on-Chip in order to study the following issues for heterogeneous many-core processors: concurrency, synchronism, and granularity, process/thread scheduling and mapping, software performance, scalability and efficiency.

Fig. 1 illustrates the importance of parallel architectures and programming for the new chip generation. In order to exploit performance and efficiency on heterogeneous many-core processors it is important to correlate architecture and programming. The first step to software development is to know the target architecture. If architecture is parallel, e.g. many-core processor, software must be parallel. However, it does not make sense to develop software based on message passing to access shared memory. This way, it does not make sense to develop software based on shared variables to access network. Now, we can look at inside the many-core processor based on 1,000 cores in order to describe three obvious hypotheses:

- In order to interconnect 1,000 cores and move data, it has a Network-on-Chip;
- In order to store data, it has several cache memories and different organization levels;
- All cores address the same main memory;
- There are different cores for specific processing, e.g. GPU cores.

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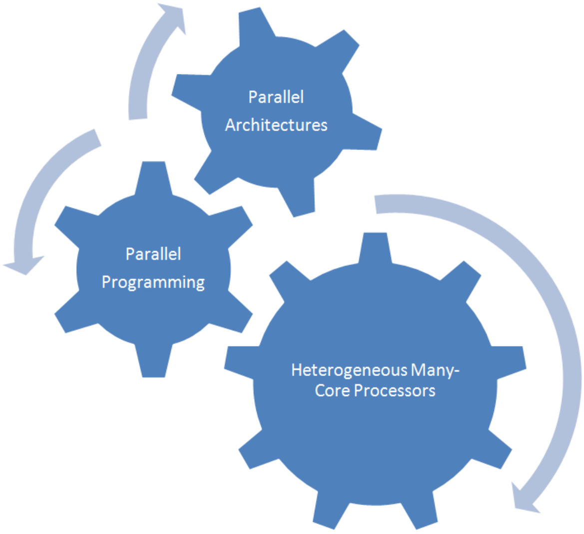


Figure 1. Parallelism and heterogeneous many-core processors

Therefore, we have a parallel heterogeneous processor that supports two programming models: message-passing and shared-variable models. However, how to program 1,000-core processor? Do we need to use both programming models? First of all, we need to understand the parallel workload model. It implies to understand all workload characteristics during processing. Parallel workload model describes parallel application characteristics (execution behavior), such as intra-chip communication intervals and patterns, shared-cache access, inter-process concurrency/dependency, and others. As consequence, it is possible to define how parallel software can exploit correctly processors in order to achieve performance, scalability and low cost. Moreover, it is possible to define how codes must be generated, for instance, packet/message size.

But, how to include all topics related to heterogeneous 1000-core processor in traditional curricula? The answer is research projects. Supported by projects, the main goal of this paper is to describe a teaching method based on parallel workload characterization and evaluation to teach parallelism. The main focus is on programming many-core processors supported by networks-on-chip. According to the scientific context, workload is based on hybrid programming model and it is necessary to support future software development for heterogeneous many-core processors. Based on workload characteristics, it is possible to design parallel software and benchmarks to evaluate new architectures in order to achieve high-performance exascale computing. Moreover, it is possible to disseminate parallelism to software engineers in a research field that emerges based on multidisciplinary concepts, since several computer components are inside the processor chip. In order words, we need to prepare (to teach) students for a new world, where parallel system is on chip and system-on-chip is different of system-off-chip. Therefore, the main contribution of this work is the teaching method based on research projects (Table I and Figure 2) as complement of traditional curricula based on disciplines.

This paper is organized into the following sections: Section II presents related work, Section III describes the proposed method, Section IV shows evaluation results, and Section V presents conclusions.

II. Related Work

The community focuses on NoC (Network-on-Chip) to design and understand the future generation of heterogeneous many-core processors. Interconnection is the basis to achieve scalability and performance. Since the first edition of NOCS (International Symposium on Networks-on-Chip) in 2007 [10], the community discusses the importance of NoC benchmarks [11], programming models [12], and concurrent applications [13].

Grecu, et al. [10] propose two types of benchmarks. The first one is called program benchmarks to exercise the entire communication architecture. The second one is called micro-benchmarks (synthetic programs) to exercise few aspects of communication. Also, Mandal, et al. [11] propose benchmarking platform for NoCs. They use NoCSim simulator and a set of synthetic and real applications benchmark. The proposal is not different from other projects that present a simulator based on set of programs to test NoC design.

The literature presents some papers related to application modeling and mapping onto NoCs [13, 14, 15]. Although they are not related directly to heterogeneous many-core processors, this procedure is important to understand workload behavior. Characteristics extracted from this type of experiment can bring new findings about workload for future software and architecture designs.

Fernandez-Alonso, et al. [16] and Paulin, et al. [17] present discussions related to programming models for networks-on-chip. Both papers show several programming models present in state-of-the-art as alternatives. The first one describes a survey of NoC design and programming models, and an open opportunity to research. The second one shows programming environment called MultiFlex for multi-processor system-on-chip based on IPv4 packet traffic management application.

In terms of method for teaching parallelism, Brown and Shoop [18] present online communities of educators and contributors. Flexible modules exploit programming exercises and supplementary materials. The modules can be used for introducing parallelism in several disciplines. This work adds information related to parallelism but the central idea is not based on heterogeneous many-core processors.

Our proposal is different from related research, since our goals focus on research projects and education [9, 19, 20, 21, 22]. Our intention is not to design new simulators, or online materials, but to propose a method based on research projects (Table I and Figure 2) that integrate experimentation and simulation to teach parallelism. The proposal is based on real parallel workloads characterization (e.g. message-passing and shared-variable models) supported by parallel infrastructure, such as clusters, multi-core machines, and well-known simulators for many-core processors.

III. PROPOSED METHOD

Projects by different agencies were planned to understand and evaluate many-core processors and workload characterization. The proposed method is supported by convergence in order to teach parallelism on heterogeneous many-core processors. Table I and Figure 2 show the projects convergence.

Table II shows three phases divided into seven activities. The method is based on workload design and characterization. The reason is explained by knowledge frontier: currently, heterogeneous 1000-core processors are not ready, so there are no known parallel applications for them.

- Phase 1 (Activities 1, 2 and 3) is related to infrastructure configuration and programs execution. Trace files are important for analysis and most simulators use them to reproduce workload behavior. So, Activity 3 generates program traces from real machines or computer clusters for next phase.
- Phase 2 (Activities 4 and 5) is responsible for analyzing traces under simulation and characterizing workload categories. Simulation is necessary since real many-core processors are not ready. Each workload can be divided into several categories. A category represents a behavior or a property, for instance, collective communication type or message size. Consequently, each category can be divided into several workload characteristics, such as communication periodicity, idle interval, etc.
- Phase 3 works on Activity 5 results. This phase is responsible for designing and evaluating parallel workload model and synthetic programs to achieve high performance. During this phase, the model is evaluated (Activity 6) as configuration data for many-core processors simulation. Activity 7 comprehends programming based on hybrid approach (message-passing and shared-variable models). Synthetic programs for benchmarking are developed, including adapted programs for simulators that do not support well-known parallel implementations (e.g. MPI and OpenMP).

TABLE I. PROJECTS PLANNED TO CONVERGE

Number	Project Details	Agency	Status
4	Title: "*GPU workload evaluation and characterization for Networks-on-Chip simulation*". This project supports undergraduate research scholarships and two multi-core/GPU machines.	FIP PUC Minas – Research incentive fund from Pontifical Catholic University of Minas Gerais	Ongoing project (2012-2013)
3	Title: "*Many-core Processors Architecture Exploitation through Simulation and GPUs focusing on Heterogeneous and Distributed Workloads*". This project supports two undergraduate research scholarships and one multi-core/GPU machine.	FAPEMIG – Brazilian agency from Minas Gerais State for research development	Done (2010-2013)
2	Title: "*Workload Characterization for Wireless Network-on-Chip*". This project supports one graduate scholarship and more two undergraduate scholarships provided by PUC Minas.	CNPq – Brazilian agency from federal government for research development	Done (2010-2012)
1	Title: "*Integrated Approach based on Experimentation and Simulation to Evaluate Networks-on-Chip Using Parallel Weather Forecast Workload*". This project supports two undergraduate research scholarships and two multi-core machines.	FIP PUC Minas – Research incentive fund from Pontifical Catholic University of Minas Gerais	Done (2010-2011)

TABLE II. TEACHING SCHEDULE ACTIVITIES

Phases	Activities	Months (Cyclic – Figure 2)											
		1	2	3	4	5	6	7	8	9	10	11	12
1	1. Preparing benchmarks for execution and simulation.	X	X										
	2. Preparing simulators and infrastructure.	X	X										
	3. Executing benchmarks to generate execution traces.		X	X									
2	4. Analyzing traces/programs under simulation.			X	X	X							
	5. Characterizing workload categories.				X	X	X						
3	6. Designing and evaluating parallel workload model.					X	X	X					
	7. Designing and evaluating parallel synthetic programs.							X	X	X	X	X	X

Fig. 2 illustrates the projects correlation. Project number 1 is responsible for creating the basis related to computer cluster experimentation and networks-on-chip simulation. This project prepares the environment for extracting workload traces. Several algorithms are studied in order to understand process mapping and its impact on networks-on-chip. Project number 2 generates results related to workload characterization for Wireless Networks-on-Chip (WiNoCs). WiNoCs are alternative to improve performance and scalability for future heterogeneous many-core processors. Project number 3 is responsible for architecture exploitation. This project creates basis to study several parallel architectures including memory organization, on-chip interconnections, instruction and thread level parallelism. Besides, this project introduces GPU-based heterogeneity. Finally, project number 4 specifies GPU cores as important feature to be analyzed in order to understand how the impact on intra-chip communication is.

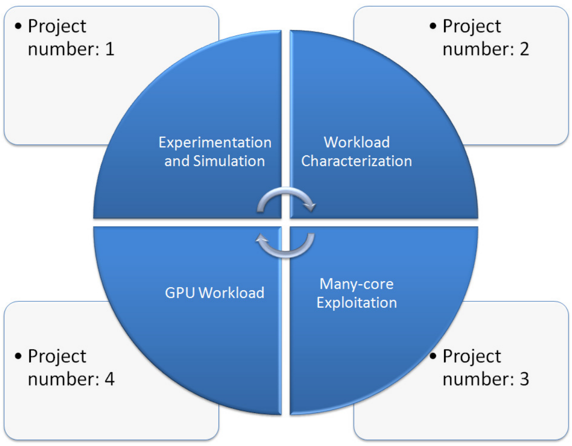


Figure 2. Projects correlation

All projects converge to create basis for teaching parallelism on heterogeneous many-core processors. The three phases highlighted by Table 2 cover all aspects discussed in projects. Consequently, we can return to project number 1 (Fig. 2) to apply the method and to teach parallelism continuously for different students.

As discussed in Introduction, it is not easy to include all aspects related to parallelism and heterogeneous many-core processor in a traditional curriculum. For this reason, the proposed method is supported by research projects based on convergence. All projects have to be planned in order to create conditions to keep students in research. For instance, Fig. 3 illustrates three targets that are important to achieve. First one is related to selection of interested students. To keep these students, the second target (scholarship) is priority. At last, the third target is parallel infrastructure. Without parallel infrastructure is not possible to execute the proposed method.

In order to select students, it is important to show that education is related to teaching and learning, but mainly, it is related to how to prepare human resources. For this reason, Fig. 4 shows the research titles organization from CArT (Computer Architecture and Parallel Processing Team). The idea is to show that, e.g. memory hierarchy (Multi/Many-core Architectures) can be related to shared-memory programming (Parallel Applications). Both can be evaluated in terms of performance, scalability and efficiency, but mainly, both can be learned together in a method that focuses on research and education.

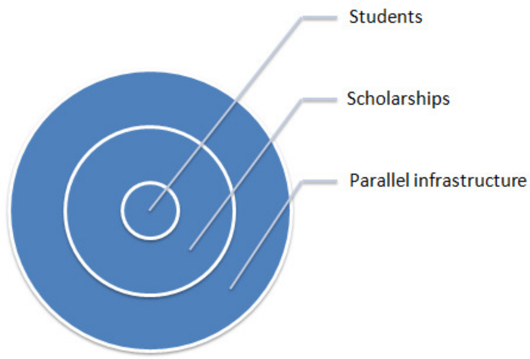


Figure 3. Method targets

IV. Evaluation Results

This section presents all results obtained from last three years based on projects execution.

Fig. 5 shows the number of students involved on projects and Fig. 6 illustrates the number of students with scholarships. There is an effort to get scholarships for all students, but it is important to take into account that some students are volunteers. This number is 7, which represents 31.8% of students. In general terms, each project has two undergraduate scholarships. The number of students per year presented in Fig. 5 represents different students. Therefore, three students from CE in 2011 are different students in comparison to 2012. For the first semester of 2013, the number of students for IS is the same and for other courses one new student is added. It is important to highlight the expressive number of students that work together as class laboratory. This class laboratory is heterogeneous based on students from different courses and levels (undergraduate and graduate) in order to exchange experiences and points of view.

Table III shows the production from 2010 to 2013. Numbers in parentheses are in execution to be concluded in 2013. For instance, there are three master's theses and two undergraduate's theses. The production is related to each project in order to emphasize the importance of each one to prepare human resources. During three years (2010 to 2012) 10 scientific papers were published related to projects. Two papers from total and one tutorial are related to education. All projects contribute to papers, but the distribution in Table III is related to student scholarships in order to eliminate replications. According to Table IV, from the total of 10 scientific papers, 8 papers (80%) have student participation. From other 20%, two papers are related to education (written by professors) without student participation from CArT.

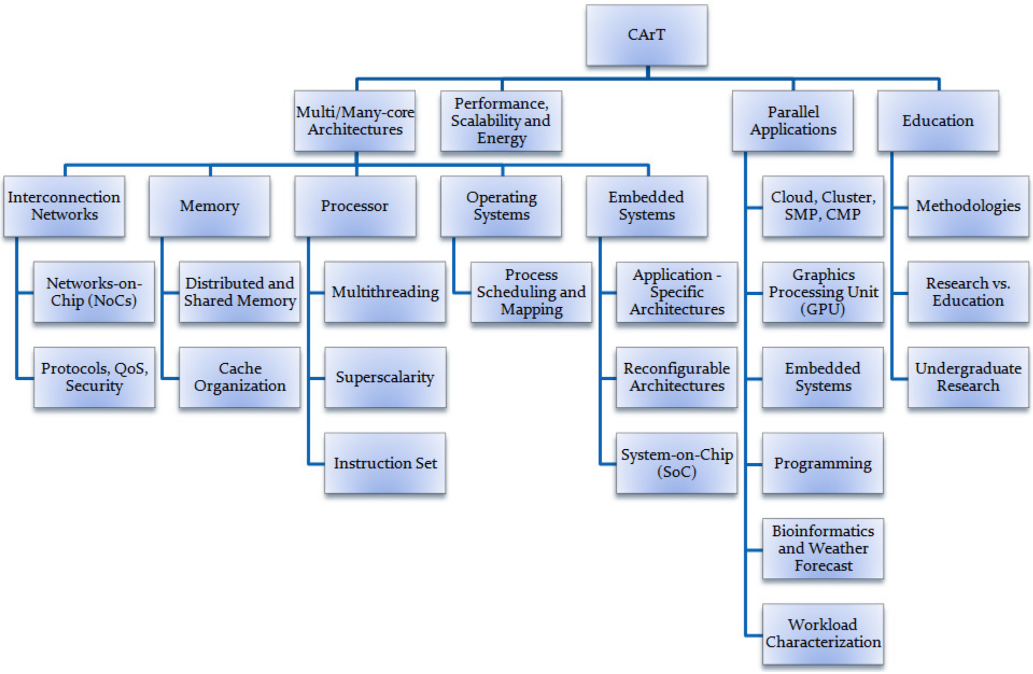
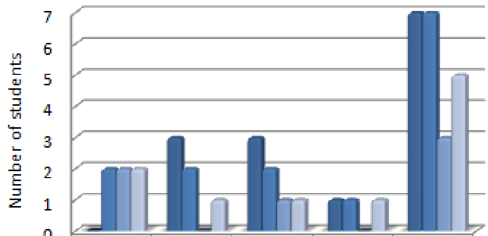
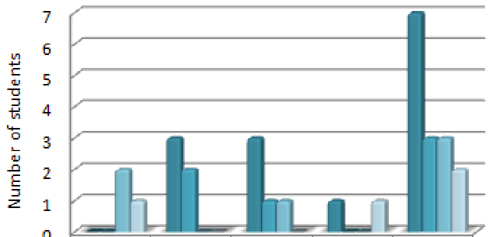


Figure 4. Research titles organization



	2010	2011	2012	2013	Total
Computer Engineering (CE)	0	3	3	1	7
Computer Science (CS)	2	2	2	1	7
Information Systems (IS)	2	0	1	0	3
Graduate in Informatics (GI)	2	1	1	1	5

Figure 5. Total number of students



	2010	2011	2012	2013	Total
Computer Engineering (CE)	0	3	3	1	7
Computer Science (CS)	0	2	1	0	3
Information Systems (IS)	2	0	1	0	3
Graduate in Informatics (GI)	1	0	0	1	2

Figure 6. Number of students with scholarships

TABLE III. PRODUCTION FROM 2010 TO 2013

Results	Projects (Table I)			
	FIP 1	FAPEMIG	CNPq	FIP 2
Master's theses	0	1(2)	1	(1)
Undergraduate's theses	2	2	2	(2)
Total number of scientific papers	1	5	4	0
Student papers	1	4	3	0
Papers related to education	0	2	0	0
Tutorial related to education	0	1	0	0

TABLE IV. STUDENT PAPERS FROM 2010 TO 2013

Courses	2010	2011	2012
Computer Engineering (CE)	0	1	0
Computer Science (CS)	0	1	1
Information Systems (IS)	1	0	0
Graduate in Informatics (GI)	0	3	1

In practice, students create an expectation related to results to publish them. Graduate students are more mature, as consequence, their accepted papers are examples to other students. Results for 2013 are not ready yet, but several undergraduate students are preparing papers for submission. Student feedbacks describe the importance to work together to their formation. The main suggestion is to create small teams based on two or three students to solve the same issue. The best type of team is one graduate student and one undergraduate student, although students at the same level can also bring good results.

V. CONCLUSIONS

Research works point out to many-core processors. A unique chip contains thousands heterogeneous processing cores in order to achieve high-performance with low energy consumption. However, there are several issues related to this new processor generation that are different. For instance, Networks-on-Chip increase scalability but increase complexity. How to program many-core processors based on NoCs? It is not easy to teach parallelism on many-core processors in a typical curriculum, since it is necessary to introduce parallelism based on multi-core processors and computer clusters. How to prepare human resources for this changing (from multi to many)?

The proposed method described in this paper is based on research projects in order to add new concepts related to many-core processors. The idea is to teach to students that we will have a new challenge in few years. Human resources are necessary not to only programming but to design new architectures. Parallelism concepts are necessary to exploit correctly all characteristics of many-core infrastructure composed of computer clusters based on heterogeneous many-core-processors.

Results indicate that students are involved and they want more knowledge about parallelism. Several papers were published and we are working in a new project that focuses on parallel workload model. Because of this, we can describe a list of benefits to students, including continuous and cooperative work along more years (future works), as follows:

- Architectural characteristics (target) that determine software programming;
- Parallel benchmarks for many-core processors supported by NoCs available to download;
- Semester-based classroom education syllabus focused on parallel programming and next generation of many-core processors;

ACKNOWLEDGMENT

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The Value of Entrepreneurship to Recent Engineering Graduates: A Qualitative Perspective

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***Abstract*—Engineering students are increasingly being exposed to entrepreneurship education and activities as a part of their academic programs in order to equip them with the knowledge and skills increasingly valued in today's economy. Data collected from a large sample of senior-year engineering students as part of an NSF-funded study titled "Entrepreneurship Education and its Impact on Engineering Student Outcomes: The Role of Program Characteristics and Faculty Beliefs," suggested that these experiences increased students' perceived self-efficacy for entrepreneurship and their intention to pursue entrepreneurial careers. This study expands on the results of previous research by conducting post-graduation interviews with recent engineering alumni who were exposed to entrepreneurship education and/or related activities. Telephone interviews were conducted with alumni who had graduated within the past 2-5 years. The study finds that engineering graduates place high value on their entrepreneurship education and the benefits that it has brought to their careers.**

Keywords—career; engineering education; entrepreneurship; professional development

I. INTRODUCTION

Economic conditions in the past few decades have led to a rise in the delivery of entrepreneurship education to engineering students [1]. Despite this growth, relatively little research has reported on the specific benefits of entrepreneurial training to engineering students. An NSF-funded study titled "Entrepreneurship Education and its Impact on Engineering Student Outcomes: The Role of Program Characteristics and Faculty Beliefs" sought to more clearly understand the level of student exposure to entrepreneurship education and articulate its impact [2]. Data collected from over 500 senior-year engineering students as part of this research found that students who had taken one or more entrepreneurship courses showed significantly higher levels of entrepreneurial self-efficacy on a number of measures and that those students felt that entrepreneurship education could broaden their career choices. This paper seeks to examine the perceived benefits of entrepreneurship education to engineering students in more depth by reporting on interviews conducted with recent engineering alumni.

II. PURPOSE AND RESEARCH QUESTIONS

The purpose this study is to identify the areas in which engineering graduates perceive value from entrepreneurship education and the degree to which it provides them with opportunities in the workplace that they might not have otherwise. It does so by answering the following research questions: (1) What are the professions that recent engineering and entrepreneurship graduates have chosen and what are their responsibilities in these roles?; (2) What are their perceptions of the relative value of specific engineering skills and knowledge to their jobs/careers?; (3) What are their perceptions of the value of entrepreneurship skills and knowledge to their current jobs/careers?; and (4) How does entrepreneurship factor into their future career goals?

III. METHODS

Telephone interviews were conducted with engineering alumni who have graduated in the past 2-5 years. The sample was comprised of 18 former students who were involved in entrepreneurship programs at two universities. The majority of participants in this study were engineering graduates who participated in a campus-wide multidisciplinary entrepreneurship certificate program. Others participated in entrepreneurship programs embedded within their engineering programs. Qualitative analysis of interview transcripts identified common themes and trends.

IV. RESULTS AND DISCUSSION

Common themes that emerged from the interview transcripts provided insight to the four research questions listed above. During the course of the interviews, other themes emerged which are also reported.

A. What are the professions that recent engineering and entrepreneurship graduates have chosen and what are their responsibilities in these roles?

The graduates' experiences in their professions varied greatly. Most of the graduates worked in engineering-related positions, but others had gone into other fields such as education, finance, or law. Some had multiple roles within their organizations, and most reported having a breadth of responsibilities. Although participants in this study had all graduated in the last 5 years, many had already held multiple positions and worked in multiple firms. Table 1 shows the participants' job titles, current company size, and the number of jobs they had held since graduation.

Results show the breadth of professions that engineering students enter. They confirm findings of other researchers that show that engineering students are increasingly employed in positions outside of traditional engineering industries [3]. The fact that a large number of participants had changed employment in their short careers is also indicative of changes in modern work patterns identified in previous research [4].

TABLE I. RECENT GRADUATES' PROFESSIONAL CHOICES

Job Title	Company Size (# of Employees)	# of Jobs Since Graduation
Engineer	200,000+	1
Mechanical Engineer	500	1
Process Engineer	10,000	1
Engineering Specialist	86,000	1
Application Engineer	150	2
Electro-Acoustical Engineer/Scientist	~5,000	2
Development Engineer	20,000	1
Patent Agent	50	2
Regulatory Affairs Leader	300,000	1
Center Director/Owner	5	3
Project Engineer	75	2
Project Engineer	250	2
CEO	35	2
Product Support Engineer/ Marketing Specialist	30	1
Entrepreneur[a]	2	2
Field Engineer	25	2
Software Engineer	65	1
Computer Programmer/ Analyst	100,000	1

a. This participant was developing a recent startup after successfully selling a previous startup.

B. *What are their perceptions of the relative value of specific engineering skills and knowledge to their jobs/careers?*

Engineering programs expose graduates to a wide range of content areas. As part of this study, researchers sought to understand what knowledge and skills, specific to the engineering (not entrepreneurship) curriculum, were most relevant to their current job responsibilities. Participants were asked to describe how well their engineering programs prepared them for their current positions. While not all graduates appraised their engineering training equally, a common theme emerged as they described how their engineering training affects their current work.

In almost all of the responses, participants emphasized that learning how to think was more important than content. Many of the participants expressed that engineering training taught them how to think and approach problems that they needed to solve. They often mentioned that the content they learned (equations, properties of physics, calculus, thermodynamics, etc.) has had much less application in their current work than the ability to reason through problems and solve them in a systematic way.

> *"I learned a lot of … how to problem-solve, how to think through processes, how to quantify things that aren't quantifiable. So, the more general skills I really enjoyed. Maybe not as much the specific … technical pieces"*

> *"It prepared me to learn some of the more advanced skill sets that are required of electrical engineers, and the few basic electrical engineering classes I took obviously helped, but it was more of a good foundation of the fundamentals that I got while I was in school and have been able to carry with me that have helped me the most as opposed to some of the more, I guess, advanced theory than we learn while we are in school."*

> *"It's intangibles that the engineering program helped teach me – how to prioritize tasks that I needed to take care of, and it taught me how to manage my time and get things done. As far as content, very little of the content I learned as an engineer do I utilize right now."*

> *"I mean, you can learn formulas, and it lets you go into a company where you're actually going to design a gear or design a heating system. You may not be using formulas, but it gave me the fundamentals and the principles to do strategic planning, to work with a group, problem-solve, really look outside of the box for answers, and research. I mean, it gave me a lot of the fundamentals, even though I don't use the actual formulas I learned anymore."*

Some participants had more negative reactions to the engineering content they were exposed to. When asked how well his engineering program prepared him for his current position, on a scale of 1 to 10, one graduate said:

> *"I would say four. … I feel like most things engineering-related were just hard enough work to prove that you had to learn how to work. It's like – in engineering classes – I feel like I learned more just how I study and how I operate than I did actually absorb the stuff I'm going to use in real life. So, that's the four, because the other six is just garbage that I haven't actually used since then. Like MATLAB and all – it's basically like I use computers, I use Excel, email, and then this* [redacted] *program, which we create, and then beyond that it's just personal skills and general computer skills, which I feel like I would have learned anyway or already knew."*

Another student was fairly negative about the content taught while still praising his engineering training:

"I would say that in my current position, the really important things are project management skills, interpersonal skills, general problem-solving skills, like Lean Six Sigma project management methodology, and general technical common sense. So, it's almost as if a lot of my engineering classes were overkill. Like, I tell people I actually don't think I've used calculus once in the past two-and-a-half years. I've done some statistics, some fluid mechanics. So, in terms of was my engineering education lacking in any way? No – … but was it particularly relevant? Maybe not necessarily."

These responses indicate that some recent engineering graduates did not associate much value with a large part of the technical content they had acquired in engineering programs. However, it is difficult to determine to what degree they used this technical training without recognizing it. For example, the quote above mentions "general technical common sense," which could include technical knowledge gained in engineering courses that is not common to non-engineers. It is possible that engineering graduates are unaware of how much more technical knowledge they have than the average person. This hypothesis has been supported in prior research that shows that engineers often participate in mathematical thinking, even when they do not consider themselves to be using mathematical content knowledge [5].

Another participant indicated that he only uses 50% of what he learned in his engineering courses, but when describing the knowledge he does use, he said, "*I feel like the engineering program helped me a lot just in problem-solving and just giving me the technical background I needed.*" In many cases, it seems, engineers do not actively use much of the content they learned in engineering programs, but the "technical background" they gain from engineering coursework is still a prerequisite for them to do their work.

Regardless of the utility of the specific content in engineering programs, engineering graduates in this study highly valued the problem-solving and analytical tools they gained. Learning how to analyze data, prioritize tasks, optimize processes, and approach problems in a systematic way is of great value to engineering graduates whether or not they remain in engineering careers.

C. *What are their perceptions of the value of entrepreneurship skills and knowledge to their current jobs/careers?*

This study focused on engineering graduates who participated in an entrepreneurship programs as part of their undergraduate studies. Participants were asked to describe the knowledge and skills they gained in their entrepreneurship program that they use in their current work. They identified 5 skills and content areas that have been beneficial.

1) Communication Skills: Many of the participants said that entrepreneurship education contributed to their ability to communicate in a professional setting:

"It was the first introduction I had to anything business related, and so, whether that's how to value your own services, how to talk to clients, how to go out and ask the right questions when you're trying to get feedback… that I do on a day-to-day basis still. So, I think – I give it credit, and I say it helped out because it was the first experience I had with any of that."

"I see too many smart people who can't communicate what they've done, and too often it winds up being that the smart people never get promoted or get put into good positions because they can't tell you what they've done."

"I think in the entrepreneurship classes … they had a lot of presentations… I think anytime you have the opportunity to build and give a good presentation and get feedback from that process, that's always going to make you better."

They often cited learning to make pitches and communicate the value of their project as being useful in their current engineering work:

"It's just a way to get organized … going through that business development plan and say, OK, what's your value proposition? What's your target market? What's your budget? How do you expect to get funding? And really being able to answer these in a concise, organized sort of way."

"Trying to sell to companies to get sponsorship money has really given me foundations and formats and different ideas to pitch my ideas to companies…[It] *tells them that I understand the business principles that they're trying to address for advertising and marketing and setting themselves apart."*

"They [entrepreneurship courses] *helped my ability to think about things from a business perspective and also how to communicate effectively. In the entrepreneurship classes they talk a lot about developing your business plan and creating an elevator pitch … So, I think having those types of skills to communicate effectively and without a lot of extra words and to just be straight to the point, I think that was very beneficial."*

Based on the responses from participants in this study, students gained the most when they were given many opportunities to present with feedback from others. They also learned from having strict time constraints that forced them to be clear, concise, and persuasive.

2) Seeing the Big Picture: Many participants in this study said that entrepreneurship courses helped them to have a broader vision than their regular engineering classes. They described how the rigor and technicality of engineering coursework sometimes led to a type of "tunnel vision" in which engineers focused on narrow aspects of design or functionality. Entrepreneurship courses, on the other hand, helped them to step outside of their narrow focus and see how it fit within a larger system:

"Provided balance with the extremely technical coursework of engineering, opportunities to engage in more social interactions in the classroom discussions, be exposed to a wide variety of ideas, and then in addition to all that, learning the fundamentals of small business creation."

"Putting that business plan together, it makes you think outside of the one thing that you're focused on, and in engineering, that's the technical aspect of a business. …but it gets you to think outside of that and then try to at least understand what the other things that you need to consider are, and that's … the most valuable part. It just got you to think outside – gave you the ability to think big picture instead of having tunnel vision."

"I think a lot of the things that a typical engineering student does while they're in college is very one-dimensional. I think a lot of it is theory-based and is problem-solving, but there isn't a lot of … practical application. So, there isn't a lot of hands-on experience necessarily. There isn't a lot of looking at the big picture how some of the things we're learning can be applied to things in the real world. I kind of wish there was more of that. [Entrepreneurship] *helps me sort of look at things from more than just an engineering standpoint. It helps me realize there's more to a business than product constraints."*

This big picture view was described by many of the participants, but it was not always clear what part of entrepreneurship education had fostered it. Some, like the participant in the last quote, thought that working through creating a business plan was responsible for helping her see the big picture. This is supported by prior research on the use of business plans in entrepreneurship education [6], [7].

3) Working With Others: Another common theme was that entrepreneurship courses help engineering students learn how collaborate and work with others, especially with non-engineers. This theme was often, but not exclusively, mentioned in conjuction with seeing the big picture:

"I think one of the primary ways I think it enriched my education was just being able to work together in groups. I mean, in engineering – there's stuff you've got to work on. … You've got to figure out or solve a particular problem, but I think that's a lot different than sitting down with an organized group, getting to work with different, multiple personalities and being able to solve numerous problems, from procedure problems to really identifying goals and tasks. That's actually another thing I found about the program was that it really forced you to sit down and meet with other people and be able to bounce ideas off of each other. You really had a chance to sit down, talk, strategize, meet, plan, and so forth, and I think that's something I carry with me even until today."

"Being able to wear a lot of hats simply because I've seen other people that have those hats has been nice. … The business world's made up of all kinds. So, having been with them in class and know what makes them tick helps when I meet other people that have had the same majors and think the same way, because marketing and sales and other majors have just different views on things. So, it's nice to have seen it before."

"I think entrepreneurship, because it's multidisciplinary, offers a good foundation, because engineers, we don't necessarily have the business or the communication/ marketing side to us. I think by working with them we can figure out different traits that would help compliment whatever career we choose but not necessarily having to go into those programs but maybe having a good understanding of traits that those programs offer."

Some combined the need to see the bigger picture and work with others and described them, together, as a necessary "real world" skill:

"I think for me it's not enough being just able to do the engineering work without having to know the other elements to go after you make the product. In the [entrepreneurship] *program we would study the marketing side, the law side … the copyright stuff, and how to really work in the team, because in the team, not only* [do] *we have people from the engineering school, we also have people from the business school, and in the real world, it really does work that way. You can't really just focus on your engineering stuff and not work with people from … the other perspective. So, being in the program, it kind of helped me in how I see it in the real world now. Mostly dealing with the people, because we have – all of us have different perspectives on how to approach things."*

"It gave me a more well-rounded understanding of what I was going to be getting into after I finished school and went into the real world."

One participant described how the entrepreneurship program helped him to be more creative in group settings:

"Everyone sees the same situation differently, and primarily it's because of how they think and how they're taught to think, and someone that comes from a psychology background as compared to an engineering background as compared to a finance background, we're all going to challenge each other on our ideas. So, we're all going to look at it differently, and if someone comes up with one way of doing something, I'm going to maybe challenge it

and say maybe we should do it this way. …you either come up with very creative ways of doing things that meet others' needs, or you're able to at least understand the perspective that someone in a different background's coming from."

All participants in the study who had participated on multidisciplinary teams said that they appreciated it. Many said that working with students from other disciplines prepared them to work with different stakeholders in their professional work. Entrepreneurship education is not the only way to expose engineering students to students from other disciplines, but it appears to be an effective way to help engineering students collaborate with others in a meaningful way.

4) Help with Obtaining a Job: Many of the participants in this study described how entrepreneurship training helped them to find employment when they finished their schooling. Students who participated in entrepreneurship programs tended to list it on their résumés. They said that their involvement in the entrepreneurship programs became an important topic of discussion with prospective employers.

"When I was first interviewing out of college – I started at [redacted]*, and they really enjoyed – they really liked the fact that I was somebody who was willing to not just take the typical coursework and then just you don't really know what they know. So, I was able to present myself as a – see, look, I'm entrepreneurial-minded. I loved the classes, got the certificate – I didn't just take blow-off electives, because I was actually interested in these kinds of things."*

"So, in my interviews my senior year … I was able to speak a lot to my experience within the entrepreneurship program, and I do think that that kind of set me apart and the fact that one of the summers I was able to intern at a very small start-up company. I think at the time the company was only maybe 30 or 35 people total. So, being involved in this entrepreneurship program really helped me get that unique opportunity to work at a small start-up."

"Well, it was definitely a talking point, especially for the first job. I mean, one of the – the impression I got – I'm not sure how accurate it was – but the impression I got from the phone interview then shortly after being hired was it was a strong interest from the business development manager there that he saw in the entrepreneurship line on my resume, and it did come up in the phone interview. … I think it definitely set me apart … to get that job."

One of the participants was hired in a dual capacity, as a member of an engineering team and a marketing team. His only exposure to marketing was his participation in the entrepreneurship program. He explained:

"I would say when I first got the interview, the one that really attracted them is that, because I put being in the entrepreneurship certificate – I mean, I majored in the mechanical with this certificate – and that's one of the points that really kind of got me the job I would say.… it really helps, because not only I'm doing the engineering work but also the marketing for the company."

In addition to the students who used entrepreneurship as a talking point in interviews, some of the participants made important connections through their entrepreneurship experience:

"You meet a lot of people through these types of programs. I mean, of course you get all the VC and angel investors and stuff that are always snooping around, but you end up meeting – I mean, my last two business partners are people that I met from that class."

"I actually met with [redacted] *when he came and spoke at one of the entrepreneurship classes there at the program, and so – he told me to get in contact with the president of the company, and then just over several months, we developed a relationship, and when this Field Engineering position opened up, I guess I was one of the first candidates for that position."*

5) Entrepreneurial Mindset: Participants in the study often mentioned that entrepreneurship training gave them a new mindset. One way that the engineers described entrepreneurial mindset was tied to the previously mentioned theme of having a big picture mindset:

"I think … as an entrepreneur … you're owning whatever you're doing, you need to have the whole picture in mind. So, I think it's helped me to maintain a big picture view on projects where I don't just get pigeonholed into focusing – tunnel vision – only on what I do, but I can see how pieces fit together with other people that might be working on it or what … their viewpoints might be as well as not being afraid to try and start something new like trying to start a new group or a new process. Instead of just complaining about it, you can go out and start something up to fix it."

Included with this participant's big picture mindset, is the idea that an entrepreneur takes ownership of things and has the power to effect a change if needed. The belief that one has the power to create change has been tied to entrepreneurial mindset in previous research [8].

Other engineers said that described entrepreneurial mindset in different ways:

"I think it's really changed my mindset in a positive way. I think it's allowed me to become a little bit more open-minded both personally and professionally."

"I would say it was perspective, and it was just an introduction to a lot of stuff that I had no clue even existed before. … it was just a whole different way of thinking about things, it really was, …in addition to building a good product, you still have business fundamentals that you

need to operate, and you still have employee psychology that you need to worry about. So, there's a perspective that there's so much more out there than just building and shipping a good product."

Some participants described increased confidence in becoming entrepreneurs as a result of the entrepreneurship courses. They describe how entrepreneurship courses helped them to see entrepreneurship as a viable career option:

"I'd say it was pretty invaluable for education, yes, but motivation probably even more so than anything … the entrepreneurship program showed me that there was another path … we met with a lot of other entrepreneurs in that class, and they got to share their stories about how they did things."

"I would say it makes me a harder worker, because I know I want to hone the skills for when I'm out on my own. So, I think there was always a generic passion in me to try do well in things, but entrepreneurship program made it closer – made it seem like the work will pay off more than … big corporate business life – because I don't think I would ever want to be CEO of a 500+ employee company. So, working up through the project management roles at a big company for the future ability to get to there doesn't hold water with me. I would rather be understanding what a small company needs to survive, and the entrepreneurship program made that seem possible."

"I think it added a lot of the education that I was really looking for and really made me realize that if I did want to open up my own business that I have the tools and the education that I could actually try something – I'll just use the phrase: pursue your dreams."

These statements seem to describe increased self-efficacy as a result of involvement in entrepreneurship courses. Participants described that they would be much more comfortable with forming or working in a startup because of the skills and knowledge they gained in their entrepreneurship courses.

D. How does entrepreneurship factor into their future career goals?

Participants were fairly divided in terms of their future entrepreneurial intentions. A few of the participants had already formed companies and experienced significant success. Some expressed a great desire to start their own companies, while some had little intention to do so. Many of the participants expressed interest in starting their own company, but said they had not found an idea that they wanted to pursue.

Each participant was asked to describe how likely they were to start their own business in the future. Participants rated the likelihood on a scale of 1 to 10. 9 of the 18 participants gave themselves a 10, saying that they were either sure that they would start a business in the future, or they had already started a business at the time of the interview. The mean score for all participants was 7.8, with a standard deviation of 2.5. These responses show that most of the participants have strong interest in starting a business in the future.

E. Other Themes

During the course of the interviews, other themes and ideas emerged that may be of interest to engineering and entrepreneurship educators.

1) Desire for Increased Entrepreneurship Training: All participants in this study expressed a desire to have more entrepreneurship training for engineering students. Participants often stated that they would have liked more depth and wished that they had been exposed to entrepreneurship earlier in their undergraduate studies.

Although they agreed that engineering students should receive more entrepreneurship training, they differed in how it should be administered. Some suggested embedding more entrepreneurship in engineering design courses and projects. Others suggested that all engineering students be required to participate in entrepreneurship minors or certificate programs. One of the participants wanted entrepreneurship to be introduced to engineering students in conjunction with leadership and management training. Among the suggestions most participants thought that engineering students should spend more time in multidisciplinary groups, but one participant felt that multidisciplinary groups make it difficult to focus and suggested having engineering-only entrepreneurship projects and teams. There is a need for more research to be done on the different entrepreneurship program models and their particular benefits.

2) Instructors were Important: Participants in the study tended to credit much of their learning to their instructors. Many described that it was important to hear the experiences of entrepreneurs who had successfully started their own companies. Some felt that association with entrepreneurs was more useful than the content of the courses. Administators of entrepreneurship programs should be aware that students place high value on having experienced entrepreneurs as instructors.

3) Real Experiences were Critical: Although participants in the study reported that they enjoyed the real-world applicability of entrepreneurship skills and knowledge, some of the engineers wished that activities could have been more experiential. They said that they would prefer to actually form startups rather than participate in practice assignments.

"I think I learned a lot going through some of the exercises and projects that we worked on as part of the entrepreneurship program. I sort of wish they made it a little bit more practical. So, rather than doing these theoretical projects where we put together projections… and then said, yes, we think this could be a successful business. I wish we would have done something more practical like being told to start a Kickstarter project, and if it gets funded, then you get an A or something. … It sort of introduced you to the beginning of the entrepreneurial

process, but you didn't get a lot of experience actually executing some of the things that were taught, but, I mean, from an educational standpoint, I would say it was helpful."

This is also an important consideration for entrepreneurship educators. Even though students see value in the program and feel that they learn a lot from it, they still want more authentic experiences and more opportunities to apply what they learn.

V. CONCLUSION

In an increasingly turbulent job market, engineering students are seeking ways to differentiate themselves and gain skills that will make them valuable to companies and society at large. In many cases, students are involved in entrepreneurship programs and activities. Prior research has studied the link between entrepreneurial training and entrepreneurial self-efficacy and intentions. This study adds to that research by using a qualitative approach to understand engineering alumni perceptions of the value of entrepreneurship courses and programs.

Engineers believe that their engineering training has been valuable to their careers whether or not they are currently in an engineering field. They reported that learning how to think and solve problems has been more valuable than the specific content they learned in school.

Participants in this study highly valued the entrepreneurship training they received as well. They credited the entrepreneurship training with helping them develop the abilities to communicate, see the big picture, work with people from other disciplines, find employment, and have an entrepreneurial mindset.

This study also showed that participants in these programs have strong desires to start their own companies in the future. The participants highly value entrepreneurship, and want more engineering students to have more exposure to it. These engineers value instructors with real entrepreneurial experience and want to have more entrepreneurial experiences of their own.

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Inculcating an Entrepreneurial Mindset in Engineering Education: Project Approach

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Abstract— **In a competitive global economy, it is important for engineering students to develop entrepreneurial skills that include effective collaboration and communication, persisting and learning from failure, management, and solving ambiguous problems. This paper summarizes a project that aims to instill these skills as part of an entrepreneurial mindset in engineering students. The project was implemented in an introductory electric circuits class with a mixed representation of students majoring in electrical, computer, civil, and mechanical engineering. Students were organized into groups of two or three to design a temperature sensor using a negative temperature coefficient thermistor. Students groups were provided with customer specifications and were given a month to research the problem and obtain a viable solution. The groups were required to provide evidence compiled into a written product proposal that included a bill of materials, cost analysis, circuit design and simulation, testing plan, layout of the printed circuit board and packaging schematic, delivery time, and the voltage-temperature relationship of the designed circuit. After submitting the written proposal, each group was given five minutes to pitch their proposal using a poster in an effort to convince the customer (in this case, the instructor) that their design was the best and most cost-effective solution.**

Keywords—entrepreneurship; electric circuits; customer appropriate value proposition

I. Introduction

In order for engineering graduates to contribute and compete in the modern global economy, strong technical knowledge by itself is not enough. Graduates are challenged with the choice of how best to enrich the economic return from their knowledge. So, they should have an ability to communicate effectively, manage time, sell ideas, recognize and properly evaluate opportunities, and incur the risk involved with acting to seize those opportunities. The aforementioned qualities lead us to the importance of developing an entrepreneurial mindset. An entrepreneurially minded engineer places product benefits before design features, and leverages technology to fill unmet customer needs [1].

As the world's dependence on technology increases, there is no doubt that the demand for engineers is increasing. This fact puts a demand on engineering institutions to produce well rounded engineers who possess qualities that are relevant to entrepreneurship such as creativity, original thinking, self-control, confidence, comprehensive awareness of market trends, prediction of future demand, conceptual ability, leadership, and initiative.

Entrepreneurship programs add value to students, the degree programs in which they are housed, and the institutions that host them [2]. Curricula that emphasize problem solving, technical writing, teamwork, entrepreneurship, and business management skills can help students overcome the barriers associated with relevance, obtain higher GPAs, and achieve higher retention rates. Specifically, it can improve the retention for women and underrepresented minorities [3]. Engineering Entrepreneurship also supports ABET program outcomes (currently defined as student outcomes) such as the ability to function on a team and communicate effectively in an interdisciplinary environment [4].

Different institutions have used different models to introduce the entrepreneurial mindset into their curricula. For example, Brown University's Division of Engineering has created a two-semester course sequence designed to introduce students to entrepreneurship through a unique merger of classroom learning and industry participation. Deliverables at the end of the two-semester sequence include a business plan and product prototype [5]. A study conducted at George Mason University shows that introducing entrepreneurial concepts in a first-year engineering course can improve students overall perceptions of the engineering profession [6]. The University of Nevada at Reno has developed a special capstone course for senior electrical and mechanical engineering students teamed with MBA students from the College of Business Administration. The course covers all phases of new product development including innovation, patent law, product liability, business, sales, marketing and venture capital [7]. Finally, Pennsylvania State University has introduced an Engineering Entrepreneurship minor that consists of five classes. The first class, Entrepreneurial Leadership, is taught during the junior year and the other four classes Entrepreneurship Business Basics, Introduction to Engineering Design, Technical Entrepreneur, and Product Development are taught in the senior year. The purpose of this minor is to build students' life skills so they can succeed within innovative, product-focused, cross-disciplinary teams [8]. At the authors' institution, the entrepreneurial mindset is also tightly integrated in the curricula through a two-course introduction to engineering sequence at the freshman level, a

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two-course capstone design sequence at the senior level, and a business elective covering the principles of entrepreneurship.

It is clear from the literature that most of the work related to entrepreneurship in engineering education has been done either at the freshman or senior level. Courses at the sophomore and junior levels typically contain the bulk of the fundamental engineering science in the curriculum. Hence, it is difficult to develop the entrepreneurial mindset in these courses without sacrificing technical content.

In this paper, we argue it is possible to add extra credit projects that concentrate on entrepreneurial concepts in courses at these levels. Such projects can help students link the gap between the concepts generally learned at the freshman level and only applied in the capstone projects at the senior level. One example of a sophomore-level technical course is electric circuits, which is a required class for most engineering majors.

The paper is organized as follows. Section two summarizes the contents of the electric circuits class. Section three describes the extra credit project that was implemented. The project is an example of a simple addition to a technical course that emphasizes entrepreneurial thinking. Section four explains the outcomes of the project and the assessment data. Section five concludes by giving some ideas on how to adapt the concepts described in this paper to other classes.

II. ELECTRIC CIRCUITS

Engineering students must acquire many skills, one of which is the knowledge of electric circuit analysis. Many branches of electrical engineering, such as power, electric machines, control, electronics, communications, and instrumentation, require knowledge of electric circuit theory. Circuit theory is also valuable to students specializing in other branches of engineering because all engineers use and operate electrical equipment and systems in practice. Mechanical engineers use motors to drive machines. Chemical engineers apply heat and drive pumps. Civil engineers oversee construction sites and use electronic surveying devices. In all of these examples, the instrumentation and control equipment is primarily electrical.

Engineering students learn electric circuit concepts and analysis skills in the Electric Circuits course, which is consolidated into a single course at most universities. That course combines both direct current and alternating current circuits, and covers various topics. Typical topics include resistive networks, nodal analysis, loop analysis, superposition theorem, Thevenin's and Norton's theorems, operational amplifiers, capacitance and inductance, first-order circuits, ac steady-state analysis, steady-state power analysis, ideal transformers, and three-phase circuits.

Despite all of this technical content, we managed to integrate an extra credit project that exposes students to entrepreneurial thinking. The next section describes the implemented project in detail.

III. PROJECT DESCRIPTION

The project was implemented as an extra credit assignment in several sections of the Electric Circuits course. Students interested in participating were asked to organize themselves into groups consisting of two to three individuals to design a temperature sensor. Each group had to pitch a proposal in an effort to convince the customer (in this case, the instructor) that their design was the best and most cost effective solution. To do so, each group had to provide supporting evidence that their design was in fact the best. The evidence was required to be compiled into a three to five page *product proposal* that included:

- a bill of materials
- cost analysis (including the profit and the team members' salaries)
- circuit design and simulation (using specific, physical components)
- testing plan
- layout of the PCB and packaging schematic
- delivery time
- voltage-temperature relationship

Each group had to develop their bill of materials, cost analysis, and testing plan based on an initial customer order of 100 sensors. Each temperature sensor was required to operate in the range of 25˚C to 100˚C. The temperature sensing element had to be a thermistor, which is a variable resistor whose resistance value varies significantly with temperature. To provide a minimal amount of structure and consistency between the groups, each group was required to use the same Negative Temperature Coefficient (NTC) thermistor produced by Murata Manufacturing Company. The specific model used was the NCP03XM102J05RL (the data sheet was provided separately).

The students were also given some of the basic operating principles of NTC thermistors. For instance, the temperature dependence of an NTC thermistor is given by the equation:

$$B = \frac{\ln\left(\frac{R}{R_0}\right)}{\frac{1}{T} - \frac{1}{T_0}} \tag{1}$$

where T_0 is the reference temperature in Kelvin [K], R_0 is the resistance of the thermistor at the reference temperature in ohms [Ω], T is the temperature under consideration (in Kelvin), R is the resistance of the thermistor at temperature T, and B is a constant called the B-constant (measured in Kelvin), which is used for a given temperature range to approximate the temperature-resistance dependence. For the NCP03XM102J05RL model, T_0 = 298.15[K] (or 25˚C), R_0 = 1[kΩ], and B = 3560[K] for the range of 25˚ to 100˚C (i.e., the operating range for the temperature sensor). The error tolerance for this model is ±5% (in resistance at a given temperature), the permissive operating current at 25˚C is 1[mA], the rated electric power at 25˚C is 100[mW], and the dissipation constant at 25˚C is 1mW/˚C. These parameters specify that as long as the current is kept below 1[mA] and power dissipation below 100[mW], then the thermistor will operate as expected (i.e., negligible self-heating). These specifications were given to help simplify the circuit analysis for the students. If they chose to operate their thermistor above this range of current or power, then they had to account for self-heating, which significantly complicates the analysis.

The students were told that the customer plans to use their temperature sensor circuit with a microcontroller that accepts a voltage in the range of 0 to 5[V] in order to close the loop and turn on some fans to dissipate heat based on the temperature. In order to design the control law to be implemented in the microcontroller, the customer needs the voltage-temperature characteristic of the temperature sensor circuit. The only specified guidelines were to make sure that the output voltage was 0[V] at a temperature of 25˚C, and 5[V] at a temperature of 100˚C.

The directions for the project were intentionally ambiguous. This was meant to encourage creativity. Moreover, we provided a vague customer specification to expose the students to realistic customer behavior. The students were given approximately four weeks to design their temperature sensors and produce the written proposal. A few days after submitting the written proposals, the students were asked to give a five minute pitch presentation where each group attempted to sell their product. The presentation was accompanied by a poster made in PowerPoint to help them make their case.

Hands On Electronics
402 W College Ave, Unit: 1799

December 5, 2012
Dear Mr. ,

Our company was thrilled when you sent us your problem involving the temperature varying circuit, the solution to which yielded a very useful piece of equipment that can be utilized for many different applications. The development of such a circuit eliminates the need for a digital sensor and utilizes analog componentry, allowing units to easily be repaired.

The attached proposal outlines the development process for the creation of the Temperature Sensing Circuit. Also included is a cost analysis, explanation of the functionality, and an analysis of the labor and production including projections for future production.

If you have any questions feel free to contact Daniel Meeks at (567) 674-0030 any time.

Regards,

Daniel Meeks,
Communications Officer

Fig. 1. Sample of a cover letter

Cost Analysis

Circuit Parts	Quantity	Price Per Unit ($)	Price for 100 Units ($)
Resistor	3	0.01	3
Differential Op Amp	1	0.23	23
Thermistor	1	0.2	20
6V Battery (rech.)	2	10.78	2156
PCB/Unit Enclosure	1	1.55	155
Wiring/Various		0.5	50
PCB board	~3 (8.5"x 11")sheets	6	18
Salary	Dollars Per Hour ($)	Hours per Unit	Price for 100 Units ($)
Manufacturing	20	0.25	500
Testing	20	0.05	100
Fixed Initial Cost			
Solution for Customer	20	5	100
PCB Design	20	1	20
Debugging	20	0.5	10
	Total Cost:	Without batteries	With Batteries
	Per Unit	$9.99	$31.55
	Total (for 100)	$999.00	$3,155

Fig. 2. Sample of bill of materials

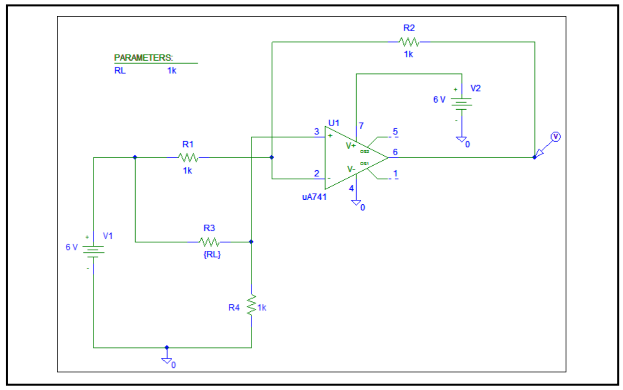

Fig. 3. Sample of a circuit design

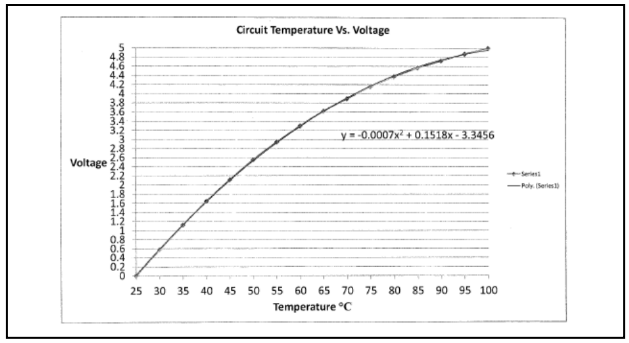

Fig. 4. Sample of a voltage-temprature relationship

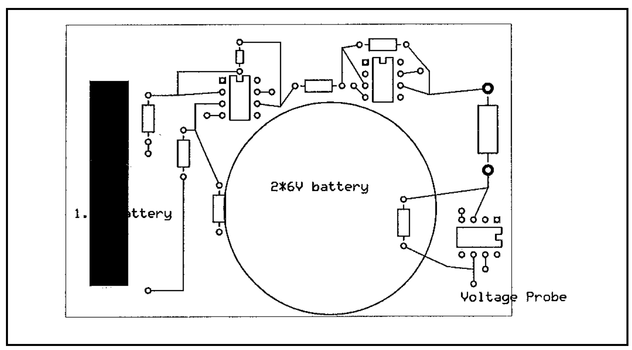

Fig. 5. Sample of a PCB layout

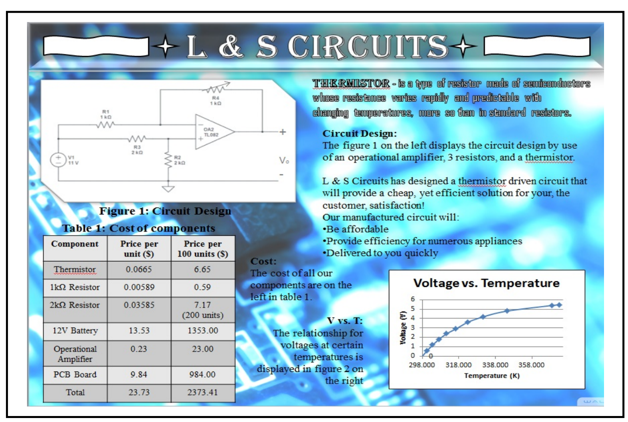

Fig. 6. Sample of a poster

Samples from different students' projects are shown above in the following manner. Figure 1 shows a sample of a cover letter. Figure 2 shows a sample of a bill of materials. Figure 3 shows an example of a designed circuit schematic. The temperature-voltage characteristic of this circuit is shown in Figure 4. Using a curve fitting algorithm, students also found the equation that relates temperature to voltage. Figure 5 shows a sample of a PCB layout. The layout has an allocated area for batteries. Finally, figure 6 shows a sample of a poster that was used as a visual aid in pitching their design.

IV. OUTCOMES AND ASSESSMENT

The project was designed to cover the following three outcomes:

- Effectively communicate a customer appropriate value proposition
- Apply critical thinking to ambiguous design problems
- Effectively collaborate in a team setting

All three outcomes are related to the entrepreneurial mindset of an engineer. The outcomes were assessed based on the students' grades along with a separate student survey.

The students were graded based not only on the quality of the design, but also on the cost of the product, and the ability to effectively communicate and sell their product. The project was worth five extra credit points, and the grading policy is summarized in Figure 7. As shown in the figure, the written proposal was given the highest weight, 50% of the score, because although the pitch may pique the interest of the customer, the substance behind the pitch is contained in the proposal, which summarizes most of the project deliverables. The pitch was given 30% of the score because the pitch is the means by which the idea is conveyed to the customer. Also, the poster is important as a visual aid to help sell the idea and weighs 20% of the grade. Finally, to model real-life competitiveness between different companies, a 20% bonus – i.e., an additional bonus point – was given only to the group that convinced the instructor that their idea was the best, while taking into account that the pitch was backed by substance.

The assessment of the elements of the total grade for the project was carried out largely through the use of rubrics that focus on the project outcomes. The written proposal rubric includes assessment of the overall organization, paragraph development, written language mechanics, and format and style. In addition to these items in the rubric, each of the required deliverables listed in Section III were assessed first based on whether it was reasonable and sound, and second whether it added value to the proposal in a way that differentiated that aspect of the proposal from the competition. The poster rubric includes assessment of the organization of the content, facilitation of communication of content and purpose, connection with the audience, and aesthetic aspects. The pitch rubric focuses on the connection with the audience and verbal and nonverbal delivery.

In any project that involves a group of students, it is usually difficult to assess the work of an individual student in the group. The deliverables are often submitted in written form so that it is impossible to determine the breakdown of contributions among the individuals in the group. However, with a pitch presentation, it is much clearer which students have contributed the most and are most passionate about their work.

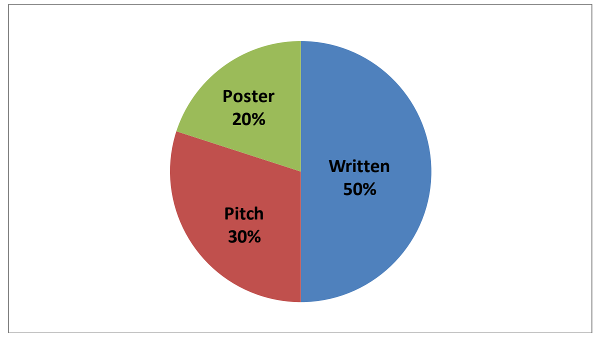

Fig 7. Grading policy

TABLE I. DISTRIBUTION OF STUDENTS' GRADES

Written Proposal			
Points	50	40	30
Number of Students	5	6	5

Poster		
Points	20	10
Number of Students	10	6

Pitch			
Points	30	20	10
Number of Students	3	10	3

A total of sixteen out of forty-eight students decided to take this project. Students who participated in the project were a good representative of all different majors in the circuits class including electrical, computer, civil and mechanical engineering. Also, their overall class grades were spread between A and F. Students who were doing well in the class material were interested in the project to improve their entrepreneurial mindset. On the other hand, students who were barely passing were interested in the project because of the extra credit. As mentioned before, the participating students were asked to organize themselves in groups of two or three. All groups assumed access to all of the equipment in the laboratory, which includes PCB prototyping and soldering stations. They were allowed to consult with the laboratory technician about the cost of operating those machines, as long as an estimated consultation fee was included in their project cost estimate.

Table 1 shows the distribution of the students' grades for the three different grading categories given in Figure 7. As shown in the Table, only two groups--a total of five students--received the full percentage on the written proposal. The remaining groups were penalized because of missing deliverables or non-convincing proposal material. Most groups did good work in their poster design and obtained all points in this category. Only three students were passionate enough to get a full grade on the pitch. Finally, the winning group that consisted of three students was the only group to receive one extra bonus point.

At the end of the project, a survey was given to the students to assess the outcomes of the project from the perspective of the students. The following statements were used in the survey:

S1. The project enhanced my understanding of the course.

S2. The project enhanced my oral, written, and visual communication skills.

S3. The project taught me how to effectively work in a group setting.

S4. The project exposed me in practical issues in an engineering design problem.

S5. The project improved my understanding of economic and fiscal issues of writing a customer-appropriate proposal.

Students were asked to rank these statements using a five-level Likert scale with one being 'strongly disagree' and five being 'strongly agree'.

Out of the sixteen students who participated in the extra credit project, fifteen completed the survey. Table 2 shows the results of this survey. The two most important statements that are closely related to entrepreneurial outcomes are statements 3 and 5. It is encouraging that most students either agreed or strongly agreed that the project taught them how to write a customer-appropriate proposal. While the results for statement 3 were also generally positive, it is interesting that one student disagreed that the project improved the student's ability to effectively work in a group. Perhaps this indicates there was a conflict within that group. Since this project had a significant design component, students strongly agreed that the project improved their problem solving skills. Students also agreed that the project enhanced their communication skills. We believe this is because the project required them to pitch their proposal orally with the aid of a poster. Finally, the results from statement 1 indicate that the project was a successful augmentation to the course. This statement is backed by the fact that the project did not hinder the overall performance of the participating students in the class. On the contrary, one student was able to pass the class because of the extra credit that he was able to receive from the project. A summary of the average scores of the five given statement in the survey is shown in Figure 8.

TABLE II. SURVEY RESULTS

	S1	S2	S3	S4	S5
Strongly Disagree	0	0	0	0	0
Disagree	0	0	1	0	0
Neutral	2	2	3	0	1
Agree	11	12	7	6	8
Strongly Agree	2	1	4	9	6

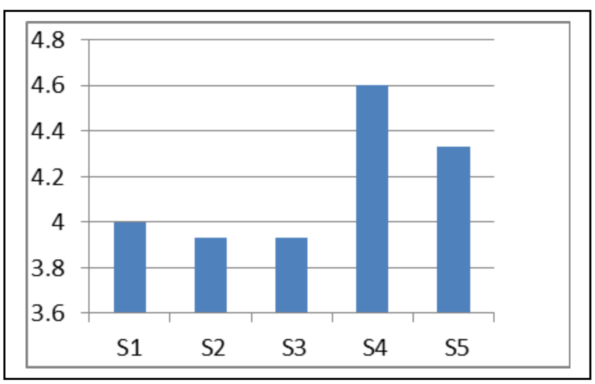

Fig. 8. Average scores of given statements in survey

V. CONCLUSION

This paper summarizes an extra credit project that was given in the electric circuits class to expose engineering students to an entrepreneurial mindset. The Electric Circuits course belongs to a group of classes that are usually given at the sophomore level and considered to be rich in technical content. While there is a lot of evidence in the literature of integrating entrepreneurial mindset at the freshman and senior level, little work has been done at the sophomore and junior levels. The focus of this paper is to cover this gap by using simple projects that can cover entrepreneurial concepts without hindering the technical content of the sophomore/junior level classes. The nature of the project can be adapted to fit in any technical class. First, the project material is related to the topics covered in the class. Second, students were given enough time to work on the project. Hence, the effort they put into the project did not hinder their performance in the class. Third, the project was given as extra credit, so students could choose not to do it. Fourth, delivering the project material only took a small portion of class time. Fifth, the project successfully covers several entrepreneurial outcomes. Overall, it is the authors' opinion that any project with the above characteristics can be easily integrated in any technical course and will instill valuable entrepreneurial skills in the engineering students. Such skills are invaluable in the workplace.

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An Agile Embedded Systems Capstone Course

Overview, Experiences, and Lessons Learned

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***Abstract*— The objective of this paper is to present the outcomes of an embedded systems senior design capstone course offered for Computer Engineering Technology students. This course has being taught five times using the presented format. At every offering, slight modifications have been done in an attempt to improve the student's experience and engagement. The most important intended learning outcomes for this course are: to enable team collaboration, to learn project management techniques, to develop a product from idea to implementation, and to make a professional presentation of their work to an audience. The innovative practices included in this course are: use of Agile Project Management methodologies, no paper trail all information is in electronic form, emulation of an entrepreneurial experience.**

Keywords — Capstone; Senior Design; Embedded Systems Design; Project Management; Agile.

I. INTRODUCTION

You are a senior undergraduate Computer Engineering Technology (CpET) student. As part of your senior design capstone course you are given the task to come up with an innovative product that will be targeted to a particular market segment. You just have ten weeks to come up with an idea and implement it. How would you choose the product? What techniques would you use to document and track it? How can you present this information to show family and prospective investors and employers that you have the capability to come up with a complete solution to solve a particular need? These are interesting problems presented to students. This paper demonstrates the approach taken to manage an Embedded Systems Design (ESD) capstone course by using Agile methodologies.

A senior design capstone is a fundamental experience for the graduates of the CpET program at the Rochester Institute of Technology. This course represents a unique opportunity for students to make use of the entire inventory of skills acquired throughout their program. What are some of the qualities of a comprehensive senior design capstone course? A short list can include the generation and reinforcement of the following skills: team collaboration, ideation and innovation techniques, generation of product specifications and documentation, project management skills, product design and development, and communications through formal presentations.

As the students go through this course, they imprint their stories on a wiki blog; they create, prioritize, self-assign, execute and close tasks; they follow a project management methodology; and they behave like an entrepreneurial start-up company that wants to launch an innovative product.

In addition, all project documentation and source code is available in a code repository for future use. In order to disseminate their work, students create and download to the web videos of their final product. There have been several variations to the course to accommodate industry collaboration opportunities, as well as feedback from students. These modifications will be presented together with an analysis of the outcomes of the course.

In this paper we introduce on how Agile Project Management (APM) methodologies have been incorporated to a CpET senior design capstone course on ESD product ideation, prototyping, demonstration and final presentation.

In Section II an overview of the target course is given. Section III highlights the importance of project management applied to senior capstone design courses. In Section IV specific implementation details of the course are given. Project categories and examples are discussed in Section V. While in Section VI a discussion of the lessons learned is reviewed. In Section VII the paper is concluded and some recommendations for future offerings are given.

II. BACKGROUND

At the end of their program, engineering students traditionally are required to take a senior design capstone course. This is an invaluable experience where students get an opportunity to apply most of the skills acquired through their program in an open ended practical project design experience. Many employers when conducting job interviews are interested in knowing details on the student's "Senior Design Project." Their objective is to get more information on how they perform when: working under pressure; collaborating as part of a team; coming with innovative solutions; setting and following a development plan; and finally their level of engagement in their project.

An embedded system is the combination of hardware (HW) and software (SW) to tailor a product to perform a specific function. Embedded systems are everywhere, from e.g. medical devices, toothbrushes, smart-phones and cars. ESD traditionally requires multidisciplinary teams.

Our CpET students have already taken a strong sequence on ESD and are proficient in both HW and SW as described

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in [1]. Until this course, their experience has been based more on weekly laboratory exercises where the expected outcomes are defined by the instructor, rather than the student being allowed to come up with an independent solution based on their already acquired set of skills.

In a senior design capstone course, students could be presented with an open-ended problem to come up with a solution using the skills and knowledge acquired through their program. In this particular course, students have to come with a realistic implementable solution within ten weeks from idea to implementation, including a working prototype and accompanying documentation.

In the presented course, students apply Agile project management techniques as a tool to develop their product. Once the project is finished, the development process is compared against traditional project management techniques. This particular course attempts to give students a comparable experience to that of a small startup company with limited resources, time to market (TTM) constraints, and facing global competition.

The most valuable aspects of the concepts presented in this course are the experiences the students go through to take a project from idea to conception. The initial ideas and format of this innovative course have been reported in a previous work in progress [2] and later in an industrial success story [3].

While the goals of this particular course were accomplished in previous offerings in a more traditional project management framework, the innovations included in this new course offering are: product specifications definition based on a target market; team self-organization; creation of a product backlog task list; task prioritization and execution during a finite period; self-assignment of tasks; work on incremental releases of the final product; creation of competitive but at the same time collaborative teams; HW/SW reutilization by the use of version control software; product differentiation; creation of intellectual property (IP); evaluation of TTM requirements; work with an open source hardware (OSH) and software (OSS) mentality.

III. PROJECT MANAGEMENT AND RELATION TO SENIOR CAPSTONE DESIGN COURSES.

A. Traditional Project Management

Traditional project management techniques such as those proposed by the Project Management Institute (PMI) are based on a waterfall approach where there is a sequence of stages and handoff procedures at each stage. This approach is excellent when the complete project has already been done at least once and subsequent implementations are just variations of the original project. Once a project has been successfully implemented, Lean Six Sigma quality improvement techniques could be applied to streamline the process.

To be able to come up with a creative an innovative product the question is: What project management techniques could be applied when:

- A project is being realized for the first time?
- There is no previous expertise?
- It is challenging to create a work breakdown structure?
- It is difficult to estimate resources at the different stages?
- It is hard to estimate the time to complete each task?

B. Agile Project Management

One of the possible answers is to use Agile Project Management (APM). One of the strengths of APM is that at every stage, a workable product is generated with a specific number of desired features. It is like compressing a waterfall process with very well prioritized objectives at every stage. Another interesting feature is that the teams are self-organized and self-managed.

In APM, product features are divided into a series of high level tasks or "user stories" and entered into a list denominated the product backlog. These tasks are then prioritized. A subset is selected for implementation during a finite amount of time called "Sprint" thus creating a "Sprint Backlog". The team members self-assign tasks from the sprint backlog and start working. Whenever a task is completed it is marked as closed and the team member selects a new one for execution. Ideally a team must be multidisciplinary and composed of 5 to 7 members. A sprint allocated time can range from couple weeks to couple months. This is done in order to make the best use of resources.

Agile methodologies are ideal for new product development since it is executed as a series of iterations. At the end of each sprint, a working version of the product is delivered. At the beginning of each sprint, a series of product features are prioritized for implementation. At the end of each Sprint, a retrospective is held to analyze the results, and a new set of features is prioritized for execution in the next sprint. This is a very important step to take since product owners or the development team can realize if the product is what they conceived at the beginning or not. Appropriate decisions can be taken at this time gateway.

In APM there are three main actors: the product owner, the scrum master, and the development team. The product owner has the vision and is the one that sets the direction of the project. The scrum master is a project manager who is in charge of providing resources and tracks the project; their vision is very broad and they do not have to have expertise in the particular implementation aspects. The developer team is specialized and their vision is very specialized or narrow, that is why a cross-disciplinary team is the best. In APM there is no team leader and all members collaborate to accomplish the tasks scheduled for that particular Sprint.

While APM techniques have been used for software design for more than a decade, just recently PMI has recognized APM as an alternative to the traditional waterfall approach. Several companies such as e.g. IBM and HP have recognized its usefulness and have available products and services based on APM [4-8].

IV. Course Development

A. Team Collaboration

As simple as it can be thought, collaboration is not an easy task. For most of their program, students have worked individually in homework assignments, laboratory exercises and have taken exams and quizzes. Team collaboration can be a natural social process or it can be very disruptive. Students are free to choose their teams but in some cases there are students that do not know other people in the course and have to be assigned to a team without prior knowledge of the team members. There are four cases with their respective advantages and disadvantages.

1) Advantages

a. A particular student may have already a very well established relationship with other students and may have collaborated in other courses and they will be proactive and have an excellent collaboration.

b. Even students that do not know each other beforehand can take a very proactive approach and have an excellent collaboration.

2) Disadvantages

a. A particular student may have already a very well established relationship with other students and may have collaborated in other courses but some of these students may not be equally proactive and there will not be a fair work distribution.

b. Even students that do not know each other beforehand may not take a professional approach and have problems collaborating.

In this course we have observed all cases being the majority 1a, 1b. Case 2a is not desirable since it depicts an unfair but real life situation. Even in these cases there have been great projects where few students have hold the project together. A few 2b cases have ranged from teams that have not been able to agree on meeting times to disruptive teams where students work independently and do not communicate.

B. Product Specification Documentation

Generating product specifications can become a daunting task. To come up with a new product innovative idea is not a straight forward task for all students. A very important part of the design process is to think thoroughly and systematically to come up with a good set of high level and functional level specifications.

Unless students have experienced this process while working in a company, most likely they have not been exposed on how to create specification documents. Furthermore, during the specification gathering phase they most likely overlook some of the product's critical features.

Students are asked to generate two types of basic documents: high level specification (HLS) and a functional level specification (FLS). The HLS has the information required in plain English for any person to understand the objectives of the project and the product features; this is the document that could be delivered to a potential investor. The FLS are a series of documents that will allow an engineer to reproduce or maintain the design and has all the technical information required.

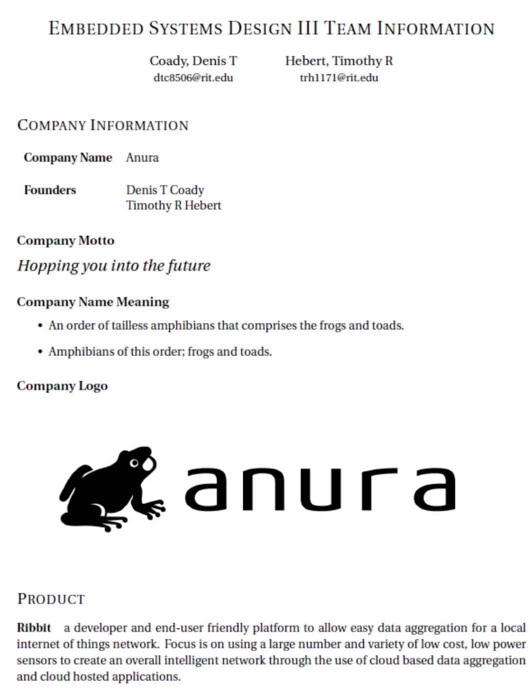
C. Entrepreneurship

In the present course, the target is to give a good capstone experience to students, and have taken some steps to make this course as close as possible to a limited entrepreneurial experience. One of the project's restrictions is that they need to choose a target market where their product could be sold. The number of products to be sold is not relevant but a niche market need or a need has to be identified.

Students work as a small startup company that needs to come up with a market specific product. In addition, the students are required to create a working prototype that is demonstrated before an audience, create an upload a video of their product and give a formal presentation. Furthermore the project should be based on open hardware and software to promote reusability and collaboration. Incoming students have access to a repository of previous projects and could start right from where a former group ended to add more functionality or extra features. Students are asked to develop a company name, motto, logo and a product name and description as seen in Fig. 1.

D. Project Management

What makes this course to stand out is the adaptation of Agile project management methodologies to a senior capstone course on product ideation, prototyping, demonstration and final presentation. We have identified that innovation requires a new set of tools and shorter life cycles in order to match TTM constraints. Students go from concept to prototyping and demonstration in just ten weeks. These are some of the reasons why more versatile project management techniques that will allow the students to


Embedded Systems Design III Team Information

Coady, Denis T dtc8506@rit.edu
Hebert, Timothy R trh1171@rit.edu

Company Information

Company Name: Anura

Founders: Denis T Coady, Timothy R Hebert

Company Motto

Hopping you into the future

Company Name Meaning

- An order of tailless amphibians that comprises the frogs and toads.
- Amphibians of this order; frogs and toads.

Company Logo

Product

Ribbit a developer and end-user friendly platform to allow easy data aggregation for a local internet of things network. Focus is on using a large number and variety of low cost, low power sensors to create an overall intelligent network through the use of cloud based data aggregation and cloud hosted applications.

Fig. 1. Company information worksheet

execute, evaluate, and make corrections in an iterative efficient way are needed.

One of the intended goals of this work is to encourage other departments at RIT to integrate the proposed techniques and extend disciplines collaboration. In order to accomplish thesea Provost Learning Innovation Grant (PLIG) has been assigned to continue, expanding and disseminating this methodology to other senior capstone design courses within RIT. A more formal approach to senior design example is already offered in the engineering school's Multidisciplinary Senior Design (MSD) (our students are in engineering technology). In this MSD course traditional PM waterfall methods are used instead of APM.

E. Project Execution

The objective of the project is to be open-ended. After the students identify the product vision and features, they start working on implementing those features selected in the sprint backlog for development in a fixed amount of time.

Being the project open-ended, there is no penalty for not implementing all the expected features like in some other courses. The difference is that in this course, there are no recipes or guidelines. Students are free to choose any hardware/software platform to implement the product's vision. Some students rely on just the acquired skills e.g. C/C++, VHDL, Altera FPGAs, and TI MSP430. Some other students embark on the task to learn complete new platforms, operating systems and programming languages such as e.g. ARM, Web Servers, Linux, Perl, Python, Java, Javascript, JSON, C#, SQL, and PHP. This is a very interesting result since students have not been limited to what was taught in courses and they have chosen to learn alternative vehicles to implement their ideas.

The results have been extremely positive in terms of student engagement; all projects have worked to an acceptable level. What is meant is that the original vision of the project has been accomplished. To observe how students research what will be the best and less time consuming way to accomplish a particular task has been very impressive. This is really important skill in these times when TTM and global competition are part of the equation.

1) Blogging

Students are asked to imprint their experience in a blog. This is where they document all the phases of their design. The course blog site is shown in Fig. 2 and a particular team's blog site is shown in Fig. 3. As mentioned previously, in this course there is no paper trail all documentation and source code are available at the different course web sites as well as in a version control repository. HLS and FLS documents are available at both the blog site as well as the version control repository. A project overview is shown in Fig. 4 as available in the blog site. As part of the blog information, students are asked to generate a story of their project. In Fig. 5 it is shown the original Microsoft Project waterfall project plan as well as project update photographs of their accomplishments.

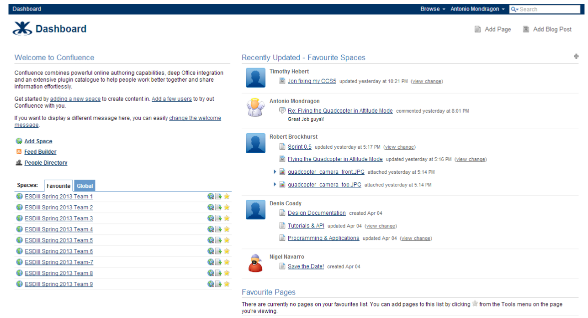


Fig. 2. Course Blog page.

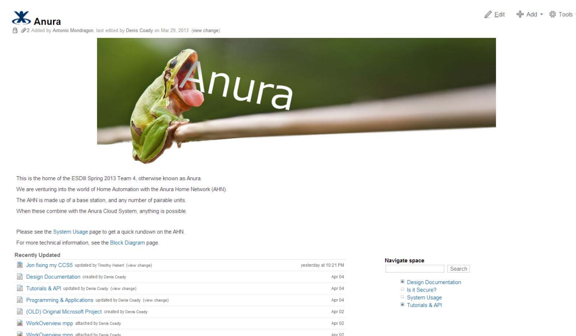


Fig. 3.Team blog site

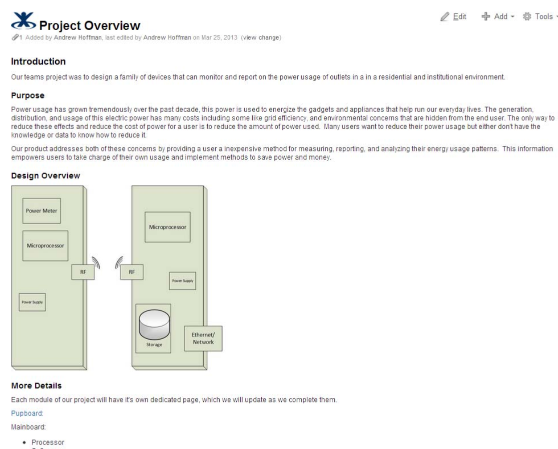


Fig. 4. High level specification document.

2) Project Tracking

In Fig. 6 it can be observed a quick view of the status for several projects. The plot on the left denotes the level of activity for a particular Sprint. The plot in the middle is a representation of tasks created against tasks completed. The right plot is a distribution of the tasks among team members. For the scrum-master this is a project progress snapshot. In Fig. 8 the "Planning Board" it is shown where all tasks for a particular sprint are organized. In Fig. 7 the "Task Board" is shown where the actual task tracking process is performed. The tasks can be in one of three states: "To Do", "In Progress" and "Done".

V. PROJECTS

There have been a total of twenty six different projects using the presented format. All projects are available at: http://antoniofmondragont.wordpress.com/

A. *Major Classifications*

- Audio (MP3 player, social network audio player)
- Energy (Power meter, smart plugs)
- Sensing (Weather meter, strain gauge measurement, vehicle surveillance, elderly care monitor, fruit ripeness sensor, internet of things)
- Video (Camera interfaces)
- Robotics (Roomba robot, line follower, quadcopter)
- Human Interface (Interactive office scheduler, wireless painter)
- Consumer (Auto diagnostics, notification system for deaf and hard of hearing, smart cane for deaf/blind, drink mixer, equalizer coffee table)

B. *Different offerings*

The first quarter the course was offered, the students had been exposed to just two different hardware platforms, one microcontroller in the second year and an FPGA that was used for four consecutive courses. As the course offerings have progressed different alternatives have been proposed in an attempt to leave students with the freedom to choose the project and then find the best hardware platforms, operating systems and languages to accomplish their goals. This is a summary of the different combinations of hardware platforms and communication used:

- FPGA only
- FPGA + Microcontroller
- FPGA + Microcontroller + Wireless
- FPGA + Microcontroller + Internet Connectivity
- Microcontroller + Wireless + Internet Connectivity

In Fig. 9, four projects are shown with different implementations of the above mentioned combinations. The “Micro Strain Gauge Wireless Real Time Measurement” was based on the Texas Instruments (TI) MAVRK platform and integrated wireless connectivity with a PC running a graphical QT interface (top left), the product owner was a joint effort between the MMET department and TI. The “aIRbrush” was a remote infrared (IR) drawing device using a Raspberry Pi, a Wiimote and a custom made IR marker (top right), the team was the product owner. The “Interactive Scheduler” came out the need to have a more systematic way to schedule appointments with faculty, the students proposed to build such a device (bottom left). The project was based on an Altera DE-2 115 FPGA board with a 7” resistive touch screen and a camera, the faculty was the product owner. The “eWaft” came out as an idea to build a device to measure the levels of methane in rotten food and over the time transformed to be a peach ripeness sensor (bottom right), the product owner was the department of Packaging Science.

Each project has been unique and all projects have worked to different levels. We have found that the individual level of student engagement has been the most important factor in project success. There have been great projects developed by complete teams and other also great where just one or two students were really engaged. Engaged students had earned better grades since weekly work is counted towards the final grade. Students have been sincere and have acknowledged who worked more and deserve a better grade.

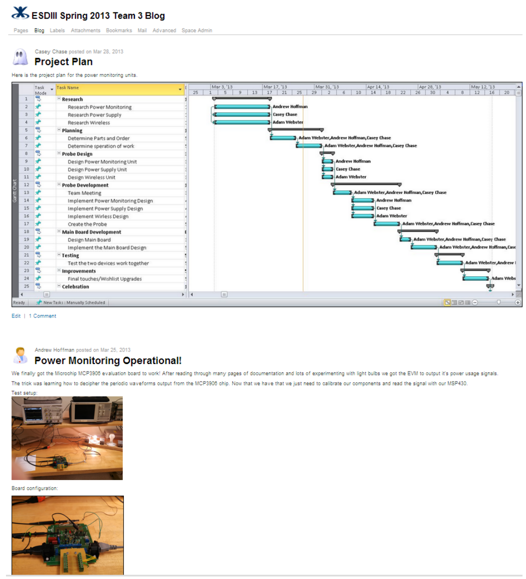


Fig. 5 Original project plan developed in Microsoft Project and project update blog and photographs.

Fig. 6. Projects dashboard.

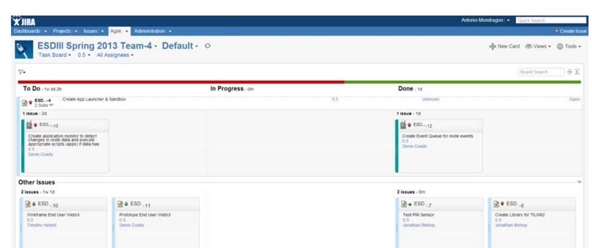


Fig. 7. Task Board

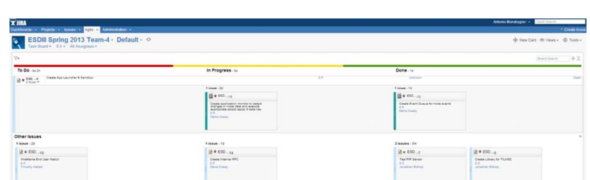


Fig. 8. Planning board

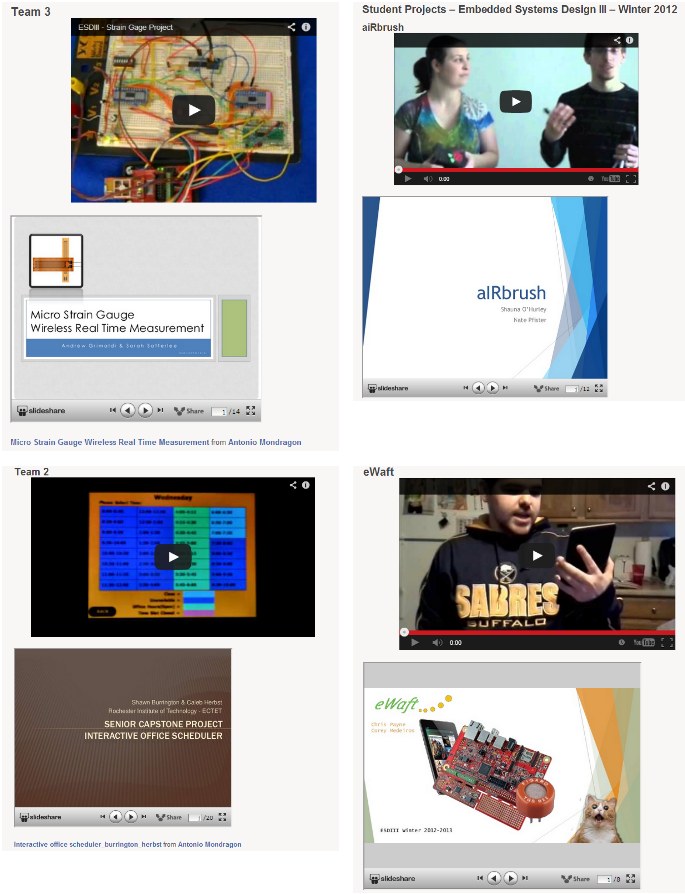


Fig. 9. Project information available for each project. Youtube video with product demonstration and slide show final presentation.

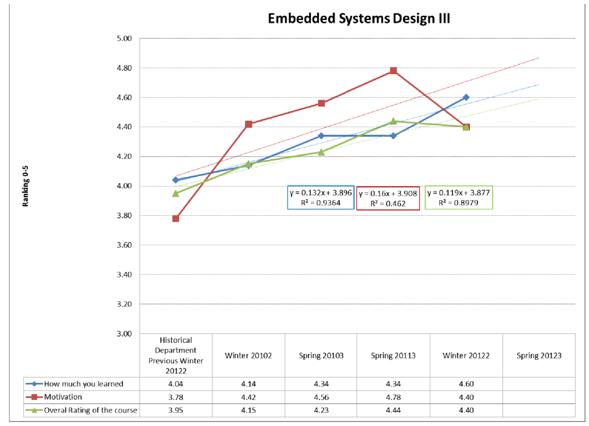
C. *Collaboration with Industry and Faculty*

There have been several interesting engagements with product owners from industry as well as faculty and even entrepreneurs looking to have somebody implement their ideas. A collaboration with TI has been published in [3] and another with Mathworks was showcased during "Imagine RIT." A large number of companies have supported this course by HW/SW gifts in kind. Many of the project ideas have been possible using the platforms introduced at the "ARM Developer Day™"[9] workshops. During the different course offerings, there have been lectures on RTOS from QNX as well as several invited lecturers which have given students another perspective from the software engineering and sustainability points of view.

D. *Course Deliverables*

As part of the grade, students are asked to deliver the following items during their final presentation and project hand-off.

- YouTube video
- Elevator's pitch
- High-Level and Functional Specifications
- Contributions & Differentiation
- Retrospective and Lessons Learned



	Historical Department Previous Winter 20122	Winter 20102	Spring 20103	Spring 20113	Winter 20122	Spring 20123
How much you learned	4.04	4.14	4.34	4.34	4.60	
Motivation	3.78	4.42	4.56	4.78	4.40	
Overal Rating of the course	3.95	4.15	4.23	4.44	4.40	

Fig. 10. Student evaluation responses for learning motivation and overall perception of the course.

E. *Course Results and Statistics*

In Fig. 10, a selected set of the university's student evaluation questions was chosen to evaluate student's perception on the course. These questions were: 1) How much you learned? 2) Motivation and 3) Overall Rating of the course. It can be appreciated that there is an increasing trend with respect to the initial values prior to the course was taught in the present format. The previous offering was modified from a traditional lab based course with a big project to a set of individual projects with different team sizes. It seems that "How much you learned?" and the "Overall rating of the course" are consistent with a fit value R^2 close to 1. It can also be observed that there is an improvement per quarter of around 12% to 16% which is encouraging. The "Motivation" shows a drastic decline in the last offering "Winter 20122" (but still 4.4/5.0 which is good). This result was very surprising since most of the students were apparently motivated to work on the project.

The motivation question results during the last offering were a very interesting result since there were actually two factors to be taken into account: first was that this was the first quarter in which the FPGA platform they used in four courses was not mandatory; and second 80% of the students already had a job secured while taking the course. On the other hand, all teams selected platforms that they have never worked with and even the developing languages for all teams were new (e.g. Python, Pearl, Squirrel, bash script). It is interesting that they were able to design their projects using totally new platforms and picked up programming and script languages in just ten weeks. Overall results seem consistent with a good senior design capstone experience and many great projects have resulted.

VI. LESSONS LEARNED

One of the most representative projects was done during the first offering of the course where two teams worked competitively to create an MP3 player. One project had two processor cores, one dedicated to audio and the other for LCD touchscreen and control. This was technically a very successful project which was showcased at Imagine RIT. The other team had organization problems and there was basically one or two members holding the project. One of these students worked on a very attractive screen display. Technically the project was not as good as the other but the user interface (UI) was really nice.

Every quarter this example is shown to students and a brief story is given, then we vote for which design they will buy. The majority chooses the second project that had limited performance but a very nice UI, while the first project was fully operational but with a simple UI. The lesson that is conveyed to students is that both parts are equally important. A product has to have all the required technical features as well as a nice external design and an engaging UI that should appeal to customers.

Another lesson learned was the following: While the DE-2 FPGA platform used in previous courses comes with examples on how to use different communication devices such as Ethernet and USB, these examples were tested using older generations of the software. When students attempted to use these, they spent a considerable amount of time trying to bring-up these interfaces without success. At that moment, decisions had to be taken in the middle of the course where some of the features had to be revised, moved to another platform or just discarded. This experience for students is very important since they are used to work in laboratory exercises where everything is tested and they know they will be able to produce the expected results. Students learned how to take decisions that completely changed the essence of the product, but not the vision.

Communication protocols was recognized as a skill that was deficient in the first course offerings. Several projects that required platform communications either between embedded devices or with a personal computer, probe to be above the level of skills students had. Students spent a large amount of time trying to create a communications protocol. This skill has been incorporated into a prerequisite course to make the students fluent in this process.

VII. CONCLUSIONS

Students are presented with an open ended problem to be solved using the knowledge acquired through their CpET program. They have to come with a realistic solution within ten weeks including a working prototype and accompanying documentation. Students apply Agile project management techniques to develop their product, and at the end of the term these are contrasted against their initial vision using traditional project management techniques for planning.

Students have been given a similar experience to that of a small startup company with limited resources, time to market constraints, and facing global competition. Students had the opportunity to give a live demonstration of their product, create a promotional video and to give a formal presentation of their work; this closes a very important aspect of their education at the same time that gives the lifelong learning skills. All projects worked as initially envisioned with limited or added functionality which again depended on student engagement and good decisions taken along the course of the project.

The student's experience seems to be consistent even several modifications have been done. Students recognize that they were able to develop a product from idea to implementation by performing extensive research, by applying project management techniques and by self-learning. They have gone through all of the facets required to have a successful product.

It is recommended to allow the students to come up with their own solutions to problems. What would be ideal is to have multidisciplinary teams collaborating towards a complete innovative product. Also it would be very beneficial to have a seminar prior to this course to go over all the material required and to start the course with a project already defined and just work towards its implementation.

This course will be offered in a semester version which will allow more time to develop their skills and get a more refined product. The objective of this work is also to look for collaboration with other engineering technology disciplines as well as other colleges. There is hope that out of these experiences students will become motivated to create innovative products and startup companies may emerge. One of the goals of this course is to plant the ideation seed to get back to the levels of innovation required to come up with practical solutions to solve every day challenges.

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Entrepreneurship and ABET Accreditation: How and Where Does it Fit?

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Abstract – **As a result of economic and workforce trends, there is a strong interest among policy makers and educational stakeholders in graduating more engineers with entrepreneurship skills and an entrepreneurial mindset. Given the role that ABET accreditation takes in shaping undergraduate engineering curriculum, wide adoption of entrepreneurship education could be driven by demonstrating the manner in which its outcomes align with accreditation mandates. This work in progress describes research taking place that is designed to develop a robust rationale for aligning entrepreneurship education with ABET Criterion 3 a-k, and to provide examples of the manner in which entrepreneurship-related outcomes can meet these criteria.**

Index Terms – Entrepreneurship, ABET, Accreditation; Engineering Education

INTRODUCTION

As a result of global economic and workforce trends, there is a strong interest among policy makers and educational stakeholders in graduating more engineers with entrepreneurship skills and an entrepreneurial mindset in order to better prepare them for a fast-changing professional environment. Consequently, over the past decade, engineering students have had increased access to entrepreneurship education and related experiential learning activities than ever before due to growing demand for engineers who possess a broader range of professional skills that allow them to lead and advocate for product and process innovation activities and venture development initiatives.

Despite heightened awareness of the relevance of entrepreneurship education to the discipline of engineering, studies have found that delivery to undergraduates is not yet widespread or institutionalized and that few students were exposed to it even at institutions with formal programs available to engineers [1, 2]. At many institutions, entrepreneurship education is often provided through elective programs, such as minors, which do not reach all engineering students. There are several major barriers, related to curriculum, that limit delivery of entrepreneurship education to engineering students. First, there is limited space in many engineering academic programs, which allow students to participate in electives that teach entrepreneurial thinking and skills [3]. Further, trends such as the increasing pressure at many institutions to improve four-year graduation rates and affordability for students, can further hamper students' ability to enroll in elective courses and participate in extra-curricular programs.

Embedding entrepreneurship-related knowledge and skills into the core of the engineering curriculum could be an effective manner to reach a wider population of students. More recently, changes in standards have emphasized a wider range of skills pertinent to engineers in order to better prepare them for "real world" engineering, broader career options, as well as management and leadership positions within organizations [4], many of which are in alignment with the entrepreneurial mindset and skills [5, 6]. From an engineering faculty and program administrator perspective, ABET accreditation is often viewed as driving the outcomes and content of core engineering courses. Better communication of the manner in which entrepreneurship education objectives meet ABET criteria could be a catalyst for programs to adopt more entrepreneurship-related objectives. It may also drive faculty to embed more entrepreneurship-related curriculum and activities into foundational or required courses.

PURPOSE OF THE STUDY

The purpose of the study is to: (a) identify and validate entrepreneurship-related outcomes that are pertinent to engineers; (b) map these to ABET Criterion a-k; and (c) develop a matrix illustrating this alignment and overlap. This work is intended to serve as the foundation for the development of an easy-to search online resource of entrepreneurship learning modules and assessment tools designed to meet ABET guidelines while infusing entrepreneurial skills into courses and programs

WORK COMPLETED TO DATE

A list of entrepreneurship education competencies pertinent to engineers was generated from a small group brainstorming session at the Stanford Epicenter Retreat in

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2012. After the retreat, a subset of researchers agreed to transform the work into a research study that would achieve the objectives above. The first step involved examining the entrepreneurship education literature to develop and expand the list of relevant competencies. Via multiple iterations, entrepreneurship-related learning outcomes were refined and organized into four content areas: (1) creativity, (2) innovation, (3) entrepreneurship and intrapreneurship, and (4) management and leadership competencies. Figure 1 shows their interrelation and the relevance of management and leadership, which are pertinent at many points along the continuum.

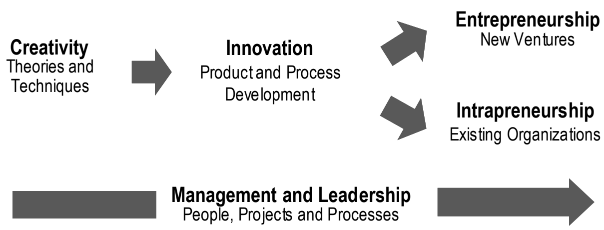

FIGURE 1
CONTENT AREAS FOR ENTREPRENEURSHIP COMPETENCIES ADAPTED FROM [7]

Individual competencies are presented in Table 1. Key words from Bloom's Taxonomy were used to incorporate the cognitive, affective and psychomotor learning domains. A preliminary mapping to ABET a-k was also explored, but not included in this summary. The next phase of the research will involve validating the competencies and their mapping to ABET a-k, by seeking input from a larger group of thought leaders within the areas of entrepreneurship and engineering education.

TABLE 1.
ENTREPRENEURSHIP-RELATED COMPETENCIES PERTINENT TO ENGINEERING STUDENTS BY CONTENT AREA

CREATIVITY - THEORIES AND TECHNIQUES

Design iteration
- Employ frequent iteration to improve a design
- Understand that failure is learning
- Extract learning from design iteration failures and successes

Opportunity recognition -- Environment
- Understand how changes in science industry and economic forces create opportunities
- Evaluate current and future trends and their impact on new venture opportunities
- Compare/contrast the different opportunities and how they create value

Opportunity recognition -- Customer focus
- Identify methods used to capture customer needs
- Detect latent or explicit unmet needs among customers
- Formulate needs into engineering problem statements

Creativity
- Use ideation techniques to generate ideas and opportunities
- Understand the environments, practices, and processes that foster creativity

INNOVATION - PRODUCT AND PROCESS DEVELOPMENT

Prototyping
- Develop specifications for usability and functionality testing
- Identify resources and techniques for prototype development
- Produce working, testable prototypes of the product/service

Feasibility analysis
- Evaluate the feasibility of moving from prototype to commercial product
- Perform market research to quantify market demand
- Conduct financial analysis of opportunity by developing budgets and pro-forma financial statements
- Relate industry and regulatory laws and standards to a design concept

Intellectual property
- Perform a comprehensive patent search for a design concept
- Justify the appropriate legal protection for a design concept
- Generate documentation necessary to file for a provisional patent

Resource acquisition/identification
- Identify potential partners for sourcing, manufacturing, and production
- Assess human capital needs
- Identify physical capital needs

Life cycle
- Analyze current product life cycles to anticipate future needs
- Demonstrate consideration of product life cycle in design decisions
- Demonstrate awareness of sustainability issues

ENTREPRENEURSHIP AND INTRAPRENEURSHIP

Legal
- Select most appropriate legal entity for new business venture
- Understand the use of non-disclosure agreements
- Understand the process and costs associated with IP protection

Marketing
- Identify sources of, and methods to obtain, primary and secondary market research
- Perform competitive analysis to develop a value proposition
- Use market segmentation to develop a marketing plan and budget

Funding/finance
- Determine financial requirements for a new venture at various stages of development
- Understand the process and requirements for obtaining funding from different sources
- Identify the pros and cons of various funding sources
- Understand business valuation

MANAGEMENT AND LEADERSHIP

Leadership
- Develop and clearly communicate a vision for the venture/organization
- Translate vision into goals and metrics
- Delegate tasks and organize work groups effectively

Communication
- Convey accurate and appropriate information tailored to stakeholder needs
- Create and give persuasive presentations and reports on status
- Collect and synthesize information from multiple sources

Project management
- Select and use appropriate project management tools and methods
- Give team members clear assignments and feedback
- Create a process for measure and reporting on progress and performance

Negotiation
- Understand and express the positions of various stakeholders
- Apply of the principles, strategies, and tactics of effective negotiation
- Identify and negotiate solutions that are satisfactory to all stakeholders (win-win)

Team building
- Identify talents and styles of individuals within a team
- Assemble work teams that make best use of members' skills and knowledge
- Implement guidelines for managing and evaluating team performance

CONCLUSION

The study is intended to provide a means to demonstrate and advocate for the integration of more entrepreneurship education in engineering programs by demonstrating its relevance and applicability to meeting ABET accreditation requirements. The next phases of the work will explore the relative importance placed by educators on particular entrepreneurship-related categories and specific learning outcomes. Ultimately, the goal will be to create a resource for faculty interested in embedding more entrepreneurship-related curriculum and activities into foundational or required courses.

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Design Wars: Developing Student Creativity Through Competition

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***Abstract*— Design Wars was developed as a multi-disciplinary design competition in which teams of students receive the same assignment, materials, technology tools for communication and time to complete the project. The student teams were separated into two groups – the documentation team (in the "design office") and the actualization team (on the "build floor'). They were tasked with designing, constructing, and documenting an engineered solution to a complex problem on site within eight hours, with all design decisions communicated between the two groups via mobile computing. The competition was developed to challenge the students' creativity and communication skills; judging was based on the elements of creativity including originality, flexibility, fluency, elaboration and aesthetics. Additionally, students were judged on their ability to document their team's decisions and alternative solutions. Because creativity in engineering is unsuccessful without functionality, the final projects were penalized if they failed in execution.**

Keywords—creativity self-assessment, design competition, mobile computing, team design

I. Introduction

Creativity is a core competency for engineers, fundamental to the process of innovation. The US National Academies of Engineering specifically call out creativity as a necessary attribute of future engineering school graduates [1]; despite this and the fact that creativity and innovation are ubiquitous terms in discussions of the role of engineering in today's society, the need to develop creativity as a skill has not developed a stronghold in traditional engineering curriculum. Kazerounian and Foley [2] suggested that creativity is not valued in current engineering education because it is antithetical to concepts of accuracy, certainty and risk limitation inherent in the practice of engineering. Creativity is also potentially stifled with the current engineering education practice when efforts are focused on determination of the single "right answer" that should be reached as efficiently as possible.

This focus on a single answer determination is one pedagocial approach that may be detrimental to the development of creativity and divergent thinking, requisite skills for finding the solution of open ended design problems. In considering the difference between beginning designers and informed designers, Crismond and Adams [3] note that one attribute of informed designers is fluency, or the number of ideas generated before settling on a solution. This identified component of creativity [4] is not developed in determining solutions of highly constrained problems. Modern design dictates that engineers need to be agile, be able to work in teams, and able to converge on innovative solutions to complex problems [1]. How big of a role individual versus team creativity plays in design processes is not entirely understood and may play a role in the educational development of engineers.

II. Motivation

Perhaps the most commonly known historical example of mobile computing and team based engineering occurred on April 13-17, 1970, when astronauts on the Apollo 13 mission worked simultaneously with mission command engineers to ensure the safe return of the crew. While much of the traditionally-defined "engineering" occurred on earth, implementation and validation of the design needed to occur at a distance of nearly 200,000 miles. This real-time, critical solution was an early validation of a concept articulated over 30 years later in the National Academy of Engineering (NAE) report, "The Engineer of 2020" [1], that engineers to exhibit numerous attributes and skills including (but not limited to):

- Strong analytical skills
- Practical ingenuity.
- Creativity
- Good communication
- Leadership
- Dynamism, agility, resilience, and flexibility (DARF).

Design Wars, a day-long team design competition, was initially developed to provide students with an opportunity to showcase and developed the skills of the Engineer of 2020, with an emphasis on communication, creativity and DARF. More specifically, Design Wars was a multi-disciplinary design competition in which teams of students receive the same assignment, materials, technology, tools for communication, and time to complete the project.

By assessing individual creativity prior to an open-ended design competition, it might be possible to identify any correlations that may be present between creativity and the success of the designs constructed in the event. A research question that arose from the development of the competition was how much impact individual creativity had on the overall creative output of the team. According to Razzouk and Shute [5] design thinking is generally defined as an analytic and creative process that engages a person in opportunities to

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experiment, create and prototype models, gather feedback, and redesign. While the competition setting was designed to require some degree of adaptability by the teams, it also provided some time for reflection and incubation of ideas prior to design implementation.

Students performed an online, self-assessment of their creativity prior to the competition, the CREAX self-assessment (available at http://www.creax.com/csa/). The self-assessment was developed by the CREAX company in Belgium and breaks down creativity into eight components: abstraction, connection, perspective, curiosity, boldness, paradox, complexity, and persistence. The CREAX includes 40 question: six demographic, 25 self-description, five word-association (testing connection), three visual tests of abstraction and one verbal test of fluency. Validation studies on the CREAX self-assessment were unavailable, so results have been used for preliminary comparison without in-depth examination of statistical significance.

III. THE DESIGN WARS COMPETITON

The design problem with which student teams were taked was to move a tennis ball from a blue foam disk, to a French fry basket attached to the top of a four foot tall closet pole (see Fig. 1). The pole was placed in a five gallon bucket with sand in it for stabilization. The ball and foam were placed on one end of two-foot by eight-foot sheet of plywood, and the basket/bucket assembly was placed at the other end at a distance of six feet. Participants were then simply told "Your goal is to get the tennis ball from the piece of blue foam to the French fry basket." Virtually no limitations were set on how students were to achieve this goal, except that, for safety reasons, they were not allowed to use electricity or fire in their final design. Many teams eventually realized that this lack of limits meant that the original configuration of the basket and disk could be altered, although some did not move either element. The only other rule was that students could only touch their design once at the beginning to start the movement of the ball, similar to rules for the Rube Goldberg competition.

Fig.1. A Design Wars booth (pre-construction) including the disk and basket initial configuration and student selected materials.

The central theme of the competition was to challenge both the students' creativity and communication skills. The four-member student teams were separated into two groups. Two members were the documentation team (located in the "Design Office") and the remaining two members comprised the actualization team (on the "Build Floor'). For communication, students were allowed to use their tablet computers and whatever software they chose to employ. Wireless internet was provided and the use of any other communications hardware (e.g. cell phones) was not allowed. The actualization team was responsible for construction. The documentation team had to accurately document the design, including considered alternatives, so that it would match the constructed solution despite having no physical presence on the build floor.

The Build Floor layout consisted of 16 curtained-off booths on an arena floor, with two work tables and power outlets in each. A large central tool station was provided, and a check out system for tool usage time was implemented. A large assortment of construction materials and carefully selected "junk", primarily donations from local businesses, were distributed about the perimeter of the booths. Also, despite the abundance of variety, there was not a large enough quantity of any single item (other than fasteners), so that all teams could use the same material. One attribute of this was that teams were required to quickly adapt their designs, or demostrate agility, if a material they had chosen was gone before they were abe to obtain it from the materials area.

In order to stress the importance of the mobile computing component of the competition, build teams on the floor were not allowed to touch any materials for the first half of the event. Instead, the build team had to communicate what materials were available to the design team and, with their help, pre-design their final configuration. The intent was to prevent teams from simply throwing things together to see what would work. In the afternoon, build teams were let loose to grab what they needed and follow the plans determined by all the members of the team. This provided an opportunity (albeit a short one) for incubation, a necessary component in creative development of ideas [6]. A three hour window for building was used to provide some sense of urgency in the build process. The format provided an environment (or the fourth p of creativity, "press") with equal opportunity to succeed, while setting time and material constraints that required unique solutions.

At the end of the build phase, team members from both the design office and the build floor were brought to the floor, and the teams deployed their designs (See Fig. 2). Scoring was based on the sub-elements of creativity: originality, flexibility, fluency, elaboration and aesthetics as described by Kaufman et al [4].

The other portion of the design score was functionality. Engineering creativity may be considered to differ from creativity in other domains because of the requirement of functionality [7]. If the final design was unable to complete the required task of moving the ball, teams were given fifteen minutes to make modifications, and then allowed to retry. The final projects were penalized if they failed in execution in the two trials.

These two trials were judged by experts from varying disciplines (Psychology, Military Aviation Consulting, Mechanical/Electrical Engineering, Industrial/Human Factors Engineering). To consider the communication skills exhibited during the competition, students were judged on their ability to document their team's decisions and alternative solutions. The final criteria, which was used to prevent teams from hoarding materials, was the usage efficiency of the materials for construction of the design. If students took materials from the main pile of available materials, the team was required to use them or they received a penalty.

IV. Competition Data Collected

The Design Wars competition was held on Saturday, September 8, 2012 at the Rapid City Civic Center. Sixteen teams of four students each, self-selected from the undergraduate population of the South Dakota School of Mines & Technology participated. Data collected included pre-competition, judging scores and post-competition surveys.

Pre-competition creativity scores, based on the CREAX self-assessment, were requested prior to the competition, and obtained from all but three of the participants. One of the main goals was to determine if a team's score in the competition pointed to any correlations between individual creativity and team design output.

The spreadsheets accounting for each team's judging scores and material efficiencies were kept for correlation with the individual CREAX data for each team. After the judges finished assessing the functionality, the top three teams, as computed across all the criteria, were awarded monetary prizes.

Figure 2. *A Design Wars final design in demonstration.*

A. Post-Competition Data and Mobile Computing Survey

A post-competition survey was administered to all participants to assess a) their perceptions of their creative output during the competition and b) their use of mobile compution for communication. The mobile computing ability of teams was crucial to their success in communicating ideas, designing solutions, and formulating contingency plans. During the competition, the wireless bandwidth was limited, which impacted the manner in which student teams were able to communicate. Data were also collected relating to their design strategies and individual/team interactions.

V. Preliminary Results

Analysis indicated almost no linear correlation between team performance on the creativity criteria average and the mean of the individual CREAX scores for a team. However, by grouping the teams a counter-intutive pattern emerged: it appears that the teams comprised of members with near CREAX mean scores performed better than teams with lower than average CREAX means, and both performed better than teams comprised of higher than CREAX mean individuals. Numerous questions that arises from this is: could it be that it is not a good idea to try to form teams of highly creative individuals (at least within a discipline)? Does time constrainst affect the ability of teams with highly creative members to develop functional solutions?

Synthesis among team members and an ability to communicate changes "on-the-fly" were paramount to success in the competition, which is strongly related to perspective, connection, and persistence – all aspects rated in the CREAX test. The analysis shows that students may possess numerous creative abilities, but may not actively realize they are using them or even believe they have them. This might explain why creativity is viewed as an abstract, unrelated section of an engineers' toolbox. These creative, and riskier, designs may provide a better solution in the end or change what common opinion feels is "certain" in practice. Engineering as a whole requires many of the critical traits related to creativity, and developing those attributes in coursework could help students develop more of the traits considered desirable for the engineer of 2020 [1].

Acknowledgments

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Engineer of 2020 Outcomes and the Student Experience

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***Abstract*— An NSF Scholarships in STEM (S-STEM) program has provided scholarships for cohorts of undergraduate engineering students since 2009, giving specific attention to the National Academy of Engineering's vision for the engineer of 2020 (E2020). Four E2020 outcomes are emphasized in Iowa State's program: leadership, global awareness and understanding, systems thinking, and innovation and entrepreneurship. These outcomes, or pillars, are being integrated into curricular and co-curricular activities. The four pillar areas are introduced in a one-semester first-year seminar and reinforced in a two-semester second-year seminar. These seminars supplement the regular program of study for engineering students. In this paper, we describe the curriculum and its planned integration beyond the scholarship program. We present student feedback about their experience in the program. We also introduce relevant core competencies associated with the outcomes as judged by faculty and industry representatives.**

Keywords—leadership, systems thinking, innovation, entrepreneurship, global awareness

I. INTRODUCTION

The E2020 Scholars Program is a National Science Foundation Scholarships in STEM (S-STEM) program. It is designed around a cohort model involving direct-from-high-school and transfer undergraduate engineering students from diverse backgrounds. It leverages and complements the college's learning community infrastructure and builds upon the aspirations and attributes of the National Academy of Engineering's (NAE) vision for the engineer of 2020. E2020 programming includes a set of student development and learning opportunities consistent with this vision and includes curricular and co-curricular activities [1], [2], [3].

The first two years include weekly seminar courses that introduce the E2020 scholars to knowledge, skills and abilities in each of the four developmental areas of the program, also called pillars. The pillars are:

- Leadership development, including teamwork, communication, and service;
- Systems thinking, including interdisciplinary engineering design;
- Innovation, including creativity and entrepreneurship; and
- Global awareness and understanding, including cultural adaptability.

Each pillar area is led by a faculty member. These faculty leaders work with other E2020 faculty to teach the seminar courses. In addition to providing learning opportunities for the scholars, the seminar courses are a means to develop learning experiences to be integrated into the first year experience or other engineering courses for all engineering students.

After completing the seminar series, and beginning in the third year of the program, scholars continue to develop a deeper understanding of the pillars through capstone-like experiences using project-based learning.

Fig. 1 illustrates a semester-based timeline for the student experience in the E2020 program over four years, or eight semesters, upon entry into engineering. The graphical icons represent the pillars of the program: star, leadership; arrow, systems thinking; exclamation, innovation; and circle, global awareness. Section III gives more details about the seminars.

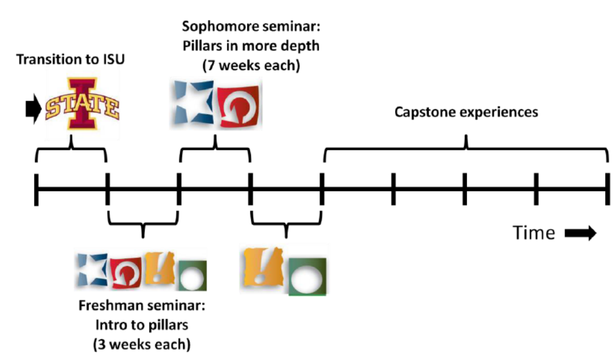

Fig. 1. The E2020 student experience.

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The E2020 program, though developed independently, is similar to a number of initiatives motivated across the U.S. in response to the NAE's report [4]. One of the earliest was the University of Wisconsin's introductory course on the engineering grand challenges [5]. Since then, Purdue University and other universities have implemented engineer of 2020 programs [6]. The Grand Challenge Scholars Program (GCSP), a collaboration of Duke University, Olin College of Engineering, and the University of Southern California, is an NAE-sponsored version of Iowa State's NSF-funded E2020 Scholars Program [7]. Several universities have established programs affiliated with GCSP.

II. Student Cohorts

The first scholarships were awarded for a cohort entering fall 2009. A total of three rounds of scholarships were awarded. The scholarship application and selection processes are described in annual reports available at the program website [2]. An online application that included essay questions pertaining to E2020 pillars was used. A selection committee reviewed and discussed every application. The entering cohorts included both direct-from-high-school (DFHS) and community college (CC) transfer students. The statistics for each cohort are summarized below.

2009 cohort:

- 22 total, 14 DFHS students, 8 CC transfer students
- 4 women and 5 minority students
- 17 of 21 entering scholars remain in or completed the program.
- 12 scholars graduated through spring 2013.
- 86% 3rd year retention in engineering; 81% 4th year retention in engineering; 90% retention at ISU.
- 2 scholars changed to non-STEM majors (economics, history).
- One scholar died in a car accident in fall 2010.

2010 cohort:

- 26 total, 12 DFHS students, 14 CC transfer students
- 12 women and 4 minority students
- 24 of 26 entering scholars remain in or completed the program.
- 10 scholars graduated through spring 2013; one scholar entered the concurrent BS/MBA program.
- 92% 2nd year retention in engineering; 81% 3rd year retention in engineering; 92% 3rd year retention in STEM; 100% retention at ISU.
- 3 scholars changed to non-engineering STEM majors (biology, industrial design); 2 scholars changed to non-STEM majors (elementary education, psychology).

2011 cohort:

- 25 total, 16 DFHS students, 9 CC transfer students
- 11 women and 3 minority students
- 24 of 25 entering scholars remain in the program.
- One scholar graduated through spring 2013.
- 96% 1st year retention in engineering; 88% 2nd year retention in engineering; 96% 2nd year retention in STEM; 100% retention at ISU.
- 2 scholars changed to non-engineering STEM majors (biology, math); one scholar changed to a non-STEM major (communication studies).

The scholarship awards have been administered through the College of Engineering student services office. Scholars who switched to non-STEM majors were no longer eligible to receive an S-STEM scholarship. Scholars who switched to non-engineering STEM majors and who remained active in the program continued to receive a scholarship. Continuing eligibility also adhered to university policies, such as satisfactory academic progress. Overall, sixty-five of seventy-two scholars remain in the program, giving an overall retention of over 90% in the program.

III. Seminar Courses

A one-credit seminar course, ENGR 110, is taken by scholars during the second semester of their first year in the program. It introduces students to each of the four pillars over twelve weeks. With three weeks per pillar, the first week introduces the students to knowledge related to the pillar; the second week focuses on developing basic skills through an active learning activity; and during the third week, students work in teams to demonstrate their ability to apply the new knowledge and skills to a real-world problem. Peer mentor sessions are interspersed with the class sessions.

Another one-credit seminar course, ENGR 210, is taken during fall and spring semesters of the second year, and provides more in-depth investigation into the pillars. The fall semester seminar is split into two seven-week periods, one for the leadership pillar and another for systems thinking. The spring semester seminar is split between the innovation and global awareness pillars. A faculty leader for each pillar has developed pillar-specific learning modules and assessment methods.

A. Leadership

"I now understand that leadership is not just about leading other people, but being able to lead myself." E2020 Scholar

The leadership seminars were designed to highlight that good leadership may be achieved differently by each leader. This concept must be understood and practiced. In the first-year seminar, we concentrated our effort on getting students to appreciate various aspects of these main topics: (1) knowing yourself, (2) teamwork, (3) communication, and (4) self-discipline. The three weeks were focused on students leading themselves. By the end of the sophomore seminar, the students were expected to achieve the following learning objectives: For any given situation, students will (1) build and foster interpersonal relationships, (2) explain why engineers must effectively communicate thoughts and ideas in writing and orally, and (3) identify ways to effectively serve as a member of a team as a leader and/or follower.

Students in the first-year seminar took the *Keirsey Temperament Sorter-II®* and received classroom instruction on personality types and temperaments [8]. Through this experience, students analyzed and described their personality and temperament preferences. Through written reflections, students performed metacognition to gain a deeper understanding of why knowing this information is important to becoming a leader. Next, students participated in a modified version of the "Stranded in the Desert" exercise from Johnson and Johnson's *Joining Together* [9]. This exercise and the following discussion helped to highlight the importance of teamwork in solving a problem. Finally, the students worked in teams to build a tower made of various common office items. Each team member was given a specific "job" and asked to perform their role. Through this experience, students were able to appreciate the complexity of solving a problem through communication, collaboration, and coordination.

The first-year seminar created the framework and opportunity for students to view themselves as leaders. During the sophomore seminar, students were introduced to new topics and exercises to emphasize the importance of interpersonal relationships, communication skills, and teamwork. Nearly every class period was delivered with students sitting in a circle or at team tables to foster the sharing of thoughts and ideas. Students were able to practice their leadership skills by working together on a service learning project. Teams were charged with finding an activity to research, plan, and accomplish together to positively impact the lives of others. Students were encouraged to find a community interest item and devote one-two hours of their time to make a difference. Students practiced their communication skills by presenting their service learning project in either poster sessions or oral presentations. Hartmann provides more background on methodology to many of these teaching methods [10].

The students were generally effective in achieving the learning objectives. After the sophomore seminar, most students were able to clearly articulate their strengths and contributions as a leader in their personal life and organizations within the university and their communities. Reflections from students indicated a greater appreciation and understanding for the importance of engineers to have strong interpersonal relationships, effective communication skills, and teamwork skills.

B. Systems Thinking

"I came to realize just how many things you have to consider when you are working on a project. Not only how something works, but also how it is going to affect the surrounding environment and those who use it." E2020 Scholar

Many definitions of systems thinking have been proposed, but several features appear in most definitions: viewing a problem broadly and holistically; identifying interdependence and feedback; synthesizing as well as analyzing individual components; and accounting for dynamic (time-varying), nonlinear behavior. In the first-year seminar, we focused on getting the students to appreciate the complexity arising from the interaction of factors from inside and outside engineering—that is, we aimed to have students explain the importance of taking a broad view of a problem and considering feedback and dynamic behavior. By the end of the sophomore seminar, the students were expected to achieve the following learning objectives involving tools of systems thinking: For complex, ill-defined, dynamic problems involving engineering, social, ethical, cultural, environmental, business, and political issues, students will (1) identify connections between subsystems with rich pictures, (2) explain relationships with causal loop diagrams, and (3) sketch the behavior over time of key variables in the system.

Students in the first-year seminar worked in teams to draw a rich picture for a topic related either to a grand challenge problem [11] or a successful team—in sports, school, music, work, etc. A rich picture uses pictures, cartoons, text, and sketches to depict connections between various elements of a systems or problem, including structures, processes, and concerns [12]. An example of a rich picture drawn by students is shown in Fig. 2. The students then presented their work either in an oral presentation or a poster session. In the sophomore seminar students chose similar problems involving at least five of the seven issues stated in the learning objective and identified the key variable measuring success or failure. Then they applied three tools of systems thinking: rich pictures; causal-loop diagrams, which show relationships between elements; and behavior-over-time graphs, in which the behavior of the key variable is sketched as a function of time. Rehmann et al. provide more details on the tools and activities [13].

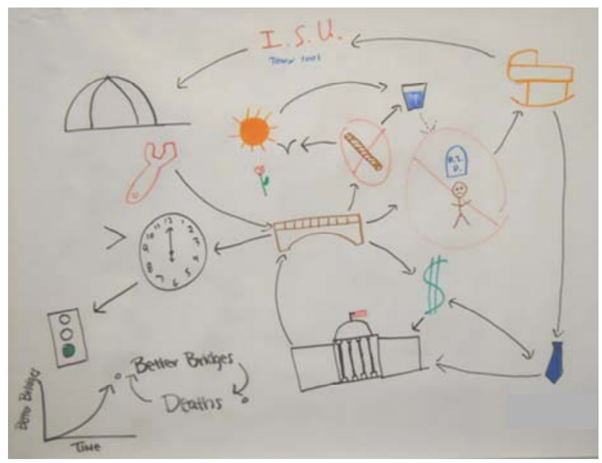


Fig. 2. Example of a rich picture drawn by a group in the FY seminar on the problem of infrastructure and safe bridges. (See [13] for a larger image.)

Based on a review of student work and written reflections, the students were mostly successful in achieving the outcomes. After the first offering of the first-year seminar, most students wrote that before the module, they did not know much about systems thinking. After the module, they knew much more and appreciated the number and diversity of issues that must be considered in a successful engineering project. In the sophomore seminar, students addressed the technical content adequately, though they struggled with identifying an appropriate key variable and sketching behavior over time. In particular, after carefully deriving a causal-loop diagram from a rich picture, many groups would mostly abandon their previous work and resort to mental models not reflected in their rich picture. Although the instructional activities can be adjusted to help students achieve the learning objectives more fully, most students demonstrated appreciation for the range of issues affecting an engineering problem and proficiency with the tools of systems thinking.

C. Innovation and Entrepreneurship

"Innovation is not just thinking of new ideas, but working together in a team, taking initiative, accepting criticism, and being creative." E2020 Scholar

Innovation and entrepreneurship involve key skills and abilities for practicing engineers. While engineering programs offer numerous design courses throughout the curriculum, these often overlook thinking like an entrepreneur. One of the primary goals of this pillar is increase students' awareness that the skills of an entrepreneur will help them to be better engineers. In the first-year seminar, students were introduced to elements of entrepreneurship and explored what it means to approach problems from an entrepreneurial viewpoint. By the end of the sophomore seminar, students developed a business plan for a proposed company to solve some aspect of a grand challenge problem [11]. The students then presented their work to a panel of judges to pitch their ideas.

The first-year seminar first introduced students to innovation by having them think about things (inventions, products, technologies, etc.) that have changed their lives. Students were then assigned to small groups, and each group selected a topic related to a grand challenge problem. The groups were asked to think more deeply about the problem and possible solutions. During the second week, students worked in their groups to refine their ideas and organize them into a presentation to the class. In the third week, groups presented their ideas, which were scored using a rubric that judges creativity of the solution as well as presentation skills. The first-year seminar concluded with feedback to the groups with an emphasis on innovation.

The sophomore seminar focused more on entrepreneurship, with the first week defining entrepreneurship and examining its relationship to engineering. The instructor again primed students on innovation, engaging them in a discussion of the greatest innovations of their time and drivers behind these innovations. These innovations were then placed in the context of grand challenge problems. Groups were formed, and each group was assigned a different grand challenge problem area. Groups were tasked to make a short "sales" pitch as to why their assigned problem area should be targeted by a company. The students then voted to select a single problem domain for their business plans the rest of the seminar. Students learned more about business plans and proceeded to work in groups to finalize their business plans. As in the first-year seminar, business plans were presented and judged. Given the same problem domain, the best plan was identified, adding an element of competition to the learning experience.

Students developed a better understanding about entrepreneurial concepts and effectively communicating their ideas. They were introduced to skills that will enhance their work as a student as well as prepare them for the workforce.

D. Global Awareness

"I never realized the importance of culture and customs in designing a product to meet a country's needs. This class has helped me to realize that there is more to engineering than just building something that works for us." E2020 Scholar

For engineers, global awareness has several possible meanings. In the E2020 project, we defined global awareness as being aware of and respectful of cultural and international differences in needs and values, understanding how regional and cultural differences affect the engineering design process and engineering business enterprise in general, and being able to work effectively with others from different cultures.

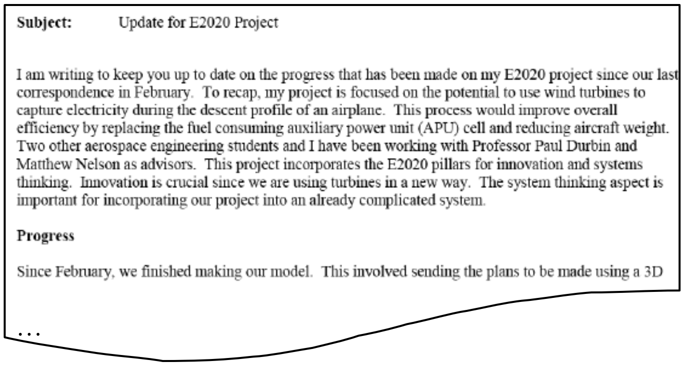
The first-year seminar introduced students to the impact of global and cultural differences on the engineering enterprise, through class discussions and brief case studies. The learning objective for the first-year seminar was that students would have a better understanding of the need for questioning and analyzing their own assumptions (about needs, values, constraints, criteria, resources, economics, etc.) when working on engineering projects.

In the sophomore seminar, the emphasis was on identifying cultural dimensions to an engineering project, with a two-pronged emphasis: one, that framing an engineering problem (and later, developing a solution) must consider the cultural and local norms and needs of the users or beneficiaries of the project, and two, that working with others from different cultures presents challenges that one can to some degree prepare for. After discussion and readings on global awareness in engineering, technology, and business, students were asked to research one of the grand challenge problems, chosen at random for each team of 4-6 students, in the context of one country, also chosen at random for each team. Drawing on the skills gained in the Systems Thinking module, in the first half of this project they were to draw a rich picture describing aspects of the grand challenge problem in their assigned country. Then through discussion and further research, each team distilled their findings to a single engineering problem statement, including constraints and criteria. Ideally, this would be aided by their work in the Entrepreneurship model to frame and communicate an engineering problem. In the second half of the project, students were introduced to Hofstede's cultural dimensions [14], a classification of major cultural norms by country; this is system widely used in international business training. The students were then asked to review their problem statement and imagine that they were paired with a team of engineers native to their assigned country, and using Hofstede's cultural dimensions, explore how each country-team might approach the problem and its solution differently, and how cross-cultural dynamics might affect their work together.

IV. Project-based Individualized Learning

After completing the ENGR 110 and 210 seminar series, and beginning in the third year of the program, scholars continue to develop a deeper understanding of the pillars through individualized, capstone-like experiences using project-based learning. Students from the 2009 and 2010 cohorts are at various stages of independent study experiences with faculty mentors. The project-based independent study assignment is described below.

As part of project management and communications skills development, scholars report their progress. A memorandum format was adopted. A memo is submitted by a student to the E2020 Blackboard site. An excerpt is shown in Fig. 3.


Subject: Update for E2020 Project

I am writing to keep you up to date on the progress that has been made on my E2020 project since our last correspondence in February. To recap, my project is focused on the potential to use wind turbines to capture electricity during the descent profile of an airplane. This process would improve overall efficiency by replacing the fuel consuming auxiliary power unit (APU) cell and reducing aircraft weight. Two other aerospace engineering students and I have been working with Professor Paul Durbin and Matthew Nelson as advisors. This project incorporates the E2020 pillars for innovation and systems thinking. Innovation is crucial since we are using turbines in a new way. The system thinking aspect is important for incorporating our project into an already complicated system.

Progress

Since February, we finished making our model. This involved sending the plans to be made using a 3D

…

Fig. 3. Memo excerpt from project-based independent study assignment.

A project-based learning (PjBL) approach was selected to facilitate independent learning and a deeper understanding of the material. Through their E2020 PjBL experience, scholars are expected to develop self-directed learning skills. As part of the assignment, scholars do the following:

- Complete a project under the guidance of a faculty mentor, selected by the scholar.
- Propose a project that meets certain criteria.
- Enroll in independent study credit to earn at least one credit per semester for the PjBL experience.
- Provide project updates, presentations, and a report to the E2020 Program.

Scholars can choose to work on projects oriented toward research, education or service. For a research project, a scholar takes an open-ended technical question, investigates it, and creates a solution. For an education project, a scholar may develop an innovation for a course that helps other students learn. For a service project, a scholar identifies a societal problem and approaches it through service learning, applying particular expertise to meet a need. A scholar is allowed to work as part of a group on a project. A scholar proposes a project in consultation with a faculty mentor and E2020 faculty. The scope and pace of a project is individualized to a particular student's situation, such as timing with respect to other activities to be leveraged (such as a design competition, study abroad, undergraduate research experience, Honors Program project, etc.). A scholar is encouraged to create a PjBL experience that complements and leverages current coursework and/or co-curricular activities.

As noted, students are encouraged to consider undergraduate research projects for their capstone experience. For example, student "Joe" transferred from an Iowa community college as an E2020 scholar in fall 2011 in mechanical engineering. He participated in the ISU BioMaP (Biological Materials and Processes) REU while a community college student during summer 2011. BioMaP consists of a variety of projects with topics such as nanovaccines, drug and gene delivery, and clinical trials with an artificial pancreas. Joe is pictured in Fig. 4, standing on the left. Joe has since participated in an industry internship while an E2020 scholar. He has benefited from early student engagement through research, first- and second-year learning experiences, and synergistic project activities. He will build on these research and experiential learning experiences to define an E2020 project that deepens his understanding and application of E2020 pillars.

Fig. 4. Project-based learning by an E2020 scholar (http://innovate.engineering.iastate.edu)

V. Student Feedback

A survey was administered to the cohorts each year to obtain feedback on their experiences in the program. Quantitative and qualitative analysis methodologies were used to analyze the survey data. Statistical evaluation of data included descriptives and frequencies of responses. Open-ended questions were coded for common themes [15] [16].

After the first year of the program, student feedback was quite positive with 89% of student respondents agreeing (indicating either Somewhat agree or Strongly agree) that their involvement in the E2020 program: was a positive experience; supported their growth as a person; enhanced their educational experience; and fit well with their courses. An E2020 scholar wrote: "I have had an extremely positive experience with being involved in E2020. E2020 has given me the opportunity to interact with students I wouldn't have otherwise met and faculty members in the college of engineering. I enjoyed coming to class once a week and I feel that I learned a lot about myself as an aspiring engineering major and of what I need to work on in order to be a successful engineer in the future." Results for the question "My involvement in E2020 has been a positive experience" are shown in Table I for the 2009 cohort.

TABLE I. Survey results, 2009 cohort: "My involvement in E2020 has been a positive experience" [16]

Response	Percent	n
Strongly agree	66.7%	12
Somewhat agree	22.2%	4
Neutral	11.1%	2
Somewhat disagree	0.0%	0
Strongly disagree	0.0%	0
Total		18

Prepared by RISE, Iowa State University

The comments by the students elicited the following themes:

- Overall: Students liked meeting other engineering students, enjoyed the discussion of the four pillars, learned a lot about being an engineer, and now think of the role of an engineer differently.
- Women: Had a very positive experience and gained greater insight into the role of an engineer.
- Transfers: The program really helped with their transition, helped them meet people, and helped them understand the four pillars.

Average transfer student responses on survey items tended to be higher (more positive) than DFHS responses, though the differences were not statistically significant. Having transfer student responses generally as positive as DFHS responses suggests that the program has provided an effective pathway for transfer students through E2020 programming.

79% of the 2009 cohort and 85% of the 2010 cohort reported that E2020 helped them feel better prepared to succeed in college. Students in their comments expressed that the pillars had expanded their perspective on the field of engineering and allowed them to see common threads across their classes. One student summarized the E2020 program experience, saying: "The ability to work with other students in different engineering disciplines on topics that are universal to all engineers will have a big impact and importance in my future endeavors as a successful engineer. Also the coordinators and my fellow scholars are amazing people!"

Results from the second survey provided a comparison between students taking ENGR 110 (2010 cohort) and ENGR 210 (2009 cohort). In the 2009 cohort, 100% percent of students agreed that the content covered in the scheduled E2020 seminars helped them to understand what the pillar concepts were all about, though students reported learning more about some of the pillars than others. In the 2010 cohort, 92% agreed. Not surprisingly, given the longer time spent with each of the pillars in ENGR 210, students in the 2009 cohort were more likely (than the 2010 cohort) to agree they had increased their knowledge, skills, and abilities in the pillar areas.

Student comments indicated that the opportunities for networking and support provided in E2020 were extremely valuable, and students commented that networking opportunities were the best aspect of the E2020 Scholars Program. Students also appreciated the learning opportunities, having a creative outlet, learning how to incorporate the four pillars into their work, enhancing their interviewing skills, having people who were willing to answer questions, learning about themselves, and learning to work in teams. The full survey reports are available from the authors.

VI. Curriculum Integration

One of the goals of the E2020 program is to identify ways to introduce the pillar topics to all engineering students, not only to E2020 scholars. The logical avenues are through the first-year experience and learning communities, using modules from ENGR 110 and 210; or via senior design, similar to the E2020 PjBL. This approach would be consistent with a recent national study that concluded:

- Engineering program chairs and faculty subscribe to most of the goals of The Engineer of 2020.
- Faculty and chairs give less attention to professional topics than to technical ones, despite the emphasis on professional skills in the NAE report and ABET criteria.
- Professional topics are typically emphasized in first-year design and capstone courses rather than integrated throughout the curriculum [17].

We have been working with the learning community program coordinators, instructors and peer mentors in the college to share instructional materials for each of the pillars. The faculty leader for the leadership pillar (Hartmann) delivered a two-part workshop during spring 2012. The faculty leader for the systems thinking pillar (Rehmann) delivered a seminar at Iowa State's Learning Communities Mid-Year Institute during spring 2013. There was interest in and outside of engineering to incorporate materials, including later in the curriculum.

Integrating E2020 pillar topics, resources and active learning experiences is an ongoing effort by E2020 faculty.

VII. Future Work

E2020 faculty have not yet formalized assessment of the pillars through well-defined student learning outcomes and instruments. Several rubrics and surveys have been used to assess aspects of the program and student learning. Previous work by E2020 faculty with the Engineering Leadership Program piloted a competency-based leadership model closely aligned with ABET student outcomes [18], [19], [20]. In the ELP model, there were eight learning outcomes that described the knowledge and skills achieved by an ELP scholar through participation in the program. Five of the outcomes were from ABET Criterion 3; three of the outcomes reflected additional skills attained through the program. These additional learning outcomes included an ability to create a vision, an ability to innovate, and an ability to value diversity and create an inclusive environment. Associated with these outcomes, ELP identified nineteen competencies and specific key actions for each competency. This competency-based approach was based on a framework developed for the College of Engineering as described by Brumm, Hanneman, and Mickelson [21].

In the college's framework, student outcomes are multi-dimensional and represent some collection of workplace competencies necessary for the practice of engineering at the professional level. Fifteen competencies are measured within this framework: Analysis and Judgment, Communication, Continuous Learning, Cultural Adaptability, Customer Focus, Engineering Knowledge, General Knowledge, Initiative, Innovation, Integrity, Planning, Professional Impact, Quality Orientation, Safety Awareness, Teamwork. Each competency is uniquely defined with a set of observable and measurable key actions that a student may take that demonstrates their development of that competency. For example, the Initiative competency has the following definition and key actions.

Initiative: Taking prompt action to accomplish objectives; taking action to achieve goals beyond what is required; being proactive.

Key Actions:

> Responds quickly. Takes immediate action when confronted with a problem or when made aware of a situation.
>
> Takes independent action. Implements new ideas or potential solutions without prompting; does not wait for others to take action or to request action.
>
> Goes above and beyond. Takes action that goes beyond job requirements in order to achieve objectives.

An assessment of the student's demonstration of competencies asks the following question for each of the key actions: "When given the opportunity, how often does the student perform the key action?" The response uses a Likert scale: 5 = always or almost always; 4 = often; 3 = usually; 2 = sometimes; and 1 = never or almost never. There is a mapping of the competencies to the ABET (a-k) student outcomes.

It would be possible to follow the ELP assessment approach for each of the E2020 pillars, resulting in a set of competencies and key actions for each pillar. This would align with and leverage the college's assessment framework. The identification of competencies appropriate for each pillar would draw from emerging engineering education research on assessment of leadership, critical thinking, entrepreneurship, and cross-cultural skills.

E2020 program evaluation is also ongoing, including annual surveys of scholars and surveying of graduated scholars.

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Development, implementation and assessment of a common first year end-of-semester engineering design project in an integrated curriculum

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***Abstract*— At the newly established University of Maine's Brunswick Engineering Program, an integrated curriculum is under development that covers the equivalent of the first two years of the B.Sc. in Mechanical, Electrical, Civil and Computer Engineering. Upon completion of the program, the students finish their degree following the traditional curriculum at the home campus. The program emphasizes a theory-simulation-experimentation approach that during the first semester is reflected in two core courses: IEN110 Integrated Engineering 1, and IEN120 Engineering Studio 1. These courses cover the equivalent of first semester courses in calculus and physics, introduction to engineering and engineering design, and engineering computation, and introduce CAD and a high level programming language (MATLAB).**

An end-of-semester project suitable for both courses needs to contribute to the individual course outcomes, as well as to the overall semester outcomes. The project goal is to challenge the students to, after suitably modeling the physical processes, explore the design space with the aid of the computational tools, and to then develop a design using 3D CAD that best meets the design parameters. The final design is then presented to the "client" (the faculty) both in report and presentation format (introducing the communication outcome), and subsequently is built and tested experimentally.

The project assessment is carried out in four phases (project planning, critical design review, build and test day, and post test evaluation), with separate grade components at each assessment point for each of the courses. Assessment results indicate a high level of perceived learning and satisfaction from the students, and strong alignment with the overarching project goals of understanding the engineering design process, developing the capability to represent real-world engineering problems mathematically by applying appropriate simplifications, and to communicate effectively both orally and in writing.

Keywords—first year programs; curriculum integration; problem based learning; design

I. Introduction

The Brunswick Engineering Program (BEP) is an effort initiated by the University of Maine to create an entry point into the engineering disciplines at the Maine Mid-Coast area, while at the same time introducing a program that enhances student learning and retention by delivering the academics in the form of an integrated curriculum that teaches mathematics and science in the context of engineering. The program caters to the Mechanical (MEE), Electrical and Computer Engineering (ECE), and Civil Engineering Departments at the Orono Campus, where the students finish their B.Sc. degrees after completing the first two years of study at the BEP.

The BEP welcomed its initial cohort of 9 students in the fall of 2012, and this paper documents this initial group's end-of-semester project experience. For the first year of the BEP, only first year students are enrolled in the program, where in year 2 the BEP will be fully operational with both first and second class years. As the program grows, it is expected that each cohort will be kept under 25 students to keep a low faculty-to-student ratio.

A variety of first year integration experiences have been presented in the literature, boasting a range of approaches. Examples of large scale applications include the Foundation Coalition [1]-[3], Southeastern University and College Coalition for Engineering Education (SUCCEED), and the Gateway Coalition [4]. In the context of the NSF-funded Foundation Coalition, a group of seven participating universities[1] implemented changes to their first year curriculum to enhance student exposure to the multidisciplinary aspects of the profession. The Foundation Coalition goals were adopted in respective programs at all participating institutions, however developed individually to suit the particular needs of each institution. A different approach to curricular integration, displaying the perhaps most comprehensive redesign of the entire curriculum, has been carried out at Olin college [5], where a brand new curriculum was designed from a fresh start in 2003.

[1] Arizona State University, Maricopa Community College District, Rose-Hulman Institute of Technology, Texas A&M University, Texas Women's University, and The University of Alabama-Tuscaloosa and Texas A&M University at Kingsville.

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All the integration approaches follow the same paradigm; to move the student into the center of the learning effort, and make him an active participant by engaging him through appropriate pedagogical techniques [6]. Typically employed approaches include Problem Based Learning, experiential learning [7]-[9], flipping the classroom and concept based learning [10]-[12]. These techniques are increasingly applied in the traditional classroom environment, however the application benefits the most when they are applied in a multidisciplinary context. In particular, presenting mathematics and science topics in the context of engineering, offers an immediate "aha" effect that not only enhances understanding of the concepts, but also continuously motivates aspiring engineers to continue their studies by making them feel like engineers from day one.

The design of the curriculum using these two pillars (a integrated presentation of the subject materials, and the implementation of student-centered pedagogy) defines the particular characteristics of the Integrated curriculum.

At the BEP, the presentation of the material is organized in a "theory, simulation, experimentation" sequence. This causes exposure to multiple learning modes, always presented in the context of engineering applications. This classroom approach is implemented using the pedagogical tools described above, and the content formulated by careful sequencing of the learning modules. The overall sequence is driven by the criterion that the curriculum needs to allow the students to seamlessly transition to the respective degree programs in year three. Thus the first required step is that of creating a "general" curriculum layout that satisfies all four degree-programs. This general curriculum is then transformed into an integrated curriculum by careful examination of the individual course learning outcomes, and arranging these in a form that allows the multiple learning modes described above.

A principal consideration in this curricular design process is the early introduction of engineering design tools and the engineering design process. This happens for a variety of reasons, with perhaps the most important one being the need for the students to have design knowledge and being able to use design tools so as to productively being able to apply the "theory, simulation and experimentation" process and the problem-based-learning and experiential learning context of the program. ABET's student outcomes further emphasize the design component in the curriculum, and the trend to include them into the freshman curriculum has been consolidating over the past decades [13]-[15].

The work presented here describes the development and implementation of a first semester design project developed in the context of the BEP integrated curriculum. This project is a collaborative effort between the two first semester integrated courses, and was designed to address individual course outcomes, as well as to start developing the systems vision of engineering practice.

II. Discussion

The first semester at the BEP is composed of two core integrated courses: IEN110 (Integrated Engineering 1) and IEN120 (Engineering Studio 1), with 10 and 3 ch respectively. IEN110 incorporates the specific outcomes typically found in traditional Calculus 1 and Physics 1 courses, as well as the equivalent of 2 credit hours of engineering computing. IEN120 introduces the engineering profession, and the engineering design process, including learning a parametric solid modeler. In addition to these courses, English Composition is also taught, but not integrated with the other courses due to the need to operate within the framework of the University of Maine general curriculum.

IEN110 and 120 are courses that have been designed to include all outcomes of the traditional sequence, however expanding them with outcomes that incorporate benefits resulting from the application of the theory-simulation-experimentation approach. Examples of these include ("at the end of the course, students will be able to…"):

- Use standard functions and develop custom MatLAB functions and apply them to real world problems
- Discuss the engineering design process
- Apply the engineering design process to design a simple structure
- Communicate design ideas via hand sketching
- Test predicted forces on a simple structure via experimentation
- Write a technical report to set standards
- Orally present findings of exploratory and team exercises

The above listed outcomes are only those that extend the "core" outcomes of mathematics, physics, Intro to Engineering, CAD, and computing by benefiting from the PBL and design dimensions of the integrated course environment. The common end-of-semester project that is the subject of this paper was designed to provide a multidisciplinary experiential environment in which to develop and assess these outcomes.

It is a challenge to select a project that incorporates these outcomes, while at the same time presenting a level of complexity that enables meaningful analysis at the freshman level. The project chosen here builds on previous design work carried out on a Rube Goldberg sequence. During the initial weeks of the semester, students were challenged to implement the engineering design sequence (up to conceptual level) in a teamwork environment, in the form of a conceptual Rube Goldberg (RG) design. While many more RG steps were discussed during this exercise, the capability to freely arrange stages that represent different physical processes without destroying the "meaning" and realism of the project, implies that a custom-tailored project can be composed that is maintained at the adequate level of complexity and incorporates all physical components of interest. In particular, the physical components of interest reflected applications of large portions of the material presented theoretically during the semester:

- Mathematics:
  - Derivative as the slope of a curve
  - Derivatives as time rates of change
  - Integration of equations of motion
  - Second derivatives; optimization
- Physics:

- o Units
- o Newtonian mechanics (physics)
  - ▪ Projectile motion
  - ▪ Collisions
  - ▪ Conservation of energy and momentum
- o Simple experimental error analysis
  - ▪ Precision and accuracy
  - ▪ Standard deviation
  - ▪ Uncertainty in a result from uncertainty in a measurement
- Programming:
  - o Functions and scripts
  - o Programming structures
  - o Numerical integration and differentiation
- Engineering Design:
  - o The design process and management of the design process
  - o CAD software (CREO2.0)
- Professional skills:
  - o Written and oral communication
  - o Teamwork
  - o Time management

Choosing a particular sequence of Rube Goldberg steps allows introducing all of these components, while at the same time providing a free-form design environment with a range of design variables that can be custom tailored by the faculty to force an exploration of the design space. The project chosen here consisted of the following steps:

1. A ball is launched from a projectile launcher into a cylindrical tube.
2. The ball rolls down the tube and impacts a mini-car, causing the car to start down a ramp.
3. The mini-car impacts the handle of a hammer, causing the hammer to pivot and fall, driving in a nail.

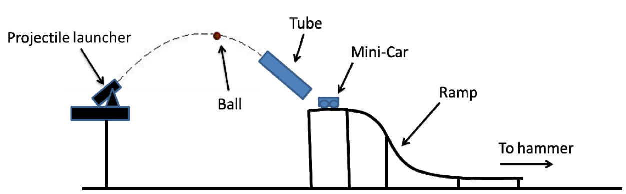

Figure 1: Rube-Goldberg Machine Schematic

The overall phases of the project are:

- Background data collection
- Project planning -> Presentation of project timeline (Gantt chart)
- Conceptual design phase -> Preliminary Design Review
- Detailed design phase -> Critical design review
- Construction -> Project build and test day
- Post test analysis

While the project is individual, the first phase, the background data collection, which includes experimentally measuring the precision and accuracy of the launcher at different angles and settings (and thus provide an assessment of the risk of the different shot configurations), was carried out in teams. Subsequent work was then done individually. The specific task at hand is to design a device that will catch the ball shot from the projectile launcher, and transfer its energy as shown above to the "receiving device", which will be a hammer that needs a certain impulse to actuate upon a nail.

The projectile launcher, tube (with its support structure), mini-car, and the hammer "receiving device" are common components that are provided and shared with the class. The launch angle of the ball and the angle the tube makes with horizontal are both adjustable from 0 to 90 degrees.

Each student then designs, models, and constructs the mini-car ramp using structural hardware available in the lab. The culmination of the project is the test of each design during the final week of classes. On test day, prior to any experimentation and in addition to the ramp geometry, each student needs to specify:

1. The launch angle of the projectile launcher.
2. The projectile launcher plunger setting ("short" or "medium" range).
3. The horizontal and vertical distances at which to place the mouth of the tube.
4. The angle of the tube axis with respect to horizontal.

The physics and mathematics needed to analyze the ball's path can be modeled with the tools that the students have learned during the course of the first semester. The projectile motion of the ball requires 2D kinematics (some students even went to the extent to include air resistance in the computation), the alignment of the tube requires a derivative; then the energy and momentum are transferred by means of a collision, and finally the kinetic energy is given by the height of the ramp. In addition to these requirements, the following "performance equation" was given[2]:

$$\text{score} = 100 - 10\cdot\left(\frac{\Delta x}{\Delta x_{avg}}\right)^2 - 10\cdot\left(\frac{2\cdot I}{I_{max}}\right)^2 - 10\cdot\left(\frac{l_{min} - l}{l_{min}}\right) - 10\cdot\left(\frac{KE_{max} - KE_f}{KE_{max}}\right)$$

Figure 2. Design equation.

This equation was developed empirically by the instructors, to reward (by means of achieving a higher "score"):

- Accurate predictions of the ball's trajectory (by penalizing the overall score for changes in the predicted location delta X)
- Accurate prediction of the required tube angle (this was measured by measuring the sound intensity f of the ball as it "rattles" in the tube),

[2] Δx: Horizontal shift of tube location from predicted location
Δx_{avg}: Distance for an "average" shift from predicted tube location (5 cm)
I: Sound intensity measured by microphone attached to tube (average of 10 shots)
I_{max}: Worst case sound intensity
l: Length of horizontal flat section of track at top of ramp
l_{min}: Minimum required horizontal flat at top of ramp (20 cm)
KE_{max}: Maximum possible kinetic energy (car + mass) just prior to impact with hammer
KE_f: Measured kinetic energy (car + mass) just prior to impact with hammer.

- Optimum energy and momentum transfer from the ball to the cart (steeper angles will transfer less momentum, resulting in a shorter (l) flat section at the tip of the ramp)
- Appropriate design of the ramp to maximize the kinetic energy of the cart at the foot of the ramp (including appropriate selection of cart weight)

These parameters are weighted so that there is no optimal solution; feasible solutions range from very steep shots using a tall ramp but a lower shot velocity, to very flat, high velocity shots that can only accommodate a short ramp (fig. 3 a and b).

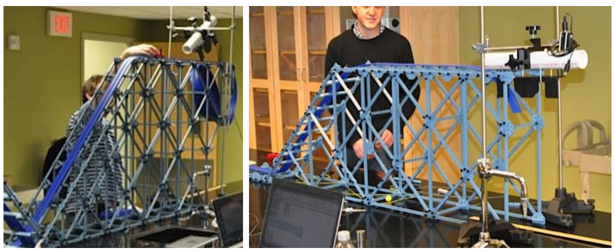

Figure 3a and 3b: Steep shot, short flat and tall ramp, vs Flat shot, long flat and short ramp

Based on the previously listed topics to be included into the final project, a set of specific project objectives was formulated, which would then serve as the basis for elaborating a set of measurable student learning outcomes. The project objectives are:

1. Apply mathematics and physics to an engineering problem
2. Apply professional engineering software tools
3. Understand that simplifying assumptions of physical systems need to be made to allow mathematical modeling of the system, and assess the validity of these assumptions
4. Experience the contradictory nature of design requirements and the iterative nature of the design process. Recognize the need for a structured approach.
5. Recognize the importance of testing assumptions with prototypes of subassemblies[3]
6. Develop the ability to bound and explore the design space to better understand system behavior
7. Recognize the need for and be able to develop appropriate simulation tools using the computational tools studied
8. Practice professional communication

These objectives then map to measurable outcomes as follows:

Learning outcomes	Project Objectives 1	2	3	4	5	6	7	8
ability to create CREO parts and assemblies		x		x				
ability to write MatLAB scripts		x					x	
ability to apply programming structures to physical problems	x					x	x	
ability to write technical reports to set standards								x
ability to elaborate and follow GANTT charts				x				
ability to follow the design process				x				
ability to model a system using mathematics and physics	x		x					
ability to orally present the results of their work								x
ability to design and conduct an experiment	x				x			

Figure 4. Project Objectives – learning outcomes mapping

These specific learning outcomes were then quantitatively assessed and constituted the graded components of the project portion of both participating courses. In addition, a qualitative summative assessment of the objectives was carried out in the form of a student survey.

III. Results

The deliverables for the project and their assigned weighting for the project grades in the IEN110 and IEN120 courses were:

1. Gantt Chart/Preliminary Design Review (PDR)
2. Detailed design report
3. 3D-CAD model of the ramp design
4. Critical Design Review (CDR) presentation
5. Demonstration day - design equation score
6. Post-test appendix

The total duration of the project from kick-off to when the final post-test analysis appendix was due was 4.5 weeks.

Based on these deliverables, the project was divided into the following phases:

A. Kick-off/background Data Collection (1 day)

For the project kick-off, both classes (IEN110 and 120) met concurrently for a joint integrated session, which consisted of two activities: a joint brainstorming session and a full experimental characterization of the projectile launcher that would initiate the apparatus.

After initially describing the project and its major deliverables, the instructors led a team brainstorming session with the students discussing questions such as:

- What design variables are important, and how do they depend on one another?
- How would you subdivide the complete Rube-Goldberg sequence into substeps that can be modeled with math and physics?
- What physical principles need to be accounted for, and can you assign specific principles to specific steps of the Rube-Goldberg machine?

[3] While the students were allowed to test specific subassemblies (such as the precision and accuracy of the launcher's different settings, and the energy and momentum transfer of the ball to the cart), they were not allowed to test the assembly.

- How do you interpret the design equation, and is there an optimum solution that maximizes its score value?
- What information do you need before you can begin designing? Is there a way to measure it?

This brainstorming session was immediately followed by a joint lab to collect data on the muzzle velocities and range of the projectile launcher for different settings. All of the raw data was collected and summarized by the instructors, and given back to the students to use in their individual designs.

B. Project Planning/Conceptual Design Phase -> PDR (1 week)

A week following the project kick-off, each student was required to submit a Gantt chart outlining their project plan and interdependencies of major project components. The culmination of this phase was a Preliminary Design Review, where each student met individually with faculty to describe their plan and initial thoughts on their design

C. Detailed Design Phase -> CDR (2.5 weeks)

During this phase, students were actively working the details of their design. The bulk of student's time in this phase was involved in creating their simulation tool in MATLAB and in the detailed CAD modeling.

Since the depth to which collision phenomena was presented in lecture was insufficient to model the ball/cart interaction, a test bench setup was made available during the detail design phase. The test bench setup isolated the subassembly where the ball rolled down the tube and collided with the cart on a flat track (the launcher and ramp were omitted). No specific guidance was provided to the students on what to do with this setup; the students were instructed to identify what (if any) useful data they could obtain, and then design a simple experiment to capture it. All students chose to use the setup in some way, with wide variation in the methodology of how. Most students used the setup in a very ad-hoc, qualitative manner, making few (if any measurements). The stronger academic students approached the setup with a very systematic plan and performed true quantitative assessments, varying the tube angle and cart position relative to the tube exit and measuring the resulting energy transfer from the collision.

The detailed design phase ended with the delivery of the design report, CAD model, and CDR presentations.

D. Construction Phase - > Project Test Day (3 days)

After the CDR, students had 2-3 days to build their designs (no construction was allowed until the CDR was completed) and then test them on the designated project test day. This phase ended with the testing of each student's design. A worksheet was provided where they indicated their choices for the major design variables (angle and setting of launcher, angle and location of the mouth of the receiving tube) which could not be changed once testing began. Each student was allowed ten shots, and the necessary data was collected to obtain the "score" from the design equation.

E. Post-test Analysis -> Appendix (1 week)

After their test-day experience and data collection, students were required to submit a post-test appendix comparing their actual results with what they had predicted in their design reports. This included an error analysis and a discussion of lessons-learned from the testing, detailing how (if at all) they would change their design.

IV. ASSESSMENT

A. Qualitative Formative Observations

Several formative assessment checkpoints were built in the project to help guide the design process. First year college students have very little experience managing a project of this scope with an (intentionally) open ended, non-concrete solution.

The initial faculty-led brainstorming session was an important observation point to understand initial student attitudes. While it was evident that many students were motivated and excited to be given such an assignment, it was also clear that to some this was a daunting assignment compared to their usual coursework. Nearly all students struggled with exactly where to begin. An open discussion of the design equation proved especially necessary, as few students initially understood what it represented or how it would influence their design. In later assessing project objectives 3- 7 this initial discussion was valuable to compare initial student reaction with how they executed the design process.

The first formal deliverable, the Gantt Chart and PDR outlining the student's overall plan, focused on project objective 4 and allowed assessment of learning outcome 5. Meeting individually with students one-on-one (rather than making this a presentation to the class) was meant to ensure it would be a forum for open two-way communication. While the activity was assigned a portion of the overall project grade, it was kept minimal to encourage students to see it as an opportunity to get feedback. At the conclusion of the project all students reported deviating significantly from their plan outlined at the PDR and in their Gantt chart; however, there was a clear correlation between student's scores at this assessment point and overall performance on the project as a whole. Those students who invested more time and effort up front devising a solid plan were rewarded with much stronger overall project outcomes.

During the detail design phase (the bulk of the overall project duration), dedicated in-class project time was used by faculty for ongoing formative assessment. This included both free time as well as faculty-led discussions on how the students felt the design process was unfolding. These sessions were critical for the faculty in assessing project objectives 3-7, which focus on the uncertain nature of design problems that are unfamiliar to typical first year students. A couple of observations follow.

As students were working on their solution, it was apparent that a major source of difficulty for students was the concept of a "design freeze". With little experience working an open-ended design problem with firm time deadlines, students were reluctant to declare their design complete and start the documentation process (i.e., writing their report and preparing their presentation). Several students tried to do both simultaneously, changing design variables and decisions right up until the CDR, resulting in poorly written reports and/or presentations.

Another observation of interest focused on project objective 7. The computing curriculum in the IEN110 course had been designed specifically with the end of semester project in mind; previous MATLAB assignments had allowed the students to build a library of subroutines and functions that were directly applicable to the project. Most students were able to recognize that these previous assignments could be assembled together to create a simulation tool that allowed them to explore the project design space systematically, which increased the number of different design options they considered. This approach greatly enhanced student's ability to meet project objective 7. Those students who created their simulation tool from scratch spent far more time building their code than running it, resulting in consideration of far fewer design options.

B. Summative Assessment

While the formative assessment was kept primarily qualitative, the quantitative assessment of the learning outcomes concentrates on the project deliverables: the design report, the presentation and the CAD model.

The design report was the primary assessment tool for project objectives 4, 6, and 7, the MATLAB Code was designed to assess outcomes 2, 3, and 7, the CAD model outcome 1, the CDR presentations outcome 8, and the post-test analysis outcomes 4 and 9. Technical writing of this scope is not common for first year students, and the results reflected that with wide-ranging quality. Compounding the problem was the situation discussed above where several students left little time for documenting their design. A major lesson learned from this experience is that first year students need assistance with their time management. A "design freeze" event, with an appropriate associated deliverable preventing students from continued design iteration and dedicating them full time to documenting the results would have resulted in improved outcomes for the report and presentation.

While the performance equation presented above was also used as an assessment tool, its primary purpose was to ensure that the design space admitted several potential solutions. It was intentionally crafted to avoid any single obvious optimum design so that students would explore the entire set of solutions and come up with different answers from one another. The results of the scores measured from the testing day indicated this to be a success; student's proposed solutions varied wildly, while the scores output from the performance equation were mostly uniform. Differences in scores between students were primarily attributed to execution (how successfully they modeled and simulated the physics) rather than which point in the design space they chose as their solution.

C. Summative Assessment – Student Survey

To assess the project objectives focusing on the student's design experience (objectives 3, 4, 6, and 7) a survey was administered at the conclusion of the project. The survey was comprised of 19 questions written to assess the project objectives. Questions were categorized by objective and the results of individual questions pooled. Student responses were measured with the following scale: 1 = strongly disagree, 2 = somewhat disagree, 3 = somewhat agree, 4 = strongly agree. With such a small cohort size (n = 9 students) the results presented are not meant to imply any statistical significance; rather, the results are useful simply as a guide to identify trends and student satisfaction with the project.

The results of the survey are presented by project objective in Figure 5. Higher question score values indicate stronger agreement by the student and are considered indicative of success in achieving the particular objective. As an example, one survey question grouped under objective number four asked for student's agreement on the statement: "I had to iterate a number of times to arrive at my final design". An average score of 3.5 for this question suggests that the project was successful in giving the students an experience reinforcing that design problems are often iterative. This question was then pooled with similar (but different) questions relating to objective four and then averaged to arrive at the aggregate score for Objective 4. The plan is to repeat the project and survey with additional cohorts in following years to increase the size of the data set to draw more meaningful quantitative conclusions.

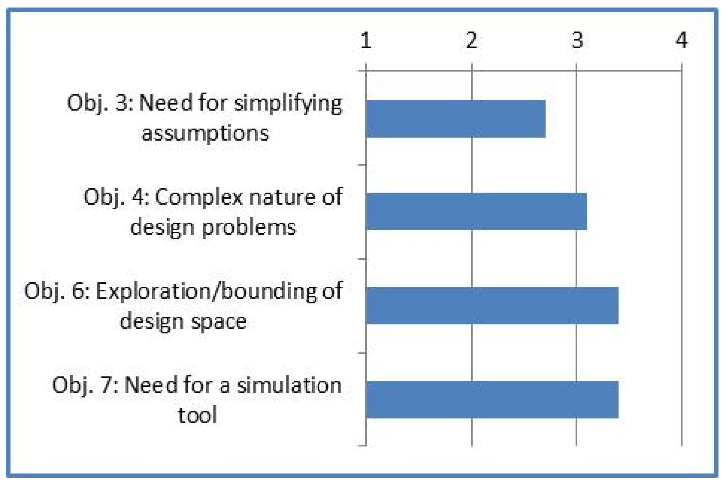

Figure 5: Student Survey Results (1 - Strongly Disagree, 4 - Strongly Agree)

Greatest student agreement was observed for Objectives 6 and 7. Students were quick to appreciate the need for a simulation tool to evaluate a large number of design options within the time constraints of the project. Weaker agreement (but still generally positive) was found for Objective 4, assessing students' appreciation for the complex, unstructured nature of design problems. Lastly, the weakest student agreement was found for Objective 3, asking about the need for simplifying assumptions. One of the requirements in selecting this particular project was to keep the level of physical phenomena in reach for a first year student. Consequently, the physical principles were fairly well defined, perhaps leading to the students' failure to appreciate how important simplifying assumptions can be to a design problem.

V. Conclusion

Overall, the project objectives described above were assessed as successful. Survey responses indicated that students were exposed to and gained an appreciation for challenges unique to design problems. In addition to the survey results presented above, additional questions, not linked to specific project objectives, were asked to gauge the level of student satisfaction with the project. These project satisfaction questions scored the highest for student of all the survey questions asked. More significantly, write-in comments on the survey from the students were consistent in pointing out how motivating and interesting the project was. The major lesson learned, that first year students' project and time management skills need extra attention, will be addressed in future cohorts.

The design-related outcomes associated with the project are thought to be a critical component to the mission of the BEP. An end of semester design experience proved to be an excellent activity for instilling and measuring these outcomes, with high student satisfaction and motivation in the project. The experience in developing this project can be generalized to other courses within the BEP curriculum. The extra focus needed to be spent in the first semester on soft skills such as time management, structuring a solution approach, making simplifying assumptions, etc. suggests a longitudinal approach to the end of semester projects within the BEP curriculum. The level of faculty support with time management and oral and written presentation skills can be pared back as students gain more experience and the technical level of the subject matter rises.

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Implementation of Just in Time and Revamped Engineering Math Courses to Improve Retention and Graduation Rates

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***Abstract* - We have created Just in Time Math (JITM) course for freshmen engineering students who show deficiency in math. The result has shifted the traditional emphasis on math prerequisite requirements for engineering classes to an emphasis on *engineering motivation* for math, with a "just-in-time" structuring of the new math sequence. Students still have to follow the traditional math sequences, however, the pre-requisites for some of the core engineering courses have changed from Calculus I to the newly developed Math classes. We have also incorporated engineering examples into the traditional and engineering mathematics courses. Since 2009, we have been offering cohorts of about 25 engineering freshmen every fall on a voluntary basis. The preliminary results indicate moderate improvements in the retention rate and GPA of participating students.**

Keywords—engineering math; retention and graduation rates

I. Introduction

There are a variety of bases that influence student retention and graduation rates in engineering [1-3]. Most academicians believe that lack of preparation in high school, especially in the areas of mathematics and physics, along with lack of motivation contribute to low retention and graduation rates. Additionally, the retention problem is more severe among underrepresented groups. Early intervention programs such as summer immersion camps, learning communities and math boot camps have moderately alleviated this problem [3-4]. In addition, to raise the level of motivation for pursuing engineering degrees, in recent years the engineering educators have infused engineering applications early in the curriculum. In numerous institutions, including UTSA, this has led to the creation of the freshman engineering courses (such as EE1323 Introduction to Electrical Engineering Profession at UTSA) that expose students to the applications of math and physics in designing and constructing the digital devices, such as DVD players and video cameras, that most freshmen are familiar with. Although the freshman engineering course plays an important role in motivating students and exposing them to the engineering profession early on, it is not considered a core engineering class. Typically, engineering students must pass Calculus II in order to enroll in a core engineering class such as Statics and Electric Circuits.

One issue that has been overlooked for many years is the math sequence that engineering students must finish before taking any core engineering class. For most students it takes three to four semesters to reach to a level that enables them to take engineering classes. During this period, students have no significant interaction with the engineering faculty, and it is also during this period that we suffer the most egregious retention problems in engineering. The purpose of this project is to revamp the engineering curriculum in order to shorten the time that it takes students to prepare for engineering core courses. As a result, students will be engaged in their field of study from the beginning. We strongly believe this will encourage students to continue their study in the college of engineering.

We have incorporated the ideas from the newly developed course, known as EGR 101 "Introductory Mathematics for Engineering Applications" at the Wright State University by Professor Klingbeil to create a Just in Time Math (JITM) for freshmen engineering students who show deficiency in math [4]. The WSU model concludes with the development of a revised engineering math sequence, to be taught by the math department later in the curriculum, in concert with College and ABET requirements. The result has shifted the traditional emphasis on math prerequisite requirements to an emphasis on *engineering motivation* for math, with a "just-in-time" structuring of the new math sequence. At the University of Texas at San Antonio (UTSA), the changes in the engineering courses are not as drastic as WSU. Students at UTSA still have to follow the traditional math sequences (Calculus I, Calculus II, etc.). However, the pre-requisites for some of the core engineering courses have changed from Calculus I to the newly developed Math classes. We have established the laboratory and developed the course materials and revamped the engineering curriculum. Thus, we have also incorporated engineering applications into the traditional Calculus and

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Engineering Mathematics courses in order to maximize the students' exposure to the applications of mathematics in engineering problems. Since 2009, we have been offering the newly developed curriculum to cohorts of about 25 engineering freshmen every fall on a voluntary basis.

II. STRATEGY

Incoming engineering freshmen at UTSA begin their study with calculus I as the first required math course. Although the majority of them pass calculus while in high school, unfortunately, about 60% of them fail the placement test and are not qualified to register in the Calculus I course. Typically, students are required to take Calculus I followed by Calculus II and Physics classes in order to satisfy the pre-requisite requirements for the core engineering classes. Considering mathematics and science deficiencies among our students, it usually takes several semesters for the majority of them to register in the basic engineering classes. Through our previous funded projects, which provided opportunities for undergraduates to participate in research laboratories, we have learned that when students interact with engineering faculty and peers at the early stages of their studies, they have a better chance of graduating within 4-6 years.

Our new revamped engineering curriculum based on the implementation of JITM course increases the interaction between new comers and engineering faculty and peers during the initial semesters. As a result, we expect to perceive more enthusiasm about engineering among students, better retention and graduation rates. In addition, since students graduate at a faster pace, the implementation of the new curriculum will reduce the overall cost of college education for both the institution and students. Table 1 shows the traditional engineering curriculum versus the revamped curriculum. The underlined courses are the deficiency classes and the courses shown in bold are the basic engineering courses that are required before taking higher level engineering courses. The courses shown in italic are either new or redesigned courses. The courses indicated as "Core" are the required general core courses for the entire university population. As shown, following the proposed curriculum, students can register for basic engineering courses such as statics and network theory in their second semester. Taking and passing these gateway courses early provides opportunity for students to get involved in their engineering curriculum and interact with engineering faculty and peers sooner.

TABLE I. TRADITIONAL VS. REVAMPED CURRICULA

Term	Traditional Curriculum	Proposed Curriculum
1	Pre-Calculus, Core Courses	*Just in Time Math*, Core Courses
2	Calculus, Core Courses	**Statics,** *Calculus for Engineers*, Physics I, Computer Programming, Core Courses
3	Calculus II, Physics I, Computer Programming, Core Courses	*Calculus II*, **Circuits**, **Dynamics,** Physics II, Core Courses
4	**Statics**, **Applied Engineering Analysis I,** Physics II, Core Courses	***Applied Engineering Analysis I,*** Required Engineering Courses, Core Courses
5	**Dynamics**, **Circuits**, **Engineering Analysis II,** Core Courses	***Applied Engineering Analysis II***, Required Engineering Courses
6	Required Engineering Courses	Required Engineering Courses
7	Required Engineering Courses	Elective Engineering Courses
8	Elective Engineering Courses	Elective Engineering Courses
9	Elective Engineering Courses	

III. SETTING AND PARTICIPANTS

The objectives of our longitudinal study are:

1) To create a new mathematics sequence, with the engineering applications, in order to prepare students for the basic engineering classes during their freshman and sophomore years.
2) To revamp the engineering curriculum based on the changes in the mathematics sequence.
3) To develop a continuous quality improvement (CQI) model to monitor, track, control, and feedback performance outcomes on our program.

A. Just In Time Math

As taught at UTSA, Freshman Seminar/JITM is a combination of topics offered to help a Freshman engineering student to make the adjustment from high school to university life, and to review and learn the mathematics employed in first and second year engineering courses such as statics, dynamics, electrical circuits, and mechanics of solids. The course is taught under the auspices of UTSA Learning Communities (LC), and includes student success topics such as preparing for class meetings, note taking, how to study, learning one another's names, advantages of group study, meetings with faculty during office hours, time management, and the importance of not falling behind during the semester. LC requires that students attend classes regularly, write two or more papers on themes suggested by LC and by the instructor, make an oral group presentation to the class, attend an orientation on library resources, and attend/participate in a minimum of 3 university life functions. These topics, as well as an introduction to engineering as a profession, are all addressed in Landis' Studying Engineering textbook[5].

The JITM features lectures and exercises on topics such as linear equations and quadratic equations, trigonometry (including applications of law of sines and cosines), matrix operations, complex numbers, harmonic functions, differentiation, integration, and first and second order linear ordinary differential equations. Homework problem sets are assigned for each topic, and a series of eight laboratory experiments or demonstrations are used to illustrate concepts. The book by Rattan and Klingbeil is used as a class text book [6].

Several of the laboratory experiments/demonstrations require students to plot their results in graph form. MATLAB is introduced for this purpose to manipulate and graph experimental data and to perform a variety of mathematical operations and numerical solutions. At UTSA, MATLAB is available for student use in computer labs, and online from UTSA Apps outside of class. MATLAB tutorials using the textbook by Gilat are incorporated into the schedule [7].

The laboratory experiments/demonstrations illustrate concepts and introduce the student to experimental error. Lab #5, Freefall Application of the Derivative is a good example. The laboratory apparatus was purchased from PASCO and consists of a paper tape and a counter which stamps (marks) the tape every 1/40 second by tapping a piece of carbon paper against the tape. A weight (about 0.3 kg) is attached to the end of the tape, and is allowed to fall about 1 m distance to the floor. As the weight falls, the tape is pulled through the counter and marks are stamped onto the tape. It takes about 0.4 seconds to perform the experiment. The tape is recovered, placed on a table, and student measures the distance of each mark from the start (the first set of marks) using a meter stick. The data for distance as a function of time is recorded by students in a spreadsheet. The instantaneous average velocity is approximated by the first difference function, $v(t) = [y(t) - y(t - 0.025)]/\Delta t$, and the instantaneous acceleration is approximated by the second difference function, $a(t) = [v(t) - v(t - 0.025]/\Delta t$.

Students are then asked to plot their data for distance, velocity and acceleration using MATLAB. When plotting the data for distance, they also use the MATLAB basic fitting function to calculate a least square error curve fit for a quadratic function to their data. Typical graphs for position, and acceleration as a function of time are shown in Figs. 1 and 2.

The position curve in Fig. 1 appears to be smooth, but the acceleration data is erratic. As students plot the data, a discussion of why the acceleration data is so variable is held. Also of interest is the quadratic curve fit to the position data which suggests that the acceleration was about 9.0 m/s^2 and not 9.8 m/s^2 as expected. Free body diagrams were discussed earlier in the course, and a free body diagram is used again together with Newton's second law to account for the lower than expected value of acceleration. The possibility that friction caused by the striker bar pushing the paper tape against the sheet of carbon paper is responsible for some of the error is discussed.

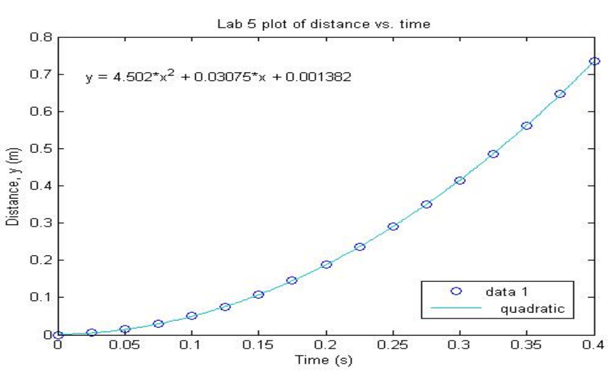

Fig. 1. Plot of lab 5 data for position vs time

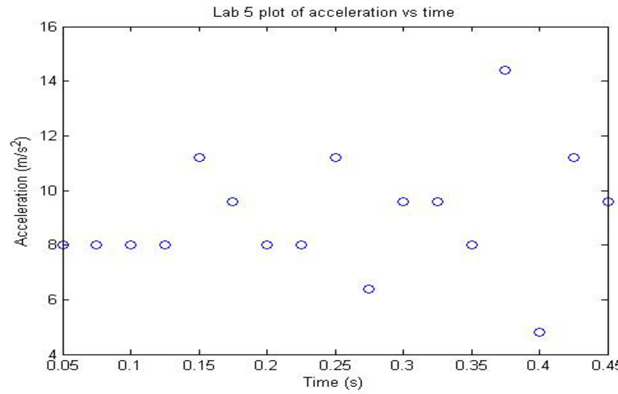

Fig. 2. Plot of Lab 5 data for acceleration vs. time

B. Calculus for Engineers

The Calculus for Engineers, which replaces Calculus I, is a new Calculus course with engineering applications. The Department of Mathematics and College of Engineering have established a fruitful collaborative relationship. At the request of the College of Engineering, the Department of Mathematics has begun a reconstruction of the Calculus sequence generally with particular emphasis on the development of calculus sections focused on students pursuing degrees in Engineering. There is much more to be done, but to this point Mathematics has set aside special sections for engineering students in which there have been some curricular changes (e.g., increasing the focus on applications), re-sequencing of some topics and the engagement of instructors with an understanding of the engineering perspective. The College of Engineering and Mathematics Department have conducted a series of workshops for the math instructors to discuss the infusion of engineering applications in calculus. Examples of the discussion topics include: application of fractional calculus in dynamical systems, and application of integrals to characterize non-uniform media. Since the fall of 2011 the College of Engineering has also provided tutoring sessions, conducted by engineering Teaching Assistants, for the calculus courses. with engineering Teaching Assistants. Overall, tutoring has improved the math grades for engineering students substantially.

C. Engineering Analysis

In the JITM and Calculus for Engineers, students are guided to get familiar with contemporary issues in engineering, use of computer-based tools, and presentation skills. The freshman curriculum should prepare students for the sophomore level Engineering Mathematics course, known as Engineering Analysis I, EA1. By the time students are registered for the EA1, they should be familiar with the basic engineering terminologies and direct experience/observation in the engineering applications. To further improve their readiness for more advanced engineering classes, we will also incorporate application of math in engineering topics by adding physical measurements to the content of the EA1. The

EA1 focuses on the application of mathematical principles to the analysis of engineering problems using linear algebra and ordinary differential equations. It also emphasizes the usage of software tools to facilitate the learning process. Topics covered in this course include: mathematical modeling of engineering problems; separable ordinary differential equations (ODE's); first, second, and higher-order linear constant coefficient ODE's; characteristics equation of an ODE; systems of coupled first-order ODE's; matrix addition and multiplication; solution of a linear system of equations via Gauss elimination and Cramer's rule; rank, determinant, and inverse of a matrix; eigenvalues and eigenvectors; solution of an ODE via Laplace transform; and numerical solution of ODE's. We have utilized the Matlab tools to incorporate engineering applications in this course by creating several simulation modules that can be used throughout the semester. Examples of such modules include time and frequency analysis of electric circuits (first, second and higher order ODE's); stability analysis of control systems (matrix algebra); and deformation of solids by forces (eigenvectors).

For the EA1, the knowledge points we o emphasize in the redesigned course include: matrix multiplications, eigenvalue decomposition, and solutions of partial differential equations. In order to fulfill the aforementioned three aspects, we have established 6 experiments for EA1. We have utilized MATLAB toolboxes to open several graphical user interface (GUI) boxes to implement these experiments. The following six experiments exhibit the assignments for the electrical engineering students in EA1. Similarly, we plan to establish new sets of experiments established for other engineering majors.

- Laboratory 1: *"Complex Numbers"* – An application on complex numbers, provides the possibility to enter numbers and visualize them in a complex plane

- Laboratory 2: *"Sinusoids"* – An application on studying and visualizing sinusoids. User can select different sinusoid parameters.

- Laboratory 3: *"RLC Circuit"* – An application simulating second order RLC Circuit where student can change R, L, and C parameters and display different results.

- Laboratory 4: *"Spectra Estimation"* – An application which demonstrates the use of matrix multiplication for spectra estimation using Discrete Fourier Transform (DFT) matrix. One can choose different type of signals, perform DFT and display the results.

- Laboratory 5: *"Compression"*– An application on using matrix multiplication and inversion for compression of images. It also demonstrates the use of Eigen value decomposition. The following matrices (1) Discrete Cosine Transform (DCT) matrix; (2) matrix composed of eigenvectors are used for the compression of images similar to JPEG format. Inverse transforms are used to reconstruct original signals with slight degradation in quality.

- Laboratory 6: *"Equalization"*– An application on using matrix multiplication, transposition and inversion for signal equalization used in communication systems to improve the reception quality.

Fig. 3 depicts the result from one experiment. The GUI shows how matrix algebra is used in solving engineering problems. It demonstrates matrix multiplication concept on the example of spectra estimation used in wireless communications, and eigen decomposition used in image compression applications.

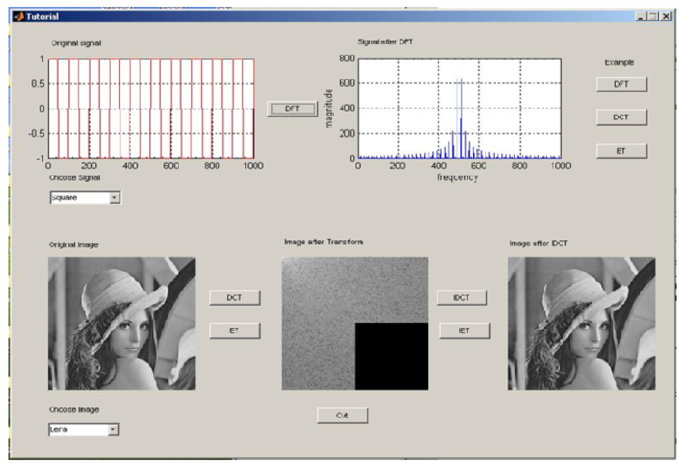

Fig. 3. Application of matrix multiplication in spectrum estimation and image compression.

IV. DATA COLLECTION

The assessment includes one factor (Program) with 2 levels (Pilot and Traditional) with 3 dependent variables that measure quality (Grade), system reliability (Retention - RET), and time (Progress Toward Degree - PTD), along with Nuisance factors (NF). The general function is shown in Equation 1.

$$(GPA, RET, PTD) = f(Program, NF) \quad 1$$

Retention is defined as the ratio of those cohorts in engineering versus the total number that began. PTD is especially important given the impetus placed on 6 year graduation rates by the State. Loosely defined, it is quantified as the ratio of number of degree catalog hours earned to the targeted number of degree hours at any point in time. As depicted in Fig. 4, would measure, at calendar time t, the ratio of completed (x) versus targeted (y) degree hours based on an N-yr graduation rate. It can be seen that when t = the actual t (ta) the student is just on track to finish in N years.

Fig. 4. Progress Toward Degree metric variables.

Several nuisance variables are accounted for as well. These are factors, shown below, that can influence the value of the dependent variables other than the treatment of interest and are not of direct interest in this assessment: college GPA (if exists); gender; ethnicity; rank of high school; math placement test score; SAT/ACT math and overall scores; engineering major; math entry level - MEL (traditional program cohorts have 2 MEL levels – Calculus II and Calculus I ready; the Pilot program cohorts have 1 MEL level – pre-calculus ready. Since the sample size is small for Calculus II ready cohorts, these students will not be included in this study. Therefore, Traditional program cohorts are those that enter UTSA Calculus I ready).

V. Data Analysis

The data collected at the end of each semester indicate that the retention rate and cumulative GPA for cohort students who participate in this study are superior compared to those of the traditional cohort. Table 2 exhibits the results for the last 3 years. In addition, Fig. 5 demonstrates the grade distribution for the Calculus I course for tutored vs. non tutored students. Based on the retention rates, we predict 4^{th}, 5^{th}, and 6^{th} year graduation rates of 30%, 45% and 60%, respectively, for the project cohorts. Meanwhile, the same graduation rates for our traditional cohorts are about 18%, 30% and 40%, respectively.

TABLE II. Retention Rates For the Project Cohorts vs. Traditional Students

	Project Cohort		**Traditional Cohort**	
	Retention	**GPA**	**Retention**	**GPA**
1^{st} year	92%	2.90	71%	1.87
2^{nd} year	82%	3.10	63%	2.79
3^{rd} year	72%	3.02	48%	2.75
4^{th} year	64%	2.96	40%	2.60

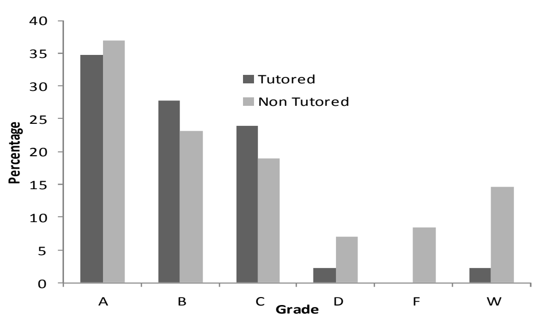

Fig. 5. Grade distribution in Engineering Calculus

VI. Summary

We have discussed the implementation of the newly developed JITM course along with the revamping of the traditional calculus and engineering mathematics courses in order to improve retention and graduation rates of engineering students at UTSA. In addition, a revamped version of the engineering curriculum has been discussed. Cohorts of students have been selected on a volunteer basis to follow the modified version of the curriculum. The primary objective for this project is to help prepare students for the basic engineering courses during their freshman year. Our initial assessment indicates a substantial improvement in the retention rates among the cohorts in comparison to the traditional cohorts. This study was initiated with 12 pre-freshman students in the summer of 2008 at UTSA. Since then, the JITM course has been taught regularly at least twice per year, either during fall and spring or fall and summer semesters. The average enrollment per semester has been about 20 students. The average grade distribution for the JITM class is A (29%), B (37%), C (25%), and D, F, and W (9%). The overall average GPA for the course is 2.83/4.0.

Acknowledgment

The support for these projects has been provided by the following agencies for the past couple of years: University of Texas System, US Department of Education (project number P120A090003) and a sub-agreement with the Wright State University, under NSF prime agreement DUE-0817332. We are also grateful to Professors Thomas Morrow and David Akopian for developing experiments for JITM and EA1 courses.

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A Web-Based Interactive Intelligent Tutoring System for Undergraduate Engineering Dynamics

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***Abstract*—A web-based interactive intelligent tutoring system was developed and assessed in an engineering dynamics course. The system consists of two learning modules to help students learn how to apply the Principle of Work and Energy to solve particle and rigid-body dynamics problems. Student learning gains were compared using a quasi-experimental research design that involved pretests and posttests in both a control semester (n = 62) and a treatment semester (n = 44). It is shown that the ITS modules increased student learning gains by 37-43%.**

Keywords: Intelligent tutoring system; quasi-experimental design; student learning gains; engineering dynamics

I. INTRODUCTION

Nearly all mechanical, civil, aerospace, and biomedical engineering students are required to take engineering dynamics, a core undergraduate engineering course [1]. This sophomore-level course is a fundamental building block for many advanced studies in subsequent courses; e.g., vibration, system dynamics and control, and machine and structural designs. However, many students fail dynamics. On the standard Fundamentals of Engineering examination in 2009, the national average score on the dynamics exam was only 53%.

An intelligent tutoring system (ITS) is an interactive learning tool that allows students to solve technical problems with the guidance of a virtual tutor [2]. During problem solving, students can ask the virtual tutor questions or request hints on what to do next, just as may occur in a real classroom environment where students can ask a human tutor questions or request hints. A properly-designed ITS is particularly helpful for large classes where instructor-student interaction and one-on-one tutoring time are limited.

In our recent efforts to improve student learning in an engineering dynamics course, a web-based interactive ITS consisting of two learning modules was developed. These ITS modules help students learn how to apply the Principle of Work and Energy to solve particle and rigid-body dynamics problems. Literature review, such as [2, 3], showed that the existing ITSs were developed for courses such as computer-aided modeling and design, circuit analysis, and physics. With the exception of the authors' own work, no other ITS has been developed for any engineering dynamics courses.

In this work-in-progress study, the effect of the two ITS modules on student learning in an engineering dynamics course was investigated. The research question is: To what extent did the developed ITS modules improve student learning in engineering dynamics? To answer this question, a quasi-experimental research method that involved pretests and posttests in both a control semester (n = 62) and a treatment semester (n = 44) was employed. Student learning gains in the two semesters are compared. Conclusions are made at the end of the paper. Beyond this work-in-progress study, future research will be focused on a mixed-methods study of how the ITS improves student learning in engineering dynamics.

II. AN ITS FOR ENGINEERING DYNAMICS

Using the Cognitive Tutor Authoring Tools [4], we have developed two web-based interactive ITS modules for students to learn the Principle of Work and Energy in particle dynamics and rigid body dynamics. Both modules contain a carefully-designed set of hints to provide students with step-by-step guidance for problem solving.

As an example, Figure 1 shows a computer graphical user interface of the second ITS module. In this problem, an external moment is applied to a rotating disk that is linked with a spring. Students must identify a correct free-body diagram, calculate the work done by all forces and moments, calculate the initial and final kinetic energy of the disk, and finally apply the Principle of Work and Energy to determine the angular velocity of the disk after it moves a given distance.

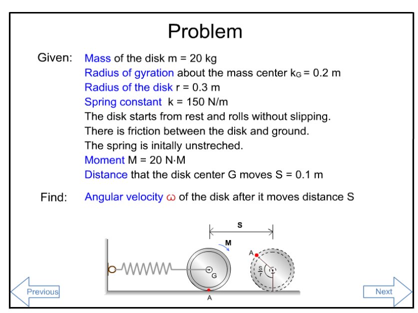

Figure 1. A rigid-body dynamics problem.

Based on students' common misunderstandings, we have developed a set of hints and incorporated them into the ITS module for use in problem solving. As an example, Figure 2 shows a hint explaining why the normal force (that is applied to the disk) does not do work.

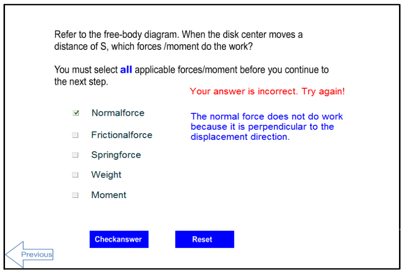

Figure 2. An example hint.

III. RESEARCH METHOD AND STUDENT PARTICIPANTS

Employed was a quasi-experimental research method that involved two cohorts of sophomore engineering student participants in a control semester and a treatment semester. The same instructor taught in both semesters. Table I shows the number of students in each semester for each ITS module. The results of t-tests showed that there were no statistically significant differences in pretest scores of two cohorts of students in the two semesters.

TABLE I. STUDENT PARTICIPANTS

	ITS module 1	ITS module 2
Control semester	n = 62	n = 55
Treatment semester	n = 44	n = 36

We have also designed a set of multiple-choice, technical assessment questions for use in pretests and posttests in both semesters. For ITS module 1, there were six assessment questions; for ITS module 2, seven assessment questions. These questions had a variety of levels of difficulty. The student learning gain was calculated for each student as

$$\text{Learning gain} = \frac{\text{Post-test score (\%) - Pre-test score (\%)}}{\text{100 (\%) - Pre-test score (\%)}} \quad (1)$$

IV. RESULTS

Based on the learning gain of each student, the class-average learning gain was calculated in both semesters, and the results are shown in Table II.

TABLE II. CLASS-AVERAGE STUDENT LEARNING GAINS

	ITS module 1	ITS module 2
Control semester	12.9%	7.0%
Treatment semester	49.7%	50.0%

As seen from Table II, the class-average learning gains in the control semester were only 12.9% (for ITS module 1) and 7.0% (for ITS module 2). The class-average learning gains in the treatment semester increased to 49.7% (for ITS module 1) and 50.0% (for ITS module 2). Therefore, it is concluded that the ITS modules increased student learning gains by 37-43%.

As two examples, Figures 3 and 4 show the percentages of students who chose correct answers to seven assessment questions used in pretests and posttests of ITS module 2 in the control and treatment semesters. Student learning was improved in all assessment questions except question 7. Question 7 requires students to *synthesize* both conceptual and procedural understanding to finally solve the problem. How to improve students' skills for knowledge synthesis still remains a great challenge for the ITS.

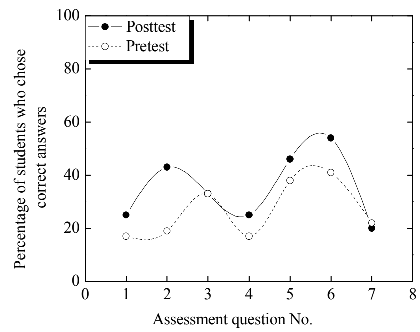

Figure 3. The control semester: students did not use ITS module 2.

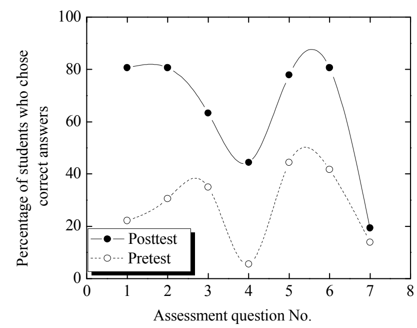

Figure 4. The treatment semester: students used ITS module 2.

V. CONCLUSIONS

In this WIP study, a web-based interactive intelligent tutoring system has been developed and assessed in an engineering dynamics course. The comparison of student learning gains in a control semester and a treatment semester shows that the intelligent tutoring system that we developed increased student learning gains by 37-43%. In the future, we plan to conduct a mixed-methods study to investigate how students use the ITS to learn engineering dynamics.

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Testing the Flipped Classroom with Model-Eliciting Activities and Video Lectures in a Mid-Level Undergraduate Engineering Course

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***Abstract*—This paper outlines an ongoing study of the flipped classroom with second and third-year undergraduate engineering students in a numerical methods course. The flipped classroom is a new pedagogical method, which employs asynchronous video lectures and practice problems as homework, and active, group-based problem-solving activities in the classroom. It represents the combination of learning theories once thought to be incompatible—active, problem-based learning activities founded upon constructivist ideals and instructional lectures derived from direct instruction methods founded upon behaviorist principles. Using a controlled quasi-experimental research design, we conduct a study with a full 15-week numerical methods course at Utah State University during the spring semester of 2013. Students in the experimental section completed model-eliciting activities inside the classroom and video lectures and homework outside the classroom. Students in the control section completed homework outside the classroom and group lectures inside the classroom. The two groups will be compared using scores from homework, examinations, and a sixteen-question numerical methods conceptual pre- post- test pair. The three main features that distinguish this study from previous research are: 1) This is a controlled study; 2) This study examines student performance on objective measures; 3) This study uses model-eliciting activities in the experimental classroom.**

I. Introduction

Many engineering graduates lack the ability to solve the type of real-world problems that will be encountered when they enter the workforce; however, these same students are well trained in solving textbook problems that require little more than the ability to determine which formula to apply based on which section of the textbook it appears in [1, pp. 39]. This represents a major shortcoming of the education currently offered in our institutions. The Accreditation Board for Engineering and Technology (ABET) has introduced outcomes a-k in part to formalize these concerns, and to charge university programs with addressing them [2].

Pedagogical approaches such as Problem Based Learning, Active Learning, and Peer Assisted Learning have been introduced for teaching these skills. More recently, Model-Eliciting Activities (MEAs) have been/are being developed and implemented based on many of these same theories [3], [4] to help engineering students develop real-world teamwork [5], [6], problem solving [7], and communication skills [8].

Despite these advances, even where active learning methods such as MEAs have been implemented, this implementation is typically limited. As an example, MEAs have been introduced at Purdue University only with first-year engineering students. At the other end of the curriculum, senior-level students at most universities typically participate in a capstone design project. However, for the majority of their undergraduate carreer, students still deal exclusively with "textbook problems." There is significant institutional resistance to comprehensive change. This may be due to anxiety over changing core courses, or to the perceived impossibility of cramming more into an already full curriculum. The situation seems to be at a stalemate with innovative educators recommending a more holistic approach, and institutions reluctant to give up traditional lectures and homework.

The flipped classroom teaching model may allow both sides to get what they want. In the flipped classroom model, lectures are pre-recorded, and played back by students on their own time[1]. Individual homework is also completed outside of class. In essence, the entire educational experience currently being provided in the classroom can now be obtained online. Despite the fears and over-reactions of some, this does not mean that institutions will be out of business. Rather, lectures and homework can be completed outside of class, while active learning activities take place within the classroom. Thus, it may no longer be an either-or proposition, with lectures and homework on the one hand and active learning on the other.

While the flipped classroom model seems to be a promising method for improving student learning and conceptual understanding, there is unfortunately limited evidence of its effectiveness. A recent survey of the flipped classroom research [9] found that while a number of papers have been published about the flipped classroom, almost none of the studies described in these publications used controlled research designs or reported outcomes of the flipped classroom on objective test measures. This provides the primary motivation for the current study.

II. Research Questions

The main purpose of this research is to begin the process of objectively evaluating the effectiveness of the flipped classroom. It is reasonable to assume that in order for the flipped

[1]While there is not universal consensus on what the flipped classroom is, our definition here captures much of what is currently being called the "flipped classroom."

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classroom to be successfully adopted in universities, students from classrooms using this model must attain at least the same level of performance as students in current classrooms on traditional performance evaluations (e.g., homework assignments and unit examinations). Failure to meet this criteria would represent a significant barrier to adoption. This forms the basis of the first research question: Will students in a numerical methods course taught using the video lecture/MEA format attain equal or higher learning performance than students in a traditional lecture-based course, as measured by student homework and exam scores?

The second fact that must be faced is that unless students in the flipped classroom gain something over students in current classrooms, there is little need to adopt this model. To this end, we examine student performance on another construct: conceptual understanding. The effort to measure conceptual understanding as a dimension distinct from what typical teacher-constructed tests evaluate is epitomized in the development of the Force Concept Inventory (FCI) [10]. Adams and Wieman [11] describe the appropriate process of creating and validating this type of test. No well-researched and rigorously established concept test for numerical methods is available; however, the development of such a test is underway [12]. We use a preliminary 16-item version of this conceptual numerical methods test to evaluate the second research question: Will students in a numerical methods course taught using the video lecture/MEA format attain equal or higher conceptual understanding than students in a traditional lecture-based course, as measured by a concept test?

III. Research Design

A. Course & Participants

ENGR 2450, Numerical Methods for Engineers, is a three-credit sophomore-level engineering course at Utah State University in Logan, Utah, which is usually offered each spring semester. It is required for engineering students in five majors: Biological Engineering, Environmental Engineering, Civil Engineering, Environmental Engineering, Computer Engineering, and Electrical Engineering. Enrollment totals for the Spring 2013 academic semester, and information regarding gender and declared major for students is shown in Table I. Ethnicity data for students enrolled in the course was not directly available. However, 83% of students at Utah State University are white non-Hispanic. Three courses are required as pre-requisites to ENGR 2450: Linear Algebra and Differential Equations, Introductory Programming, and Calculus II. However, ENGR 2450 and Linear Algebra and Differential Equations may be taken concurrently. ENGR 2450 meets three times a week for 50 minutes. There are a total of 45 class periods over the course of the 15-week semester. One of these is a 110-minute period reserved for the final exam. Seven general topics mirroring those presented in the required text [13] are introduced in this course. These include number representation and error analysis; root-finding and non-linear equations; numerical linear algebra; interpolation, polynomial, approximation and curve fitting; integration and differentiation; ordinary differential equations; and partial differential equations.

Table I
Demographics for Students in ENGR 2450 Spring 2013

		Section			
		C	T	Total	Percent
Gender	Female	17	10	27	16.46
	Male	68	67	135	82.32
	Not Available	2	0	2	1.22
Major	Biological Engineering	23	6	29	17.68
	Civil Engineering	29	32	61	37.20
	Computer Engineering	10	8	18	10.98
	Electrical Engineering	15	21	36	21.95
	Environmental Engineering	2	4	6	3.66
	General Engineering	4	4	8	4.88
	Mechanical Engineering	3	1	4	2.44
	Other	1	1	2	0.61

Note. Section: C = Comparison Group; T = Treatment Group.

B. Treatment Section

The treatment section of the course was redesigned to integrate web-based video lectures and model-eliciting activities. The same topics were presented in the same order, except that all in-class lectures were supplanted by web lectures. Among the recommendations for best practice noted in the literature, a quiz or pre-class activity is said to provide motivation to watch the video lectures, and establish continuity between web lectures in-class activities [14], [15]. Consequently, a short quiz on the corresponding lecture material was required before class starts. Classroom attendance is required. The first topic of discussion in every class will be on the questions from this quiz.

Two MEAs are being conducted throughout the semester, with each MEA spanning approximately six weeks. Working in groups of 3-4, students were required to complete a total of three drafts of their work for each MEA. Each group both provided and received peer feedback between the first and second drafts of the MEA memo. Between the second and third drafts, students receive feedback from a graduate teaching assistant.

C. Comparison Section

The comparison section of ENGR 2450 is being taught in the usual manner. Specifically, thirty-four class periods will be used for in-class lectures and review. Ten class periods will be used for administering the concept test and examinations. Only minor changes will be made to ensure equivalence between the experimental and comparison section. For example, students in both sections will have access to similar written materials, and students in the comparison section will complete programming assignments in order to offset the time spent on MEAs by the students in the treatment section.

IV. Results

Results are forthcoming, and will be presented at the conference.

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OpenAnswer, a framework to support teacher's management of open answers through peer assessment

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***Abstract*— Open-ended questions are an important means to support analysis and assessment of students; they can be of extraordinary effectiveness for the assessment of higher cognitive levels of the Bloom's Taxonomy. On the other hand, assessing open answers (textual, freely shaped, answers to a question) is a hard task. In this paper we describe an approach to open answers evaluation based on the use of peer-assessment: in a social-collaborative e-learning setting implemented by the OpenAnswer web system, the students answer questions and rate others' (and may be own) answers, while the teacher marks a subset of the answers so to allow the system inferring the rest of the marks. The aim of our system is to ease the teacher's marking burden and allow for a more extensive use of open ended questionnaires in her/his teaching activity.**

Keywords—assessment, peer-assessment, social collaborative e-learning

I. INTRODUCTION

Open ended questionnaires (where questions can be answered through free text writing) can play a crucial role in the activity of evaluation and analysis of a learner's knowledge.; from a pedagogical point of view, they can be of extraordinary effectiveness for the assessment of skills [1,2].

On the other hand, assessing open answers is a hard task. A good deal of research activity has been performed in this regard, applying a variety of Computer Science techniques (see Sec. II).

In this paper we describe an approach to open answers evaluation based on the use of peer-assessment in a social-collaborative e-learning setting; we implemented it in the OpenAnswer web system, where a student answers questions, rates others' (and may be her/his own) answers, while the teacher marks a subset of the answers so to allow the system inferring the rest of the marks. The aim of our system is to ease the teacher's marking burden and allow for a more extensive use of open ended questionnaires in her/his teaching activity.

OpenAnswer allows to: 1) deliver open ended questions to groups of students; collect the open-answers; 3) collect each student's peer assessment of some of the answers given by others (and possibly by her/himself); 4) managing a student model representing learner's competence and her/his ability to assess/self-assess; 5) support the teacher's analysis and grading of the answers, by iteratively suggesting the next answer to assess so to reach a configuration in which all the remaining answers can be graded basing on the peer evaluations and the implicit endorsement derived by the teacher's marks. The student model is managed through a simple Bayesian-networks based approach, grounding on the student's given peer assessments and their correspondence to final grading of the answers related to those assessments. The next-question-to-grade mentioned at point 5 above, is selected by taking into consideration the grades actually given by the teacher, the students models computed basing on such grades, and the peer assessments available on the remaining answers. This process brings the system to eventually assigning grades on a part of the answers still not graded by the teacher. This is done by exploiting the possible trust on the students' peer assessments, as pointed out by the underlying Bayesian networks model.

So a complete grading of the starting set of answers can be reached, saving for the teacher a part of the direct grading work, and making the use of open ended questions more feasible in a didactic setting. We think that a good side effect of the use of OpenAnswer is in the students being exposed to assessment and self-assessment, which are high cognitive level activities in the Bloom's Taxonomy [2].

In previous work we have dealt with the definition of the formal models deemed to support the marking process, with a Constraint Logic Programming based approach and with a Bayesian Networks based model [3,4,5]. We hadn't yet implemented a system able to let teachers use either models, nor we performed real experimentations (limiting to simulated experimentations). Here we show the OpenAnswer web-based system, the implementation of Bayesian networks propagation and analysis, some basics of the underlying formal system, and an experimentation involving real students data.

II. RELATED WORK

Data mining with natural language processing and concept mapping have been used to summarizing questionnaires, extracting customers opinions and defining products reputation [6,7]. Mainly, in these cases, marketing and commercial applications were pursued. An overview of educational applications of the Data Mining Technology is in [8].

In [9] concept mapping is used to define and apply so-called "coding schemes" for answers: answers are labeled by such schemes to be analyzed and classified. Classification is supported by *semantic annotations*, labeling answers' parts; labels are by human "coders" applying the coding-schemes. In [10] an implementation of a (partially semi-)automatic assessment of open-answers is shown, based on the use of ontologies and semantic web technologies. The ontology formally defines the domain of knowledge related to the questions. Then the ontological labels that have to characterize the answers are expressed as "Semantic annotations". When also the answers have been labeled in terms of the ontology, they can be analyzed, by evaluating the similarity of their ontological labels against the question's ones. Such evaluation is followed by grading.

In [11] open answers are represented by set of algebraic transformations; they are analyzed to determine the implicit conceptions (and mis-conceptions) of the students, and to treat them with the ways of an intelligent tutoring system. An evaluation of this system has proven worthy when applied to answers constituted by purely algebraic expressions, without intermixed text in natural language. The work exploits admirably the fact that the derivation and evaluation of expressions of a formal language is highly automatable [12] and a possible expansion of the work points at integrating the comments intermixed in the answer in the grading process.

III. THE OPENANSWER SYSTEM

OpenAnswer is a module integrated in a preexisting PHP-based Leaning Management System (named sLMS). In it, each course can be upgraded so as to use OpenAnswer services. A teacher in OpenAnswer can

a) define a questionnaire associated to a course;

b) define a questionnaire session, that is an occasion for administering the questionnaire to a group of students;

c) open/close the "answer time" for a session;

d) open/close the "peer-assessment time" for a session;

e) examine a session that has been peer-evaluated: here the teacher can assess and mark (some of) the given answers;

f) publish the session grading for students.

In phase a) the teacher specifies some information on the questionnaire, namely 1) the number of open ended questions, 2) how many answers will be peer-assessed by each peer, 3) cardinality of each group of students (they have to be partitioned in groups of 10-25 students, otherwise the computation burden of the system would make unfeasible its response time), 4) whether the student could be presented with her/his own answer to be assessed (and with what probability: always, never, 33% or 66%), 5) whether the answer should be anonymous or bear the author's username. Moreover the question(s) used in the questionnaire are selected from a repository (presently associated to the course, with no tag related to the topic). When a question was defined and added to the repository: a set of criteria was associated to it. Criteria are defined in a special repository. The association between a question and some criteria is important as it will help providing some directions to students during their peer-reviewing activity. When a question is selected for the questionnaire, the associated criteria are shown and some or all of them can be checked for the purposes of the specific questionnaire. In phase b) the teachers defines a session, basically by specifying what questionnaire will be used and how the groups of students are composed. In phase c) the questionnaire is submitted to the students, and the answers are entered. Then the answer period is closed the peer-assessment can take place. Consider that these time-spans can last as long as the teacher wish (from minutes to days; the only constraint is in the answer phase being closed before the peer-assessment starts.

In phase e) the teacher start the analysis of a session. The present implementation of the system the main goal is support to experimentation, so two specific services are provided (which will probably not be part of the final release): 1) it is possible to "clone" a session that has been already peer-evaluated, and 2) it is possible to select the method (strategy) that will be used by the system during the marking phase for the session (cfr. next section for the different strategies that can be used to support the teacher and suggest the "best next answer to mark"). Having clones of the same (peer-evaluated) session allows to apply and compare different strategies. One of the selectable strategies is the "manual" one: the teacher will assess all the answers (and this also is a relevant option in the present experimental phase). In this phase the teacher can select a session to grade (and select the strategy to apply) and start marking. The teacher is presented with the list of answers for the session/group (Fig.1).

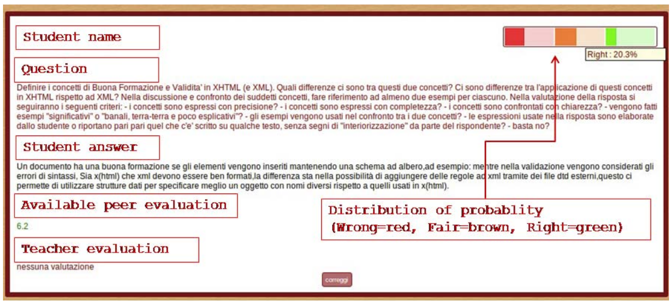

Fig. 1. Guided correction: For each answer in the list, the distribution of probability of being Wrong/Fair/Right (cfr next section) is shown. E.g. the answer in figure is more likely to be wrong/fair, than right, according to what the system can infer so far during the grading phase).

The first question is the one suggested for grading (at any stage of grading, it is supposed to be the one that helps better the system to converge towards the possibility to grade automatically the answers not yet graded by the teacher, according to the strategy in use).

In OpenAnswer a Student Model (SM) is managed: the competence of the student on the subject matter at hand, and her/his ability to assess others' and own answers are stored as the distribution of probability for her/his K and J variables over the values Good/Fair/Bad (cfr next Section). Each session grading starts using the present values in the students SMs; these values evolve, in a protected computing environment, according to the propagation mechanism occurring during teacher's work on the session. So, after a session has been graded, temporary new values for the students SMs are stored: they are not directly used to update the global values of students SMs, rather they can be used to do that, if the teacher activates the updating process. This is because, in the present implementation of OpenAnswer we can have clones of a same session, to be graded by different strategies, and we would not like the modifications of the SM due to a grading done by a given strategy affecting the results of the same-session grading performed through another strategy; so, if there are several sessions graded, when the temporary SMs produced by one of them is used to update the global students SMs, then this possibility is lost by all the other graded sessions.

IV. The Bayesian network module

In OpenAnswer a Yap Prolog ([13,14]) module supports the management of the Bayesian network. The module

- reads the run parameters from the DB;
- builds the Bayesian network corresponding to the peers' assessment network;
- introduces as evidence the currently available teacher's corrections;
- propagates the evidence through the Bayesian network to compute the probability distributions of the answers' correctness;
- selects the next answer to be corrected depending on the given strategy and the computed probabilities;
- writes back to the DB both the chosen student and the computed probabilities.

A. A simple Bayesian network model

The Bayesian network modeling the peer-assessment (defined through the CLP(BN) library available in Yap Prolog) is made of 3 finite-domain variables for each student:

K: Knowledge (good, fair, bad)

J: Judgment (good, fair, bad)

C: Correctness (right, fair, wrong)

The Knowledge variable is independent and based on the following probability distribution:

	good	fair	bad
P(K)	0.5	0.2	0.01

Notice that the above and the following probability distributions tables are "synthetic", that is they have not been (yet) extracted from actual experimental data. This is presently acceptable, we think, because our aim, for the moment, is to test if the methodology works sufficiently well with the Bayesian approach. An important property of Bayesian networks is that such probability distributions can be learned from experimental data. Thus, later, we will obtain these distributions from the student's interaction with the system.

The 3 variables of our model are related through two Conditional Probability Tables (CPTs), that (for the moment, according to what specified above) are as follows: the first table relates the student's knowledge about the questionnaire topic and the correctness of her/his answer

P(C|K)		K		
		good	fair	bad
C	right	0.5	0.2	0.01
	fair	0.4	0.5	0.3
	wrong	0.1	0.3	0.69

The rationale for this assumption is that the answer is open, therefore the student could not guess its content (for the moment we are ignoring plagiarism issues).

Similarly, we model the Judgment variable as probabilistically dependent on Knowledge. The rationale being that judging the answers of peers is a higher cognitive activity respect to both *knowing* and *using* the knowledge useful to answer. In this we take inspiration from the Bloom's taxonomy of cognitive abilities.

P(J|K)		K		
		good	fair	bad
J	good	0.5	0.2	0.01
	fair	0.4	0.5	0.3
	bad	0.1	0.3	0.69

The variables modeling a student are connected to the other students whenever a peer-assessment takes place. The student is presented with some (e.g. 3) peer answers and should choose the best (more correct) one.

We model the choice by defining 3 cases respect to J:

J = good: the student can discriminate among peers' answers, i.e. (s)he can tell apart the different values of Correctness for the answers presented:	right != fair != wrong
J = fair: the student is able to discern only among wrong and right answers	right = fair != wrong
J = wrong: the student is not able to distinguish and chooses at random	right = fair = wrong

The above rules are implemented in the Bayesian network through a CPT defining the probability of choosing answer q1, q2 or q3 depending on the student Judgment (J) and on the correctness (C1, C2, C3) of the proposed answers

P(Choice | J, C1, C2, C3)

A corresponding CPT can be easily obtained by generating all possible combinations of J, C1, C2, C3 and by assigning a uniform probability distribution only for the q1, q2, q3 answers that satisfy the above choice cases. Some examples follow:

J	C1	C2	C3	P(q1)	P(q2)	P(q3)
good	right	wrong	right	0.5	0	0.5
fair	right	fair	wrong	0.5	0.5	0
wrong	right	wrong	fair	0.33	0.33	0.33
good	wrong	wrong	wrong	0.33	0.33	0.33

Similar CPTs can be computed for peer-assessments with less or more than 3 answers to assess.

The resulting Bayesian network interconnects all student models through the Choice variable, and propagates evidence coming from the teacher's correction both:

- towards the corrected student's Knowledge (and thus to his Judgment),
- and through the Choices where the corrected answer was proposed, to the Judgment of the peers (and thus to their Knowledge and Correctness).

B. Selection strategies

Four selection strategies are available to suggest the next answer to be corrected:

- min_diff: the answer with the minimum difference among its maximum and minimum correctness probabilities is chosen. Rationale: the more the probability distribution of C is flat, the more the answer's correctness is ambiguous.
- max_entropy: the entropy of the answer's correctness probability distribution is maximum. Rationale: the answer's correctness is the most ambiguous one.
- max_wrong: the probability to be a wrong answer is highest. Rationale: students would not deem acceptable to fail "just because the Bayesian model said so", without the teacher actually checking their answer. Thus the teacher is forced to correct/check at least all the answers deduced "wrong". By grading these answers first we hope to collect enough information to deduce the rest without further work.

V. INITIAL EXPERIMENTATION

Some initial experimentation has been done by collecting data at the end of the "Web programming languages" course, part of the Computer Engineering Bachelor curriculum of Sapienza University of Roma, Italy. The first data-set (named 'marco' in the rest of the paper) is made of:

- 1 proposed question,
- 10 students answers,
- 1-3 peer assessments were made by each student,
- marks were given in the 0 – 10 range,
- the teacher graded all answers.

A second data-set (named 'carlo' in the rest of the paper) has been made available by the colleague Carlo Giovannella of Tor Vergata University, Rome, Italy. The data has been collected in a Physics course, part of the Computer Engineering Master curriculum and has been used for a different study on peer-assessment:

- 3 different topics have been used,
- 6 related questions for each topic were proposed (of which the first 4 were mandatory and the last 2 optional),
- 8-40 students answered,
- 1-3 peer assessment were made by each student,
- marks were given in the 0 - 2.5 range,
- the teacher graded all answers.

Both data-sets actually belong to other peer-assessment experiments, and collect the numeric marks awarded by the students to their peers' answers, and thus some adaptation was required 1) to transform the teacher's marks to the Correctness domain used in OpenAnswer, 2) to compute the students' choices and 3) to map back the probability distributions to the Correctness domain.

The student's choice is obtained by selecting the highest mark among those given. The Teacher's votes are discretized by using the following mark ranges:

data-set	**wrong**	**fair**	**right**
marco	0.0 – 5.5	5.5 – 7.0	7.0 – 10.0
carlo	0.0 – 1.0	1.0 – 2.0	2.0 – 2.5

The above ranges are also used to map probability distributions to Correctness values, which is a required step to evaluate the percentage of False Positives and False Negatives in our simulations.

VI. METHODOLOGY

The collected data-sets allows us to compare the different correction strategies and termination criteria with respect to:

- *Length*: percentage of answers graded.
- *OK*: percentage of the remaining answers deduced with a mark equivalent to the teacher's mark. Positive marks ("fair" and "right") are considered equivalent.
- *False Positives*: percentage of the remaining answers deduced with a mark better than the teacher's mark (e.g. "fair" or "right" instead than "wrong").
- *False Negatives*: percentage of the remaining answers deduced with a mark worse than the teacher's mark (e.g. "wrong" instead than "fair" or "right").

A. Mapping probability distributions to marks

To compute False Positives and False Negatives we first need the grades we would assign to the remaining answers, given the computed probability distributions. To map the probabilities to grades we first map each correctness label to its corresponding numeric range then we compute the linear weighted combination:

$$\begin{aligned} M = \ & P(C{=}wrong) * (MinWrong + MaxWrong)/2 + \\ & P(C{=}fair) * (MinFair + MaxFair)/2 + \\ & P(C{=}right) * (MinRight + MaxRight)/2 \end{aligned}$$

and then we map back the numeric mark obtained to the corresponding discrete value.

E.g. if we use the 'marco' data-set ranges, and

- *P(C=wrong)=0.4,*
- *P(C=fair)=0.1, and*
- *P(C=right)=0.5*

M comes out as *M = (1.1 + 0.625 + 4.25 = 5.975)* i.e. *C=fair.*

B. Simulating the correction to evaluate the strategies

The correction is simulated by repeating the following steps:

- read the peer-assessment and current marks and suggest the next best answer;
- introduce as evidence the teacher's mark for the suggested answer;
- test if the correction can be stopped, else repeat.

C. Termination strategies

As we aim to obtain a good but short correction, we need a stopping criterion, describing when the deduced marks for the remaining unmarked answers are good enough to stop.

Two termination strategies have been defined (by mapping first the probability distributions to marks in the Correctness domain as explained above):

- no_wrong: there are no more remaining answers deduced "wrong".

  Rationale: see the max_wrong selection strategy.

- no_flip(N): the current marks are the same than in the previous N simulation steps (default N=1).

  Rationale: the grades deduced are stable.

VII. INITIAL RESULTS

Table I shows the results of simulations done on the 'marco' data-set, listing for each <Strategy, Termination> pair the percentage of: answers corrected (Length), False Positives (FP), False Negatives (FN) and correct grades (OK, I.e. the percentage of marks inferred by the system in accord with the teacher's). From the table we notice that:

- The no_wrong termination criterion produces the longest correction (90%) on this data-set, obtaining 0% False Negatives (by design).
- No False Positives are present in this data-set.
- The highest percentage of OK is on the max_entropy, max_wrong and min_diff selection strategy.
- The lowest percentage of False Negatives is obtained with the no_flip(3) criterion, yet the percentage is high.

Basing on that we could come to the conclusion that even if this data-set is too limited to give us strong evidence, yet OpenAnswer is able to help the teacher by reducing the correction length of about 30% (the OK value).

Table 2, instead, shows the simulations conducted on the, bigger, 'carlo' data-set.

TABLE I. SIMULATIONS BASED ON THE FIRST DATASET

marco data-set		Termination criteria			
Strategy		**no_flip(1)**	**no_flip(2)**	**no_flip(3)**	**no_wrong**
max_entropy	Length	10%	20%	30%	90%
	FP	0%	0%	0%	0%
	FN	60%	50%	40%	0%
	OK	30%	30%	30%	10%
max_wrong	Length	20%	30%	40%	70%
	FP	0%	0%	0%	0%
	FN	40%	40%	30%	0%
	OK	40%	30%	30%	30%
min_diff	Length	10%	20%	30%	90%
	FP	0%	0%	0%	0%
	FN	60%	50%	40%	0%
	OK	30%	30%	30%	10%
min_max	Length	10%	20%	30%	90%
	FP	0%	0%	0%	0%
	FN	70%	60%	50%	0%
	OK	20%	20%	20%	10%

TABLE II. SIMULATIONS BASED ON THE SECOND DATASET

carlo dataset		Termination criteria			
Strategy		**no_flip(1)**	**no_flip(2)**	**no_flip(3)**	**no_wrong**
max_entropy	Length	6%	16%	22%	89%
	FP	45%	40%	37%	7%
	FN	7%	7%	7%	0%
	OK	41%	38%	34%	4%
max_wrong	Length	10%	14%	20%	18%
	FP	50%	49%	46%	51%
	FN	3%	2%	1%	0%
	OK	38%	35%	33%	31%
min_diff	Length	6%	15%	22%	89%
	FP	46%	40%	37%	7%
	FN	7%	7%	7%	0%
	OK	41%	38%	34%	4%
min_max	Length	6%	13%	25%	89%
	FP	46%	41%	33%	7%
	FN	8%	8%	7%	0%
	OK	40%	39%	35%	4%

From Table II we may observe that

- the best correction quality (OK) ranges from 30% to 40% for a rather good number of combinations.
- The no_wrong termination criterion produces very short corrections (Avg. Length=18%) but only when paired with the max_wrong selection strategy. The quality of the correction in this case is around Avg. OK=30%. Yet, the Avg. FP is 51%.
- The lowest percentage of Avg. FP + Avg. FN = 7% is (obviously) obtained at the expense of longer corrections (Avg. Length = 89%), when the no_wrong termination criterion is used.
- The number of False Negatives (negative marks deduced for good answers) is very low in all cases: max of Avg. FN = 8%.
- Even with the very short corrections (Avg. Length = 6-10%, corresponding to the no_flip(1) termination criterion), where just 1 or 2 corrections are made, OpenAnswer is able to correctly deduce a good percentage (Avg. OK = 40%) of grades.

- The number of False Positives of the no_flip(1, 2, 3) corrections decreases when the correction size increases and more information is collected.

Conclusions regarding the second table are manifold. First the <max_wrong, no_wrong> pair seems to be the best choice, as it gives short corrections (Avg. Length=18%) with no FP (by design) and good number of right deductions (Avg. OK=31%), but with a slightly higher number of good marks given to bad answers (Avg. FP = 51%) than the others combinations. A second conclusion is in that even with the *synthetic* probability distributions (cfr. beginning of Sec.IV.*A*) OpenAnswer is able to help the teacher by reducing the correction load of at least 30%. A final conclusion stemming from these simulation is that surprisingly short corrections are able to produce a good picture of the class' knowledge.

VIII. CONCLUSIONS AND FUTURE WORK

Assessment of skills and knowledge is a crucial factor in systems supporting e-learning in general, and personalized e-learning [15,16,17] and social-collaborative e-learning [18,19,20] in particular. The use of open-ended questions and questionnaires is deemed important in the area, while this is one of the assessing methods more work-intensive for the teacher.

We have presented the OpenAnswer web-based system, built to help the teacher marking open-answer questions through a simple Bayesian network model of the student's peer-assessment choices.

The initial experimentation and simulation shows that, even with a very simple model of grades and peer-assessment, the teacher can be helped in the correction of a set of open answers, by iteratively suggesting the most informative answers to correct first and spread the information acquired through the marking onto the network made by the students models, the peer evaluations of the answers and the teacher’s grading.

Our future lines of research can be summarized as follows.

A. Using OpenAnswer as a group diagnostic tool

Teachers need to quickly assess how much the students know the topic, either to plan further explanations or to move on to other topics. As we have seen that even short corrections, in OpenAnswer, can give some sufficient understanding of the distribution of skills among the class mates, we plan to use it as a group diagnostic tool.

B. Learning the parameters of the model

The Bayesian network modeling the peer-assessment depends on:

- the CPTs describing the probabilistic dependencies of C and J respect to K.
- the probability distribution of K

Therefore, the next required step in this research is to collect enough data to learn the above CPTs and probability distribution (for a total of 6+6+2 = 14 parameters) through machine learning of Bayesian networks parameters.

C. Using a more detailed Correctness domain

The CPT modeling the student's choice is easily computable for any domain size of the Correctness variable. Thus it is not difficult to extend OpenAnswer to use standard grades (such as the one ranging through A-F of an Anglo-Saxon grading model, or the one ranging between 5 and 10, more familiar to the authors). Yet, the domain size does impact on the K-C CPTs size, which will in turn require us to collect more data to learn the CPTs.

D. Modeling more informative peer-assessment choices

Here we mean that the amount of information coming for the peers activity can be increased (presently we just ask to select the best out of several answers). Independetly of the possible modifications of the number of answers proposed to the peer for evaluation, the planned improvements are:

- asking the peer to point out both the best and the worst answers, out of the sample;;
- asking to sort the answers, in an order related to thei correctness (such as from the worst to the best);
- asking the peer to grade individually each one of the proposed answers (according to a stated grading mechanism and to the defined evaluation criteria).

E. student model and personalization

The Knowledge variable is a description of how much the student knows about the topic. Thus it can be used a (yet very simple) student model. In our simulation we have used a “uniform” student model, without a specific representation for each involved student. As the teacher's marks entered as evidence propagate through the Bayesian network and update the Knowledge probability distributions of each student, we can update the initial student model by storing the final Knowledge distributions for each student. Even better, if enough data is available we can compute, by machine learning, the correct Knowledge distributions for each student and topic, that would allow to finely personalize the grading process, by taking into account the specific strengths of an individual.

F. Modeling plagiarism and anonymity

For the moment, we are ignoring two common student behaviors: plagiarism of answers (from peers or from external sources) and lack of anonymity during peer-assessment. We intend to model these behaviors by:

- enhancing the Bayesian student model by introducing a “Cheater” and a “PeerKnown” variables, addressing the two aspects;
- enhancing the peer-assessment CPTs to model the different cases arising from blind/disclosed peer-assessment. In this the ability of the system to learn the CPTs after the experiments will be useful.

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A new approach to analyze the curriculum structure using the Students' Evaluation of Education Quality instrument

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***Abstract*—There is a considerable number of engineering courses that suffer with failure rates and high withdrawal of students in their first year, especially in fundamental discipline areas like mathematics and science. In order to detect the educational quality indicators, a study was conducted to validate the application of Students' Evaluation of Educational Quality (SEEQ) instrument in an engineering course, using Factor Analysis (FA). The choice of FA to validate the instrument is that this method has been used to validate the SEEQ instrument from the students' point of view but using this structure does not allowed us analyze the disciplines in focus, then we need to validate this same instrument into our research context according to a latent structure performed by the disciplines. We validate the application of the factor analysis by the Kaiser-Meyer-Olkin (KMO) and Bartletts' tests that investigate the sample adequacy. After the validation of the sample adequacy, the factor analysis validate the structure of the questionnaire, and we can state that the SEEQ instrument is valid for application in a teleinformatics engineering context to analyze the disciplines. As a final result of this procedure, we guarantee the consistency of the instrument for the application to analyze different disciplines under different criterions that can possibility a deeper analysis of the curriculum structure.**

***Index Terms*—SEEQ instrument, Factor Analysis, Curriculum , Higher Education.**

I. Introduction

Many studies have attempted to identify important factors and features that influence the evasion and failure rates in the first year of an engineering course, especially in fundamental discipline areas like mathematics and science [1][2].

Recent studies presents the use of mathematical techniques, widely used in the areas like pattern recognition and signal processing, in the evaluation contexts, however these fields are related to engineering applications, this techniques has been applied in order to processing the information and reveal other possibilities to analyze the dataset collected. The Educametrics [3][8] becomes a key area of knowledge to explore concepts related to subjective aspects of education, taking into account mathematical approaches.

Relevant contribution has been achieved by researches in the curriculum design field in an engineering course [8][7], but an important step of methodological procedure has not been done: the instrument validation. In this sense, we point out the necessity of an instrument that has the ability to capture this information with a solid and reliable structure for analysis. It is necessary that all formal instrument must be validate and only after this the inferences can be made.

In order to detect possible indicators in the quality of education as well as explaining the factors such as evasion, failure rates and to promote possible suggestions for restructuring the Teleinformatics Engineering (TIE) course's curriculum, a study was conducted in order to validate the application of Students' Evaluation of Educational Quality (SEEQ) instrument in an engineering course, using factor analysis. Factor Analysis (FA) is a psychometrics procedure that can do this validation, this method can be viewed as a mathematical approach that reveal the latent structure clustering the information that are intrinsically close to others [15]-[19].

The choice of FA to validate the instrument is that this method has been used to validate the SEEQ instrument from the students' point of view using only information related to the students and this structure does not allowed us analyze the disciplines in focus, then we need to validate this same instrument into our research context according to a latent structure performed by the disciplines.

II. Teaching Evaluation using Students' Opinion

The evaluation, in its widest sense, can be defined as a process that aims the collection and use of this information that

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allow decision making on an educational program, therefore, should be understood as a diversified activity that requires taking many kinds of decisions and the use of a great number of different information.

The use of formal instruments to measure students' evaluations of their teachers and students' perceptions of the quality of their programmes has been a good way to support the decision making from managers and students point of view [4]. In general, these instruments can provide important evidence for assessing the quality of teaching, for supporting attempts to improve the quality of teaching and for informing prospective students about the quality of course units and programmes [5].

Certain student rating forms provide important feedback that can be used to improve teaching performance [10][6]. The feedback in question usually takes the form of students' ratings of their level of satisfaction or their self-reports of other attitudes towards their teachers or their course units.

An instrument was created in order to obtain the students feedback. This instrument is called Students' Evaluation of Educational Quality (SEEQ) that appears to measure the most broadly representative set of scales and has the strongest factor analytic support of these instruments [10]

The factor structure of the SEEQ has been confirmed in several studies. In particular, Marsh and Hocevar [12][13] showed that it was invariant across teachers of different status and across course units in different disciplines and at different levels.

Marsh [9]-[13] conclude that Students' Evaluation of Educational Quality (SEEQ) is:multidimensional, reliable and stable, primarily a function of the instructor who teaches a course rather than the course that is taught,valid in relation to a variety of indicators of effective teaching, relatively unaffected by a variety of variables hypothesized as potential biases and is considered to be useful to students to use in course selection, to administrators to use in decisions about staff and to teachers as feedback on teaching.

In this research, we consider these factors from the measured statistical data that comes from the application of the SEEQ instrument applied to students in the first year of the TIE course, under the organizational and operational approach of linear algebra (Factor Analysis).

III. Factor Analysis

Factor Analysis is a statistical method commonly used during instrument development to cluster items into common factors, interpret each factor according to the items having a high loading on it, and summarize the items into a small number of factors. Loading refers to the measure of association between an item and a factor. A factor is a list of items that belong together. Related items define the part of the construct that can be grouped together. Unrelated items, those that do not belong together, do not define the construct and should be deleted. Computationally, this method is equivalent to low rank approximation concept. This technique was originated in psychometrics, and it is wide used in behavioral sciences, social sciences, marketing, product management, operations research, and other applied sciences that deal with large quantities of data [15]-[19].

Exploratory Factor Analysis (EFA) is a particular factor analysis method used in this research to examine the relationships among variables without determining a particular hypothetical model[].

The Confirmatory Factor Analysis (CFA) help us to validate the application of the SEEQ instrument into the Federal University of Ceará - UFC context [15]-[19]. However this instrument was widely validate, an important step in our research is validate the application of this instrument since we use a brazilian portuguese translation version and we can lose some information about the instrument when the translate was made.

A. Validating the Factor Analysis

We can assess sampling adequacy by examining the Kaiser-Meyer-Olkin (KMO) output provided in the factor analysis. A KMO correlation above 0.60 - 0.70 is considered adequate for analyzing the EFA output [14]. In addition to examining KMO for sampling adequacy, it is important to evaluate the correlation matrix of all survey items to determine if the matrix can be analyzed using factor analysis. If the correlation matrix is an identity matrix, ie there is no relationship among the items, it cannot be analyzed. Bartletts test of sphericity provides a chi-square output that must be significant, which indicates the matrix is not an identity matrix. If the KMO correlation indicates sample adequacy and Bartlett's test of sphericity indicates the item correlation matrix is not an identity matrix, researchers can move forward with the factor analysis.

IV. Methodology

A. Subjects and Course

1) TIE Course: The Teleinformatics Engineering (TIE) course was created in 2003 under the responsibility of the Department of Teleinformatics Engineering that put together two important areas, Computation and Telecommunications, with the perspective of forming professionals with skills and competencies that dealing with both areas in an integrated way with a great impact to the contemporary society.

2) Characteristics of the Sampling: The research was administered with students in the 3rd and 4th years of the TIE course. The SEEQ instrument was performed in 4 classes of students. Students were invited to participate voluntarily in this research, ensuring their anonymity as well as teachers. Students were selected, because all of these had already attended the all basic disciplines of the TIE first year and we also had a prior authorization of the teachers to apply the SEEQ. During the application of the questionnaire, some characteristics of the instrument were clarified to the participants like the importance to identify current problems into the course's curriculum, and also a awareness process was done, highlighting the importance and necessity of the questionnaires to be answered in the most faithful and true to the reality of events during classes taught in the disciplines investigated

TABLE I
FACTOR ANALYSIS RESULTS WITH THE EQUAMAX ROTATION WITH KAISER NORMALIZATION.

SEEQ Factors	Questions	10 Latent Factors									
Learning	Q1									$\|0, 77\|$	
	Q2	$\|0, 632\|$									
	Q3	$\|0, 476\|$									
	Q4	$\|0, 714\|$									
Enthusiasm	Q5		$\|0, 483\|$								
	Q6		$\|0, 532\|$								
	Q7		$\|0, 853\|$								
	Q8		$\|0, 518\|$								
Organization	Q9			$\|0, 595\|$							
	Q10			$\|0, 608\|$							
	Q11							$\|0, 51\|$			
	Q12			$\|0, 512\|$	$\|0, 516\|$						
Interaction Group	Q13				$\|0, 646\|$						
	Q14				$\|0, 679\|$						
	Q15				$\|0, 718\|$						
	Q16				$\|0, 716\|$						
Individual Rapport	Q17					$\|0, 666\|$					
	Q18					$\|0, 757\|$					
	Q19					$\|0, 646\|$					
	Q20					$\|0, 657\|$					
Breadths	Q21						$\|0, 588\|$				
	Q22						$\|0, 641\|$				
	Q23						$\|0, 716\|$				
	Q24						$\|0, 77\|$				
Examination	Q25							$\|0, 651\|$			
	Q26							$\|0, 771\|$			
	Q27							$\|0, 66\|$			
Assignments	Q28								$\|0, 802\|$		
	Q29								$\|0, 914\|$		
Overall Discipline	Q30									$\|0, 642\|$	
Overall Instructor	Q31									$\|0, 532\|$	
Student and Discipline Characteristics	Q32										$\|0, 775\|$
	Q33										$\|0, 84\|$
	Q34										$\|0, 529\|$
	Q35										$\|0, 947\|$

in the first year. Of the total of 120 students, 100 students completed the questionnaire, yielding a participation rate of 83.3%.

B. Data Collected

The data obtained has a three dimensional structured since we have the information related to students, disciplines and SEEQ questions.The original SEEQ instrument has 40 questions, distributed into nine factors. In this research, an adaptation of the questionnaire was made using only 35 issues and the number of factors was increased to 11 in order to analyze more aspects of the questionnaire.

Although we have a tri-dimensional data structure, an average was performed into the discipline mode in order to reduce the dimensionality of our dataset. For reasons of space, the questionnaire used in this study is not given here, but is available upon request.

Just for the knowledge, the disciplines that have been analyzed: Fundamental Physics (FP), Experimental Physics (EP), General Chemistry (GQ), Engineering Design (ED), Fundamental Calculus (FC), Linear Algebra (LA), Programming Techniques (PT) and Digital Logic Project (DLP) .

V. RESULTS AND DISCUSSION

A. Reliability of the Dataset

The Cronbach's α was calculated to estimate the reliability of the dataset, and the results revealed high internal consistency. The α-coefficient of the dataset was high at 0,9536. The reliability analysis showed the scales to be highly reliable.

B. Validating the SEEQ instrument

The Table II shows the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests that indicate the suitability of our data for structure detection. It is important to notice that this is an important step into Factor Analysis context, since we need to prove that our dataset is useful for this kind of analysis.

The KMO test is a statistic that indicates the proportion of the data variance that can be considered common to all variables, namely that can be assigned to a common factor, then: the closer to 1 (unity) the result is better, ie, the sample is better suited to the application of factor analysis.

The sphericity Bartlett test verify whether the correlation matrix is a identity matrix, which would indicate that there is no correlation among the variables. In this way, we looking for a significance level (Sig.) of 5% to reject the null hypothesis of the identity correlation matrix.

TABLE II
KMO AND BARTLETT'S TESTS.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.886
Bartlett's Test of Sphericity	Approx. χ^2	2919.637
	Sig.	0.000

These tests validate the Factor Analysis application into our dataset, since we have value higher than 0.5 in KMO and the

Sig. less than 0.05 in the Bartlett's test, the last one means that the correlation matrix of the dataset is not the identity matrix [17]. The chi-square coefficient is a value of dispersion for two nominal scale variables, used in some statistical tests. It tells us to what extent the observed values deviate from the value expected if the two variables were not correlated. According to [19], the chi-square test testify that our variables are correlated.

A Confirmatory Factor Analysis (CFA) was conducted to verify if the domain configuration theoretically of the SEEQ instrument, defined by Marsh and Bailey previously [10], could be confirmed empirically. This procedure was chosen because it has been applied by the developer of the instrument in order to validate their ability to assess its application context.

As we can see in Table I, only the items Q1 and Q11 are nonstandard, these two items does not influence into the validation of the SEEQ instrument, since we have a total of 35 items and a average has been performed into SEEQ factors. In the final analysis, these items were removed when the average matrix of the students' responses was calculated. Nevertheless, this does not mean a lot of change, because the item's average not change too much.

Although factor analysis has provided 10 clusters, the cluster 9 will be unbundled in two more factors (Overall Discipline and Overall Instructor), as a matter of the importance of these two factors in the overall analysis of the factors for their relevance in relation to the other factors. This situation was discuss in [10].

This study presents limitations. We used a small number of disciplines belonging to the curricular unit of TIE course and a panel composed of 100 students, a number that is not representative of the population but this not invalidate the factorial structure obtained.

VI. Conclusion and Perspectives

To validate the data collection instrument, the confirmatory factor analysis has been applied on the data collected by the SEEQ instrument in order to validate its application in the context of the TIE course. As a final result of this procedure, we guarantee the consistency of the instrument for the application in the TIE course's context. This is an important step to ensure the correct analysis of the data collected. This instrument allow us to analyze the curriculum structure, in an engineering course, as we can see in [8][7]. This analysis can contribute to potential changes in the curriculum and requirements among the disciplines of the course.

An important topic for future research is the application of high order factor analysis in order to validate the tri-dimensional structure of the dataset collected. This procedure can reveal another kind of relathionships among the factors obtained in a bi-dimensional model [20].

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Analyzing the quality of the engineering course's management using information processing based on multivariate statistics: A case study under the professors' perspectives

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***Abstract*—Processes and evaluation methods are gaining prominence in the social and educational contexts. In this context, it is proposed to contribute to the improvement of the higher education quality, through the analysis of information obtained in six engineering courses offered by the Federal University of Ceará. The study seeks to strengthen the interface among data analysis methods typically used of engineering contexts in order to allow the analysis of the relationship between academic management processes of engineering courses and outcomes from external evaluations. This discussion aims to propose a mathematical model to support the academic management, based on multivariate analysis (MVA) and data processing, such as Principal Component Analysis (PCA). The instrument created aims to identify professors' point of view about the management practices developed in their academic courses where they work. The application of the reliability tests revealed the suitability of the sample for the application of PCA. In the PCA application, we observed the formation of three responses' clusters, that has been well characterized by the similarity of their factor loadings that are related to students' academic education, academic formation processes and institutional environment. It should stand out even that the application of MVA showed strong evidence for a relationship among the methods of management in higher education, through the manifestation of latent variables in order to define a mathematical model based on MVA academic management support.**

***Index Terms*—Courses' management, Factor analysis, Principal component analysis, engineering education.**

I. Introduction

Nowadays, in Brazil we experienced an increase in the vacancies in courses in higher education. This demand has been followed by the need to develop processes and evaluation methods [1][2]. This interest gains strength in the Brazilian context of the current moment expansion of Higher Education Institutions in the country. Thus, the necessity of a more effective evaluation of these institutions has been growing [7][8].

The assessment is used in order to provide input for the analysis and improvement of classes, projects, programs, and institutional processes even more complex systems, such as the education systems at various levels. Currently, we highlight some experiences of assessment in the context of engineering courses [1][3][13][14][15]. In this scenario, stocks and faculty members of educational administration should position themselves against these processes, remodeling ideas, techniques and criteria, to promote changes that characterize a new way to lead to the desired quality of education at all levels [9].

The Brazilian education is under a process of expansion within in Higher Education, and must find mechanisms that enable the "control" of teaching quality in order to verify that the goals set are being achieved and consequently to observe critically the training provided to professionals from several areas. In this study, we will investigate the process of formation of an engineer in the context of the Federal University of Ceará-UFC, located in northeastern Brazil.

The search for data/facts your organization in the form of structured information allows the identification of patterns and a qualitative/quantitative analysis that can generate proposals for intervention and produce positive results to the management in higher education. This view is gaining prominence both in relation to aspects of a quantitative but also qualitative. Thus, it is proposed, during the research, contribute to the analysis of information obtained in six university courses in engineering offered by the UFC that have undergone external evaluations in recent years. Aiming to this study to identify management practices and their consequent contributions in

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quality indicators, especially in external indicators applied periodically by the government agencies.

In this research, we will investigate the potential for applying a mathematical tool of multivariate statistics, called Principal Component Analysis, in the assessment of undergraduate engineering on the teachers' perspective. It is expected to recognize patterns and determine significant clusters in the processing of information collected, enabling the identification of previously unknown relationships and contribute to the evaluation of undergraduate courses in general and also its possible application to the institutional evaluation and its consequent improvement of management methods.

II. Educational Management in Higher Education

Institutions in a general way have been going through a process of renewal in their ways of acting in recent years, aiming to better meet this target audience. Educational institutions are not out of this process of renewal, and required changes in its management practices[4].

The educational management has a ratio of the areas of administration and education. However, there is a complexity arising from the need to manage processes related to teaching and learning in its several instances. There is a need for a multi-mode educational quality [10]. This research can contribute to address the existence of the relationship between quality and their indicators or indices, and this is supported by the analysis of the factors added to the process [11]. The educational management should add other knowledge to strengthening the interdisciplinary characteristics in the process of students' education.

Assessment in higher education can be used to verify other aspects beyond the institutional process of teaching and learning, such as: mission, institutional development plan, policy research, extension, graduate, social responsibility, human resources policies, physical and pedagogical infrastructure [4].

According to Ralph Tyler [5], evaluation and educational measure are distinct processes. The educational measure is important in the evaluation process, however we can not limit the assessment to only those aspects. Thus, we can gauge that the assessment now covers programs, curricula and educational systems and not just the assessment of student using the learning criteria. Featuring the model Tyler, the importance of goals in the evaluation process that guide and direct the assessment enabling decision making, from the reality/context of the program/course and their respective institutional function.

The assessment/evaluation from the Tyler's perspective [5][6], provides grants for a critical analysis of the institution, since from the assessment the institution may investigate the causes of ineffective elements, reorganize and readjust positive aspects of its operation. We also highlight important aspects of its assessment model, such as: interaction teacher/student, education as a process of creating standards of conduct, diversity of instruments in the evaluation process, among others.

Based on the assumptions presented, the evaluation of undergraduate courses on the UFC provide subsidies that contribute to the improvement and constant pursuit of educational excellence desired by the educational institution as well as providing a better service to the society.

III. Multivariate Analysis Method

In this research, the Principal Component Analysis (PCA) is used to analyze the relationships among the variables analyzed. The PCA is a multivariate statistics technique that aims to achieve a rank reduction of a dataset with $X_{m \times k}$ dimension into a new dataset with $X_{m \times p}$ dimension, where $p < k$. This new dataset has some important algebraic features such as orthogonality of column vectors, which characterizes the non-overlapping of information [16][17].

The decomposition of the original database into a new database with orthogonal properties, is given by the fact that the PCA be treated as a case of reduction of rank of a matrix using eigenvalue decomposition [17]. This decomposition brings with the possibility of extracting the most important factors of the original database in order that we can relate the relevance of information with the eigenvalue associated with it , called Principal Component - PC, ie, the larger the eigenvalue greater the importance of that information due to the original database. In this sense, there is a compression of information, called latent variables, without loss of relevant information, since the arising analysis should enable a connection with the original data in the process.

It is necessary to let two concepts very clear, the latent variable and manifest variable. The first one is widely used in social and behavioral sciences, concepts they are constructed with the purpose of a particular area of interest, on which there is no method to measure operational. Furthermore, the observed variables can be viewed as observable manifestations of latent variables, by which they are characterized [12].

IV. Scenario and Methodology

This research was conducted in the Technology Center and the Center for Agricultural Sciences at Federal University of Ceaá - UFC. We had a total of 6 courses that participated in this research, they are: Civil Engineering, Fisheries Engineering, Mechanical Production Engineering, Teleinformatics Engineering, Electrical Engineering and Chemical Engineering. The research seeks to identify the perspective presented by professors of engineering courses about procedures/methods/ management actions in higher education in each of the courses. A total of 23 professors answered the research, which proved to be satisfactory for the results analysis. We seek to establish a relationship of the procedures/methods/actions and their respective concepts/grades/indicators achieved by courses in external evaluations.

A. *Measurement Instrument*

A formal instrument for obtaining the information from professors was developed in brazilian portuguese language (see Table I). This instrument consists of 15 statements and has as response, the level of agreement of the respondent's

TABLE I
INSTRUMENT FOR THE DATA COLLECTED.

1	The course's coordination contributes to the students academic formation, monitoring their performance and help them when needed.
2	The course's coordination contributes to students and teachers performed the Course Educational Policy Project on their part.
3	The course's coordination encourages students to participate in academic events (scientific conferences, meetings technology, sports activities, extension and/or artistic, etc).
4	The course's coordination explains the students about the importance of participating in the Brazil National Survey of Student Performance (ENADE).
5	The course's coordination discusses the results of ENADE with the internal community.
6	The course's coordination promotes, systematically, moments of dialogue about formation, curriculum and labor market.
7	The course's coordination encourages students to evaluate teachers.
8	The course's coordination encourages students to assess the disciplines (or modules) of the course.
9	The course's coordination contributes to providing a climate academic conducive to a meaningful and sustainable learning for the students.
10	The course's coordination takes reasonable actions steps to ensure the maintenance of support specific equipment (computational, laboratory, etc).
11	The course's coordination seeks to maintain bibliographic updated and able to the full use by teachers and students.
12	The course's coordination contributes to the development of curricular internships.
13	The course's coordination adopts reasonable actions steps to ensure the maintenance of the physical structure of the course.
14	The course's coordination has recognized academic competence.
15	The course's coordination have recognized competence in managing academic and administrative support.

using a six-point Likert scale (1-Totaly disagree ... 6-Totaly agree).

The availability of the instrument was made through an electronic address where teachers accessed and sent their responses by the website. For reasons of space, the questionnaire used in this study is not given here, but is available upon request.

B. Mathematical Modeling

The PCA was applied to analyze the interrelationships of management methods as a major factor in the performance of the courses on the results obtained on the external evaluations conducted primarily by the federal government.

C. Computational Tools

For the data treatment, we have used two computational tools: the MAtrix LABoratory - MATLAB® and the Statistical Package for Social Sciences - SPSS®. The decision to use both tools is due to the fact that the research has a hybrid character, seeking an interface between the methods of engineering, mathematics, statistics and education through the study of methods of educational management, especially with regard to the higher education.

V. RESULTS AND DISCUSSION

A. Validating the Results

1) Cronbach's alpha: In order to guarantee the reliability and internal consistency of the data, we applied the Cronbach's alpha index [15]. For the data set collected, the Cronbach's alpha was high at 0.9391, ensuring uniformity of data and validating the analysis.

2) Kaiser-Meyer-Olkin and Bartlett's test: The first step for the application of PCA is the verification of the sampling adequacy to use this technique. The tests of sample adequacy is the Kaiser-Meyer-Olkin (KMO) and Bartlett's Sphericity tests that check whether the data variables are correlated with each other, generating a hypothesis that the correlation matrix of the variables is the identity matrix, in this case we have uncorrelated variables [16]. The application of the tests validated the applicability of PCA in the dataset at a value of 0.684 for the KMO test and rejection of the hypothesis that the correlation matrix is the identity matrix was obtained by Bartlett's test [17].

B. Selecting the number of Principal Components

The Scree plot was used as a resource for obtaining the number of principal components to be used in this research, which presents a graphical view of the descending order of the eigenvalues in terms of the principal components [18].

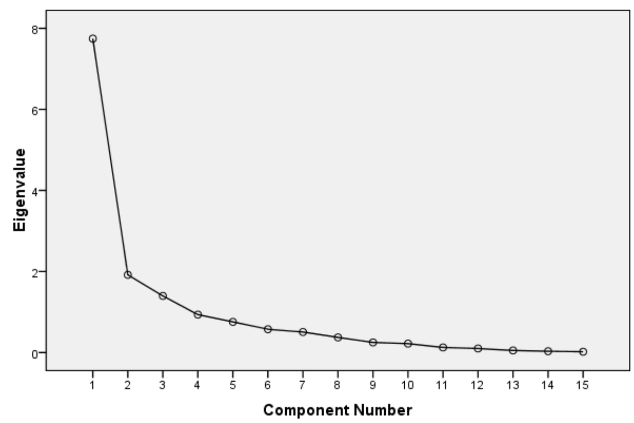

Fig. 1. Scree Plot.

Observing the behavior of Fig. 1, we realize that there is a decay curve of the graph line to its stabilization. This decay occurs abruptly until the second component, tending to stabilize on the following components. In this sense the graph suggest the extraction of the first two components and relating the eigenvalues observed we highlight that the first two components have a cumulative variance of the 64.411% over the representation of the original data. Percentage considered satisfactory for researchers.

C. Clustering Analysis through PCA

From the two principal components selected, we can see the relationships among the variables (questions) observed. Is worth noting that all questions are uncorrelated then the analysis will be done through the intrinsic information related to the original database.

Analyzing the Fig. 2, we can observe the formation of three clusters, well characterized by the responses' intrinsic correlations, however, we note the existence of two outliers (questions 10 and 13). The explanation for the occurrence of these outliers, may be linked to the fact that these issues have been understood as actions outside the jurisdiction of the course coordination.

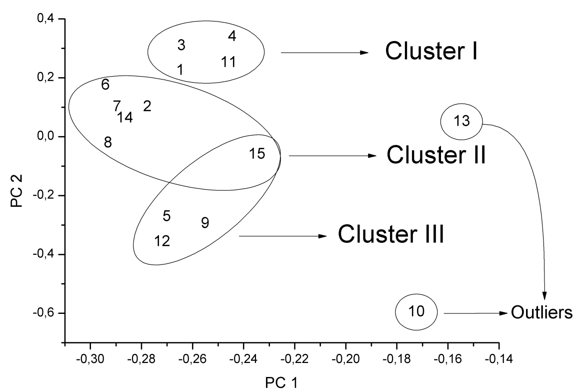

Fig. 2. Components Biplot.

Starting to the analysis of the clusters identified, it can be seen that in Cluster I, formed by the questions 1, 3, 4 and 11, which have in common the fact that they refer to the students' academic training. The Cluster II, formed by the questions 2, 6, 7, 8 and 14, point to the definition of a latency-related leadership the course coordination with regard to the assessment and management processes of academic training in higher education. Then, Cluster III (questions 5, 9 and 12) presents characteristics related to institutional environment facing the higher level training, ie describes the ambience of learning in the course's context.

We highlighted that the question 15 belongs to the Clusters II and III, this is due to the fact that it has an meaning hybrid, bringing leadership characteristics related to the the coordination regarding the academic and physical structure.

It is intended that these results can serve as support for educational planning and strategic decision-making in this field, seeking to contribute to the consolidation of the use of mathematical tools and its analysis applied to the educational context - the Educametrics [15][13], a term that still has been uncommon in the literature.

VI. Conclusions and Future Works

The purpose of this research was the application of a technique for interrelationships analysis based on multivariate statistics on a dataset related to management engineering courses at the Federal University of Cear- Brazil.

The main results show the viability of using the PCA to analyze data of an educational nature, being the relevant information brought to the application of this technique. From the observed latent variables, we highlight the creation three clusters of responses that are related to the students' academic training, the leadership on the of the courses' coordination assessment and management processes of formation and the characteristics related to the institutional environment in the formation level.

As seen, we have evidence that there is a relationship among the methods of management in higher education, through the manifestation of significant latent variables. Showing that there is the possibility of making inferences about the actions and methods of management and thus enable the delineation of interventions that may contribute to the improvement of teaching and learning in engineering courses.

This study has limitations regarding the small number of professors' respondents, which despite being small the whole dataset is adequate for analysis by PCA. As a future perspective, we emphasize the analysis of a higher number of courses that enable the analysis of the relationship of management processes with the index calculated by external evaluations.

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Peer Evaluation in an Undergraduate Database Management Class: A Quasi-experimental Study

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***Abstract*—This study is to evaluate whether peer evaluation increases student participation and thus improves learning achievement in an e-learning 2.0 environment. We first implemented an e-learning 2.0 platform and then collected data from student participants, including RSS, blogs, Wiki, and other online forums. A quasi-experimental design was used in the study. The student participants were divided into an experimental group (N=52) and a control group (N=60). The results indicated that the e-learning 2.0 platform had a positive effect on student learning process. When comparing the academic performances of the control group and the experimental group after using e-learning 2.0 for a period of time, students in the experimental group had significantly better academic results than those in the control group.**

Keywords—peer evaluation; e-learning 2.0; quasi-experimental design

I. INTRODUCTION

E-learning has become a trend in higher education. Learners in such an environment can learn anytime and anywhere [1]. Recent e-learning research studies indicated that collaboration and interaction are important learning factors, particularly when incorporating Web 2.0 technologies into e-learning courseware design [2-4].

Among many e-learning studies, exploring students' motivation in the e-learning 2.0 environment has become an important issue [5-7]. Our study is to evaluate whether peer evaluation increases student participation and, as a result, improves their learning achievement. To evaluate the effectiveness of peer evaluation in the e-learning 2.0 environment, we first implemented an e-learning 2.0 platform and then collected data from student participants to investigate the research purpose. Data sources include RSS, blogs, Wiki, and other online forums.

Four major research questions were investigated. First, students' satisfaction toward e-learning 2.0 was identified. Second, the relationship between student participation and peer evaluation in e-learning 2.0 was examined. Third, we studied the effect of student participation in peer evaluation process on their learning achievement. Finally, we examined the relationship between student participation and their satisfaction.

II. SYSTEM IMPLEMENTATION

An e-learning 2.0 system was implemented in the study to function as an evaluation platform (hereafter referred to as TeachSys). The implementation of the system was based primarily on the concepts of knowledge sharing, peer evaluation, and the characteristics of collaborative learning. It provided keyword links to Wikipedia and other external resources such as Yahoo+ by way of text mining technology. In addition, TeachSys allowed users to publish articles, responses, and discussions in the framework of knowledge sharing.

III. SYSTEM EVALUATION

To evaluate the effectiveness of peer evaluation in the TeachSys, a quasi-experimental study was designed to achieve the research purpose. We divided participants into an experimental group (N=52) and a control group (N=60). The control group was taught using a traditional face-to-face teaching method, while the experimental group followed the same course outline but was additionally assisted by the TeachSys e-learning 2.0 platform that incorporated peer evaluation mechanism.

The experiment lasted 18 weeks. All students, regardless of which group they were assugned, had similar work during the semester. The control group using the traditional bulletin board e-learning system, which received information from teacher without interacting with classmates online.

In the experimental group, students' participation rate in peer evaluation process was recorded through the TeachSys system. The procedure of the experiment was introduced in the first class. The assigned work for the term was then posted in the TeachSys system. The participants were asked to discuss their work in the e-learning platform before the next lecture. The students could express their concerns and discuss with their classmates through the platform.

A. Subjects

The participants in this study included two separate classes of undergraduate students who were enrolled in the same academic course taught by the same instructor during two different semesters. The ratio of males to females was nearly

1:1. The ages of the participants ranged from 18 to 20 years. There were 52 students who participated in the experimental group; another group of 60 students in the same department who were not using the e-learning platform was used as a control group for comparison.

B. Instructional Context

Both groups of students enrolled in an undergraduate Database Management course that focused on fundamental database management skills covering ER data model, SQL, database design, functional dependencies, normalization, query processing, transaction processing, concurrency control techniques, and distributed architectures.

C. Independent variables:

One independent variable was examined in this study: TeachSys platform usage. A group of students who did not use this platform was used as a control group in the experimental design.

D. Dependent variables:

The measurement instruments in this experiment included a five-point Likert scale questionnaire for evaluating student satisfaction toward system usage and student learning achievement from post-tests.

IV. Results

A. Academic achievement post-test

The academic achievement of the control and the experimental groups was determined by a U test. The results of the first midterm examination (control = 81.67, experimental = 73.58; $p < 0.01$) indicated that the mean score of the control group was significantly higher than that of the experimental group. In contrast, in the second midterm examination (control = 65.28, experimental = 75.30, $p < 0.01$) and in the final exam (control = 75.44, experiment = 81.92, $p < 0.01$), the mean achievement of experimental group was significantly higher than that of the control group.

B. Correlation between participation and learning satisfaction

In academic achievement, compared to the different levels of participation, there were no significant differences found between the “RSS”, “Blog”, “Wiki”, or “Recommend” categories. However, online discussions ($F = 5.013$, $p = 0.013 < 0.05$), personal collection ($F = 9.248$, $p = 0.012 < 0.05$), peer evaluation ($F = 3.346$, $p = 0.049 < 0.05$) and TeachSys overall function ($F = 5.505$, $p = 0.009 < 0.05$) demonstrated significant differences. It seemed that students had different preferences in Web 2.0 technologies for e-learning 2.0. Moreover, a possible explanation was that greater participation in peer evaluations and online discussions was required before these technologies would have an effect on their performance.

V. Conclusion

According to the results in this study, the e-learning 2.0 platform seems to have a positive effect on learning as the majority of the students indicated that the e-learning 2.0 and the Web 2.0-related application tools provided significant assistance as they engaged in the learning process. When comparing the academic achievements between the control group and the experimental group after using e-learning 2.0 for a period of time, the academic performance of the experimental group was significantly better than the control group.

The results showed that there was a direct relationship between participating in e-learning 2.0 and student satisfaction. The more the students engaged in and used the Web 2.0 features, the higher the students’ satisfaction with e-learning 2.0. Although most of the students’ learning needs were satisfactorily addressed, part of the design features still had room for improvement. Providing more usable tools would enhance user participation in and satisfaction with e-learning 2.0. When students spent more time discussing and interacting with peers in the e-learning 2.0 environment, their learning achievement was significantly improved.

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A longitudinal study of the effects of a high school robotics and computational thinking class on academic achievement (WIP)

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Abstract—**While there has been a rising interest in computational thinking (CT) and a push to include it into the K-12 curriculum, there is little empirical evidence that a class that teaches CT will have any measurable long-term effects on student performance. Using robotics as an example of CT instruction, I propose to examine a high school that has had a large number of robotics students over the past six years to find evidence for the long-term benefits of CT. I will analyze school records (e.g. STEM class enrollment, STEM test scores, SAT scores) for differences between robotics and non-robotics students and compare interviews with selected students.**

Keywords—robotics, computational thinking, longitudinal

I. Introduction

In 2006, Wing [1] wrote an influential opinion piece that described "computational thinking" (CT) as the way that computer scientists think about problems, design systems, and understand behavior. She asserted that CT is applicable to a wide variety of other fields and that it should be considered a foundational skill to be taught to all students. Since then, CT has been the subject of many papers and panels, e.g. [2]-[5]. Proponents have advocated for CT instruction in public K-12 education and have hypothesized how students with CT skills, such as problem decomposition and abstraction could apply them to medicine, law, and other disciplines [6]. While enthusiasm for the subject is high, the connection between CT skills, and long-term benefits is still theoretical. There is little direct evidence that actual CT students are able to apply the skills to other disciplines to perform better than students who do not have CT experience.

II. Background

As an emerging field, the exact definition and boundaries of CT are still forming [6]. To move the field forward, the Computer Science Teachers Association and International Society for Technology in Education have published an operational definition that states:

> CT is a problem-solving process that includes (but is not limited to) the following characteristics:
>
> - Formulating problems in a way that enables us to use a computer and other tools to help solve them
> - Logically organizing and analyzing data
> - Representing data through abstractions, such as models and simulations
> - Automating solutions through algorithmic thinking (a series of ordered steps)
> - Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
> - Generalizing and transferring this problem-solving process to a wide variety of problems [7, p7]

While there have been disagreements on the precise definition of CT, one principle that is commonly held is that CT is not the same as programming. "CT is an approach to solving a problem that empowers the integration of technologies with human ideas" [7]. Some researchers believe that CT is a prerequisite skill for programming [8]. Thus separated from programming, it is argued that parts of CT can be taught outside of a traditional programming class.

One non-traditional field where CT skills may be learned is through educational robotics, such as LEGO MINDSTORMS or VEX. Through robotics, students are exposed to open-ended problem-solving tasks that require design, implementation, and debugging. In addition, students are required to program the microcontroller to accept input from the sensors and drive the motors. Though there is some programming, they do not learn a general purpose programming language as in a traditional programming class. Depending on the age of the students and the scope of the curriculum, a full year class in robotics has the potential to address most or all of the CT characteristics listed above.

While there have been some studies on the effects of robotics education, they have typically had strong limitations. Barker and Ansorge [9] tested the domain knowledge gained by students, but had a very small number of students and only tested information about robotics instead of transfer to other subjects. Lindh and Holgersson [10] and Hussain, Lindh, and Shukur [11] tested a large number of students in math and problem solving skills, but they did not follow the students for multiple years to find if the gains were maintained over time. Similarly, Iturrizaga [12] had examined several hundred students on a diverse set of subjects, such as math, technology and reading, and triangulated his data with interviews, but did not follow up with his participants over multiple years. Gibbons [13] measured the effect of a robotics intervention on convergent and divergent thinking, but the intervention time was only a few hours long and the post-tests occurred shortly after the intervention. While not strictly a study on robotics, Wolfgang, Stannard, and Jones [14] followed students from pre-school through high school. They compared students who were proficient in constructing with LEGO when they were young against ones who were not, using standardized test scores and enrollment in advanced STEM classes. While certainly taking a long-term perspective with transfer to other subjects, the study has less than 20 subjects. None of these studies were able to study a large number of students who have had a long, consistent intervention and examine the effects on other academic subjects over multiple years.

III. Study Proposal

I have identified a public high school in the southern United States that offers a full year educational robotics elective class for academic credit. Over the past six years, between 400 and 600 students have taken the class. The curriculum incorporates topics identified by [7] as CT skills, such as algorithmic thinking, and identifying and implementing possible solutions. My project will use existing school records to compare the robotics students to control groups of students who are enrolled in the same school, but did not enroll in robotics. The research hypothesis is that students who complete a robotics course will outperform students who do not take robotics on:

1. Math/science standardized grade-level test scores
2. Grades in math/science classes
3. Enrollment and grades in elective math/science classes, including AP scores
4. SAT/ACT scores

Since I am particularly interested in long-term effects, I will be emphasizing the scores, grades, and elective enrollment that occur several years after the robotics instruction.

Where appropriate, I will use matched data sets by selecting control group students so that each robotics student will have a corresponding non-robotics student that has one or more similar demographic or previous achievement measure (e.g. gender, ethnicity, or previous math standardized scores). This will allow the matching variables to be used as covariates in an ANCOVA statistical analysis.

In additional to the quantitative data, I will also conduct semi-structured interviews with a number of students who have recently completed the robotics classes. The questions they will be asked include:

1. What did you learn in robotics class?
2. What did you expect to learn in robotics when you enrolled in the class?
3. What did you not learn in robotics that you wish you did?
4. What factors influenced your decision to enroll in the class?
5. Are you more likely to take more STEM classes than before you took robotics?
6. What did you learn in robotics that you believe will be useful in your other classes or in your life?

A number of students who completed the robotics class in previous years will also be interviewed. In addition to some of the questions above, they will also be asked:

7. What skills did you learn in robotics class that you still use?
8. Did your robotics experience cause you to enroll in classes they would not have enrolled in otherwise?
9. Did robotics change the way you approach challenges?
10. Did robotics make you more enthusiastic about STEM classes or a career in a STEM field?

The quantitative data and the interviews will be analyzed separately, but also compared to each other. While it is likely that the results of the data sources will reinforce each other to provide a consistent conclusion, it is also possible that they will contradict. Robotics may leave a strong impression on the students, but have non-significant effects on test scores and class enrollment. Robotics may also have more subtle effects, nudging the students in a particular direction, but outside of their perception. In former case, we must stop and revisit whether our chosen quantitative instruments are the appropriate ones to measure effects of the curriculum.

IV. Summary

In the past few years, there has been a tremendous push to incorporate CT into an already crowded K-12 curriculum. The rationale for this movement is the theoretical hypothesis that students who study CT will be able to apply this knowledge to a wide variety of fields that they will encounter in future. While the arguments are persuasive and the benefits tantalizing, there has been relatively little empirical evidence that learning CT skills results in higher academic performance or the transfer of skills into other domains. Robotics has a high overlap with CT skills and is already being taught in some schools. However, previous studies on robotics classes have frequently suffered from small sample size, limited intervention time, inconsistent instruction, or a lack of a long-term study.

This proposed study focuses on a high school where over the last six years, a relatively large number of students have completed a full year academic robotics class. There are a significant number of samples, extended intervention time, relatively consistent instruction, and student data for multiple years after the class. Using a combination of high school transcripts and semi-structured interviews, I will statistically analyze the quantitative data and triangulate with the interviews. When completed, this longitudinal study will provide some empirical research to support or refute the assertion about the usefulness of robotics (and by extension, CT) education.

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Web-based Collaboration System to Improve the Interactivity for Mobile Education through Smart Devices

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***Abstract*—Mobile education is a term that describes a relatively new way of education. Generally speaking, mobile education is aimed to facilitate teachers, students, and parents to interact with each other through mobile devices. This term gains much popularity especially in recent years with the smart devices coming into vogue. With the development of broadband networks as well as the evolution of smart devices, more and more people have come to realize that smart devices can become an effective medium for mobile education. This paper proposes an innovative approach to implement a mobile education system through web technology, which is regarded as an effective mean of overcoming cross-platform obstacles caused by the diversity of smart devices. Considering the constraints of web technology, research and development are undertaken to enhance the stability of the connection as well as the instantaneity of communication. Also, an awareness component is designed for detecting the user's environment such as location, network condition, and hardware specification in order to provide appropriate services. Our research and development lead to significant improvement in the interactivity and the usability of a web-based system.**

Keywords—interaction; smart device; mobile education; mobile learning; remote education; web-based system

I. Introduction

A. Concept and Background of Mobile Education

Mobile education is a term that describes a relatively new way of education. One definition of mobile education that is commonly accepted by the public is that educational activities can happen anywhere, at any time, by taking advantage of mobile technologies. The concept has gained much popularity in China in recent years.

When this technology was just beginning to develop, a number of apparatuses were exclusively designed for mobile education, one such example being a series of digital learning devices produced by the Noah Corporation, which undertook a case study on the implementation of mobile learning in basic education [1]. However, this type of apparatuses faced several challenges such as the low performance on its hardware, difficulty to upgrade software, and the high cost for maintenance. Later, people began to try implementing mobile education through mobile phones [2]. Nevertheless, these types of systems were only able to provide teachers and students with limited functions owing to limitations of network bandwidth and hardware performance at that time. With the development of broadband networks as well as the evolution of smart devices, more and more people have come to realize that smart devices could become an effective medium for mobile education and some researches have already been undertaken in recent years [3] [4].

B. Necessity of Mobile Education

It is anticipated that mobile education makes flexible and ubiquitous leaning possible. Meanwhile, another "side-effect" of mobile education is that it can greatly enhance the interactivity between students and teachers by using the smart devices. It is widely acknowledged that students' learning efficiency can be greatly improved through interactive pedagogical activities. Based on this point, many educators are seeking new approaches for education with the principle of enhancing interactivity. In this paper, an innovative mobile education system for classroom scenario by taking advantage of smart devices is introduced, which also takes the special need of China market into consideration.

C. Prerequisite for Mobile Education

In order to fulfill the functionalities of mobile education, which is to make flexible and ubiquitous learning possible, several prerequisites should be considered.

- Network condition: In this paper, a survey on the 3G network services provided by several major providers in China in terms of the accessibility and expense is conducted. A report from China Telecom, which is one of the major telecommunication carriers in China, indicates that on average 97% of the urban area and 92% of the rural area have been covered with 3G networks by the end of 2012. In addition, the proportion of the users who have subscribed the telecommunication plan with the bandwidth of no less than 4 Mbps to all has reached to 70% by 2012. Besides, the expense varies from 80 RMB per month to 300 RMB per month based on the available utility time and data volume, which is affordable for the majority of the families in China. Therefore, the network infrastructure in China has provided a ready-to-use environment for mobile education.

- Mobile devices: With the advent of smart devices, it is widely accepted that these inventions can become a useful tool for mobile education. An earlier study [5] shows that students are more willing to use mobile devices for learning because such devices can provide them a flexible way of assimilating knowledge. In the meantime, the physical design of the most recent smart devices such as accessibility of wireless network, large screen size, and user-friendly interfaces makes them easier to be utilized for mobile education.

Therefore, the development of wireless and mobile technologies makes it feasible to implement the mobile education in China right now.

D. The Obstacle for the Implementation of Mobile Education from the Perspective of Technology

An earlier study [6] points out that one of the core issues for mobile education is how to facilitate users to utilize different devices to participate in educational activities. Currently, the most commonly used operating system for smart devices are iOS, Android, BlackBerry, and Symbian. As a result of that, the biggest headache for the developers of mobile education is to implement the interconnection among all kinds of smart devices. Thus, this paper also presents an effective way for solving this problem by taking advantage of web technologies.

E. The Outline of the Paper

This paper consists of four parts, among which the first one introduces the concept of the mobile education. It also gives analysis of the necessity, the prerequisite, and the difficulty of mobile education. The second part illustrates a mobile education system from the perspectives of functionalities, architecture design and workflow, followed by the third part, which evaluates the characteristics of the proposed mobile education system. Finally, the market promotion information related to this system is presented and certain future works are proposed in the fourth part.

II. System Design

A. Functionalities

After analyzing the most frequently used teaching methods, it is found that in the majority of situations, the teacher employs pedagogical techniques, while the students passively follow the teacher's instructions and explanations. Therefore, the following functions are designed for teachers and students based on the principle derived from the above phenomena.

1) Teacher:

a) Lesson preparation: The proposed system provides teachers an interface to prepare a lesson easily. A survey conducted by Hitachi researchers shows that most of the Chinese teachers prefer making courseware such as PPT, PDF, and short videos in advance. Consequently, the designers for the mobile education system consider the habits of the teachers and provide them a flexible approach to utilize their existing courseware. The proposed system allows the teacher to upload the prepared courseware beforehand.

b) Courseware distribution: As stated earlier in this paper, teachers get used to taking advantage of the courseware which is prepared in advance for efficient teaching. The proposed system provides them a convenient way to distribute their courseware which is uploaded during the "lesson preparation" phase. The courseware can be mainly classified into two categories, one of which is the document such as Word, PDF, and PPT, the other is the multimedia such as short videos and audios. After a teacher starts a lesson, the server of the proposed system will send related courseware to the teacher's and the student's clients according to their operations.

c) Teaching and demonstration: The proposed system provides teachers the functionality to demonstrate the courseware. These functions can be classified as two categories, one of which is for demonstrating documents such as Word, PDF, and PPT, the other is for demonstrating multimedia such as videos and audios. For instance, if the teacher chooses to show a PPT, he or she can directly flip to the slide which is required to demonstrate to the students. Besides, the client of the teacher provides basic tools for the teacher to make annotations directly on the document which can be kept even after the end of the lesson for the students to review later. These tools, such as straight-line pen, rectangle pen, and ellipse pen, can greatly facilitate teacher's teaching process. In addition, the system provides the teacher unlimited white boards for drawing and writing. In this way, all these valuable and useful notes can be conserved completely, which solves the problem caused by limited space of one white board in the traditional classrooms. For another instance, if the teacher chooses to play a video, he or she can click down and drag the playback progress bar to adjust the playback progress.

d) Camera and microphone control, question collection: The proposed system allows the teacher to open the student's local camera to transmit video image back to the teacher. Besides, the teacher can also open his or her local camera for the students to look at the teacher. This function is necessary and essential especially when there is a strong demand for demonstrating the experiment process during the class such as chemistry, physics, and biology. Besides, the teacher's client will automatically display the questions which are collected from the students' clients. This can greatly help the teacher to understand the difficulties that the students encounter during the course of learning, and then adjust the teaching process appropriately and timely.

e) Controlling transfer: During the teaching process, the teacher may often need to appoint one student to temporally act as the teacher to give a presentation. In this case, the proposed system allows the teacher to transfer the controlling right to a specific student, which enables the student to carry out all the operations just like the teacher.

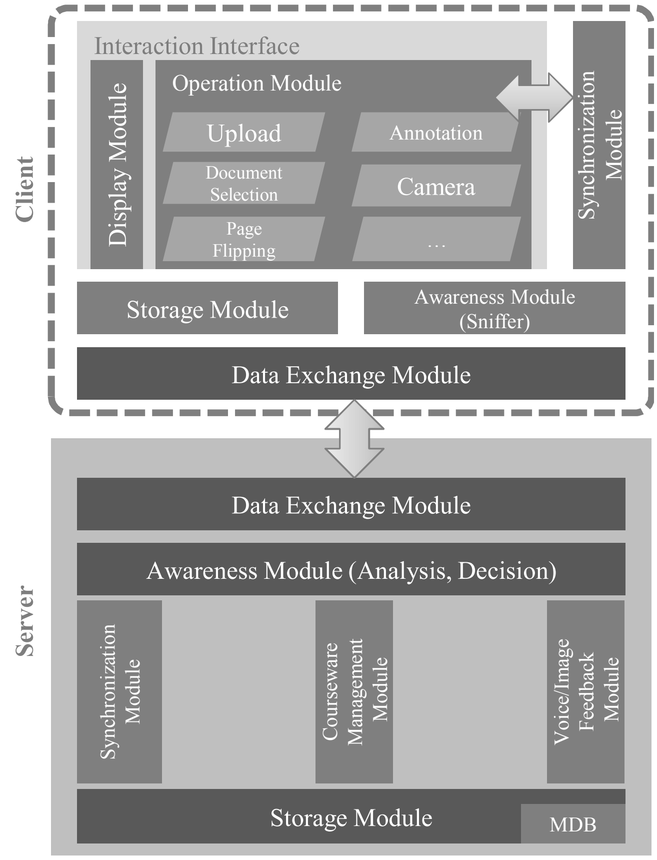

Fig. 1 Architecture of the mobile education system

However, the teacher can retrieve the controlling right at any time.

2) *Student:* The system provides students two modes to use, which are the passive mode and the active (self-study) mode. The student can decide to switch over between the two modes according to his or her own choice. If a student chooses the passive mode, the student no longer need to do any operations and his or her client will duplicate the main client's operations (main client is the teacher's client, otherwise it is the student's client to which the teacher transfers the controlling right) without the student's triggering. For example, once the teacher flips a document, the documents on the student's client will be flipped automatically. Once the teacher broadcasts a video, the video will be played on the student's clients simultaneously. Besides, all of the annotations made by the teacher will be synchronized to the student's client in real time. However, students can type their questions into a text area and then send to the teacher anytime during the class. In contrast, if a student chooses the active mode, then the student can operate to view all the courseware separately.

B. Architecture

The design of the architecture for the proposed system is aimed to eliminate the technical obstacles raised in the first part, which are the instability and the delay over ordinary network environment between various smart devices as well as the cross platform issue.

Browser-Server structure (BS) is chosen as a basic framework to implement the system. Since the HTML5 progresses greatly in the recent years, it has greatly increased the capability of web browser by supporting the latest multimedia. Besides, some of its new features make it possible to complete complex and smooth interactive operations through a web browser. Furthermore, almost all kinds of the operating systems for smart devices integrate the web browsers, so BS structure can help eliminate the cross platform issue easily.

Fig. 1 shows the architecture of the proposed system. In order to explicitly illuminate the architecture, this section explains the client and the server separately.

1) The architecture of the client consists of the following parts:

a) Interaction Interface: Interaction interface contains two modules, which aim at bridging the system and the users. In other words, it provides the functions directly related to users. One of the modules in it is the display module that renders certain contents on the client's screen. The other one is the operation module that processes the commands received from the user or the synchronization module.

b) Synchronization Module: This module helps implement the function related to synchronization by managing a status record of its own client. The format of the status record is shown in TABLE 1. Each courseware, such as the document or the multimedia (video and audio), is assigned a unique ID after the teacher uploads it to the server. And each client keeps the record of the "Document ID" and the "Video/Audio (V/A) ID" of which are being demonstrated. Meanwhile, the "Page Number" of the demonstrated document and the "Playback Time" of the demonstrated video or audio are kept. Besides, the status of the local camera and the microphone is also kept in the record.

If a client is a main client, for example, the teacher's client, it will send the status of its own to the server automatically for other's synchronization. If a client is a subordinate client, it will retrieve the status of the main client and compares it with its own. After that, certain functions of the operation module in the interaction interface will be invoked automatically for synchronization if it finds differences.

c) *Storage Module:* It mainly stores two kinds of content, one of which is the courseware downloaded from the server, and the other one is the client's status information which is used by the synchronization module.

d) Awareness Module (Sniffer): This awareness module

TABLE 1. STATUS RECORD

Courseware				Camera and Microphone
Document		Video and Audio		
Document ID=0	*Page Number=0*	*V/A ID*	*Playback Time*	*no/off*

collaborates with its counterpart on the server side to acquire appropriate services for the client according to its environment. The client's awareness module collects the environment parameters such as the network bandwidth, the available memory, the screen size and resolution, then sends them to the server.

e) Data Exchange Module: It is designed for establishing and maintaining the connection between itself and the server.

2) Corresponding to the client architecture, the architecture of the server consists of the following parts:

a) Data Exchange Module: It collaborates with the client's data exchange module to implement the communication between the server and the client.

b) Awareness Module (Analysis, Decision): It receives and saves the information which is collected by the client's awareness module (sniffer). Then, this information is analyzed by the server for better understanding each client's environment. Finally, the decision is made on what kind of services should be provided to each client.

c) Synchronization Module: This module maintains a copy of the status record for the main client. It modifies the record as long as the record of the main client changes in order to keep them unified. Subordinate clients then keep synchronization with the main client by comparing the record of their own with the record of the server.

d) Courseware Management Module: This module manages the courseware, including compressing, storing, and acquiring documents and multimedia uploaded by the teacher.

e) Voice/Image Feedback Module: This module controls each client's camera and microphone for retrieving image and voice.

f) Storage Module: This module abstracts database accessing from the upper level. The upper level modules send the requests with the unified format to this module for the requirement of storing and acquiring information. In order to provide rapid synchronization among all devices, frequently used data and public information such as the main client's status record is kept in the memory database (MDB).

C. Workflow

This section explains how each module cooperates with each other to complete the interaction between the teacher and the students. It is supposed that all the courseware has been uploaded to the server through the teacher's client before the class. When the class begins, all clients, including the teacher's and the students', connect with the server and each of their display modules shows a courseware list.

The Fig. 2 illustrates the workflow of the function that a teacher selects a document and then a student synchronizes with the teacher's operation. The part rounded by the dashed line is the main procedure that implements the synchronization, which is introduced below in detail.

First, the teacher selects a document through the operation module. Then the synchronization module modifies the status

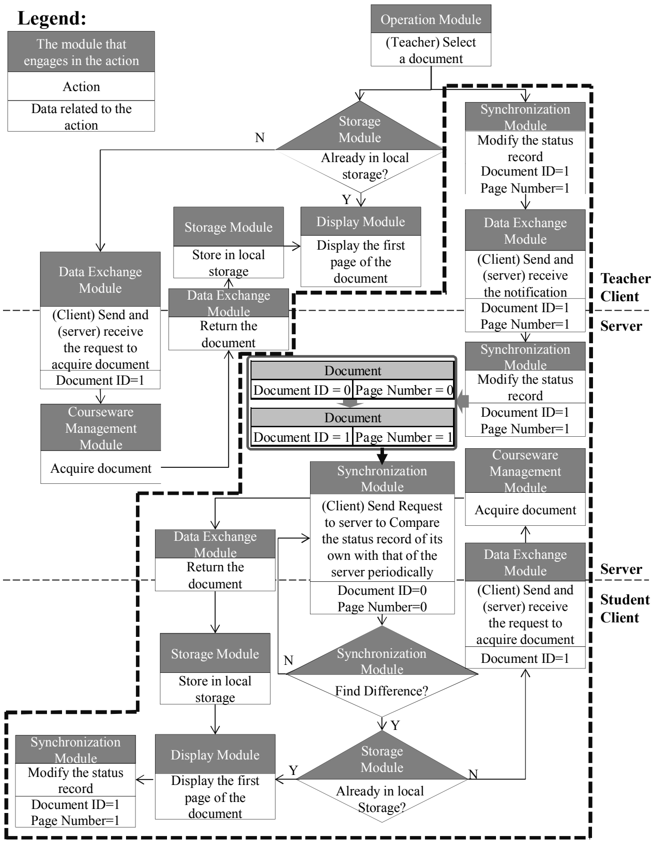

Fig. 2 Workflow

record from the initial state (Document ID = 0, Page Number = 0) to a new state (Document ID = 1, Page Number = 1), and the data exchange module sends a notification to notify the server in the next step. After receiving the notification, the synchronization module of the server also modifies the status record from the initial state (Document ID = 0, Page Number = 0) to the new state with "Document ID = 1" and "Page Number = 1" in order to keep the same with the teacher's client.

The synchronization module of the student's client sends requests to the server to compare the status record of its own with that of the server periodically. As soon as a difference is found, it will invoke certain process to synchronize with the server.

After the server modifies the status record, the student's synchronization module finds that its own status record (Document ID = 0, Page Number = 0) differs from the server's. Then the storage module checks whether the document with the "Document ID = 1" has already been stored in its local storage. If so, the display module will display the first page of the document and the synchronization module will modify its own records with the "Document ID = 1" and "Page Number = 1" to keep the same with the server's. If not, the student's client will send the request to the server for acquiring the document with "Document ID = 1" then store it in its local storage for displaying. After that, it will modify the status record to be identical with the server's.

TABLE 2. WIRELESS ROUTER SPECIFICATION

Cisco CVR100W	
Wireless transmission rate	300Mbps
Transmission standard	IEEE 802.11b/g/n

TABLE 3. SERVER AND CLIENT SPECIFICATION

		Server	Client (iPad)	Client (Sumsung P5110)
Hardware	CPU	Intel G645	A6X	NVIDIA Tegra 3
	Memory	4GB DDR3	1GB	1GB
	Storage	250GB	32GB	16GB
Software	OS	Windows 7 ulimate	iOS 6	Android 4.1
	Browser	Chrome v21.0.1180	Safari	Chrome Android

D. *Awareness*

The proposed system also contains an awareness function, which can take the environmental information into consideration for providing teachers and students with appropriate services. There is an awareness module in both the client and the server but they are different in functionality. The awareness module on the client side is responsible for collecting client's environmental information such as the network condition, the available memory, the screen size and resolution, which will be sent to the server periodically. The awareness module on the server side is responsible for saving the environmental information for each client. Furthermore, it analyzes the information in order to better understand the users' circumstances so that it can adjust the services provided to the teacher and students accordingly. For instance, a student's client reports its network bandwidth every five minutes to the server through its awareness module. The server notices that this client's bandwidth is decreasing for certain reasons. As a result of that, the server makes the decision that documents with the lower resolution should be provided to the client for avoiding the transmission delay. After that, the server sends the client the documents with a lower resolution each time the client sends a document acquisition request.

The awareness module on the server side can work independently. It keeps records of the decisions made for each client. As long as there is a request to provide certain service to a client, the server can refer to these decisions and take action reasonably.

III. EVALUATION

A. *Evaluation Purpose and Approach*

The purpose of this section is to verify the stability and the instantaneity of the system. The system is built in a real classroom environment, and the monitoring software WireShark 1.6.3 records the data transmission time and the data size.

First, a wireless local area network is established through the router "Cisco CVR100W". Then one server and ten clients, including five iPad and five Samsung P5110, are connected to the network so that they are interconnected with each other. The technical specification for the router, the server, and the clients are listed in the TABLE 2 and the TABLE 3.

B. *Test Results*

The main functions that have been tested are document selection, page flipping, and annotation creation. The synchronization time for each operation begins at the moment that the main client makes an operation and ends at the moment that the last subordinate client completes the same operation. The transmission data size for each operation is the total size of the data that is required to be transmitted between the server and a client for synchronization. Each operation listed in the Fig. 3 and the Fig. 4 is repeated for one hundred times. The synchronization time and the transmission data size for each operation are recorded and the average values are calculated accordingly. The Fig. 3 shows the result that in the various operations, the average synchronization time of the system is 886 milliseconds, which is less than 1000

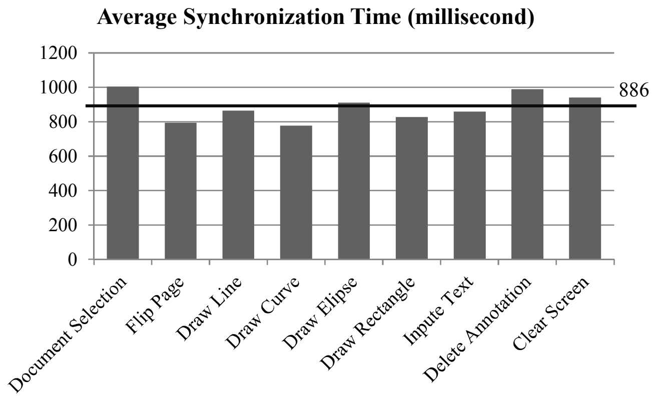

Fig. 3 Average Synchronization Time

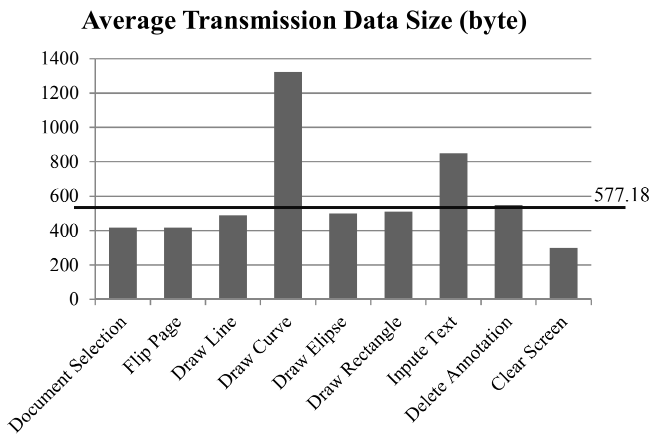

Fig. 4 Average transmission data size

milliseconds. The data proves that it can support smooth education process with tolerable delay in the real classroom environment. The Fig. 4 shows the result that in the various operations, the maximum transmission data size is 1300 byte, and the average data size is 577.18 byte. The regular 3G networks should be able to carry this kind of data amount with full capability to achieve the stable and real-time data communication for educational purpose.

IV. CONCLUSION

This paper proposes a relatively new way to implement a mobile education system. Through introducing the latest web technology, the system has many advantages such as zero cost deployment, cross-platform, and high interactivity. These features are always the key factors that determine whether a mobile education system can be successful.

So far, this system has been proposed to many Chinese local education bureaus and showcased at a number of exhibitions. The fact that numerous feedbacks have been received indicates that it has huge potential to become a dominant product in education industry in China. Many teachers comment that this system truly incorporates their teaching demands and habits, which makes it easier for them to accept and use. On the other hand, this system takes good advantage of children's interests in smart devices, a fact that can potentially trigger their desire for learning.

There is still a long way to go to improve the mobile education system. As mentioned at the beginning of this paper, the system considers only the teaching phase currently as the first attempt. It also has the potential to be adopted as a tool for remote education. In order to build a complete education system that covers the whole education process, further investigation and research must be carried out.

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Interactive Sketching in Multi-Touch Digital Books. A Prototype for Technical Graphics

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***Abstract*—In this paper, we present a functional prototype of an interactive multi-touch book with drawing capabilities, intended to enhance the understanding of engineering graphics concepts and improve visualization skills. Our multi-touch book combines textual elements with rich media content and interactive exercises to allow students to practice technical sketching in an environment that simulates traditional paper-based drawings and tools. Additionally, finished drawings can be submitted to the instructor via email directly from the digital book, which facilitates management tasks. A comparative study of traditional and digital sketching using our prototype was conducted with a small group of participants to evaluate the effectiveness of the tool. Preliminary results show positive reactions and acceptance.**

Keywords— multi-touch book; virtual sketching; interactive book; mobile learning

I. Introduction

Freehand drawing and sketching have been traditionally considered fundamental building blocks of the engineering design process and important activities in the development of spatial skills. In engineering education, the Accreditation Board for Engineering and Technology (ABET) lists the “ability to communicate effectively” as one of the eleven student outcomes required for accrediting engineering programs [1]. This outcome is typically interpreted as a broad term that comprises written, verbal, and graphical communication [2].

In 2004, the Engineering Design Graphics Division of the American Society for Engineering Education piloted a study to categorize the most important outcomes for engineering students in terms of graphical communication [3]. In this study, the “ability to create 3-D solid computer models” and the “ability to sketch engineering objects freehand” appeared at the top of the list. Despite major adoptions of Computer Aided Design (CAD) software, many engineering schools still require students to be able to sketch and communicate their ideas graphically without the aid of computer tools as part of their curricula.

According to the taxonomy proposed by [4], sketches can be classified as thinking sketches, aimed at guiding non-verbal thinking; talking sketches, used to support the design discussion with colleagues; and prescriptive sketches, which provide instructions to the draftsman/designers in charge of developing the final drawings. Sketching is considered a powerful design instrument, which can greatly boost creativity and innovation. It is among the best forms of documentation in the early stages of the engineering design process and an effective tool to communicate preliminary design ideas to others [5].

In educational settings, sketching is usually practiced using paper-based exercises and traditional tools such as pencils and erasers. Drafting books and engineering graphics teaching materials typically include design problems and drawing activities that must be completed freehand. Although electronic books are being well-received in many areas, paper-based activities are still dominant in sketching and technical graphics courses. This is due, in part, to a lack of appropriate digital alternatives.

Although both traditional books and sketching have transitioned to digital forms, they have done it separately, creating a disconnection between them. On one hand, current electronic books are designed to read and visualize content, but users cannot draw or sketch directly on the pages. On the other hand, digital sketching software and tools allow users to create freehand drawings in the computer, but these tools are not fully integrated within electronic books. Digital sketching tools are becoming commonplace in engineering and product development, particularly during conceptual design stages, but in educational contexts, a closer integration with existing teaching materials is desirable.

In this paper, we present a prototype of an interactive electronic book with built-in digital sketching capabilities targeted at engineering graphics and visualization courses. Our system takes advantage of the multimedia elements offered by modern eBooks and the interactive multi-touch features available in tablets. The result is an integrated digital resource with enriched interactive learning materials and “digital worksheets” that students can complete either by touching the tablet screen with one finger or, preferably, with a stylus pen. Additionally, these "worksheets" can be submitted electronically to the instructor using the email functionality also implemented in the digital book.

II. Electronic Books

Electronic books, or eBooks, are considered to have started with Project Gutenberg in 1971 [6, 7]. It was that year when the idea of digital books for personal computers was originally conceived. Project Gutenberg pioneered the concept of digital library and since then, multiple events, especially after the introduction of the World Wide Web in 1990, have contributed to the growth and popularity of eBooks.

In 1995, Amazon opened the first online bookstore. Two years later, in 1997, electronic ink (E-ink), a popular technology used by modern e-readers, was developed. Best-selling author Stephen King released his book "Riding the Bullet" exclusively in digital format in the year 2000; and in 2004, Internet giant Google launched Google Print, a service that made thousands of books and magazines available online.

The first commercial eBook readers, or e-readers, with black and white electronic paper displays appeared in 2006. Most devices included Internet access to online digital bookstores, which along with the development of popular file formats for digital books such as epub, contributed to increased eBook sales worldwide [8].

In early 2010, Apple introduces the iPad, the first commercial tablet with a multi-touch screen that allows users to interact with all multimedia elements associated to a personal computer (images, video, interactive graphics, 3D models, etc). Since then, other companies have released their multi-touch tablets, making electronic books more popular than ever before [6, 7]. Finally, in 2012, Apple releases *iBooks Author*, an authoring tool to create multimedia books for iPad. The tool was released free of charge and represents another step forward in the evolution of electronic books.

A. Standards for Electronic Books

Standardization of digital formats is a fundamental requirement for proper compatibility and interoperability between applications. Standards establish consistent and reliable protocols that ensure that information is clearly communicated and universally understood.

There are currently multiple formats for electronic books at different stages of standardization [9]. EPUB, for example, the main open standard for eBooks, is in its version 3 at the time of this writing. The popular PDF file format has been the de facto standard for printable documents for many years. In 2008, it was released as ISO standard 32000.

Because of the wide variety of formats, not all electronic books are supported by all devices. Furthermore, support for multimedia components within eBooks is currently not standardized, which means that different eBook formats may support different types of multimedia content. After selecting a representative group of eBook formats and comparing their relevant features and multimedia support, Apple's iBook format was selected for our prototype and tests.

Fig. 1. Prototype eBook in Digital Tablet

The availability and affordability of mobile devices, particularly tablets, as well as the ability to incorporate multimedia content make multi-touch books a very attractive tool for educational applications, particularly in technical and scientific areas with significant visual content (medicine, biology, etc). In the area of engineering design graphics, for example, three-dimensional models can be very effective when used to illustrate the concept of orthographic projection. 3D visualizations can also help students understand certain architectural and civil engineering structures.

Visual content in educational materials was traditionally created by graphic professionals and technical illustrators and was limited almost exclusively to static images [10]. The use of multimedia content in tablets and eBooks represents a major improvement over classic educational resources [11].

A view of the prototype eBook described in this work can be seen in Fig. 1.

III. Digital Tablets

The development of digital tablet devices started few decades ago. In 1972, Alan Kay designed the Dynabook [12], a portable educational device for children. Multiple uses and applications for this design were described, but the Dynabook was never produced despite reaching the prototype stage.

In the early 1990's, portable computer devices such as NCR system 3125, IBM's 2125, and the Apple Message Pad, also known as Newton, were released commercially [13]. For about a decade, the Personal Digital Assistant (PDA) dominated the world of tactile portable devices, where Palm positioned itself as the market leader. In 2001, Microsoft introduced the Microsoft Tablet PC, a pen-enabled computer running Windows XP Tablet PC Edition. During the following years, other notebooks and portable devices with reduced price and size were also launched. In 2010, Apple announced the release of its revolutionary digital tablet, the iPad, which takes advantage of the company's previous experience with multi-touch mobile devices already in the market (iPhone and iPhone Touch). The popularity of these devices is partly due to a successful combination of hardware, built around the device's multi-touch display, and Apple's operating system iOS, and to the creation of a virtual store (App Store) for applications. This store provides a digital software distribution platform with applications for Apple devices that can be directly downloaded from the Internet. Since 2011, other brands and manufacturers of digital tablets have created their own application stores, such as Google Play for Android devices.

The popularity and rapid expansion of portable electronic devices, particularly smart phones and tablets, are gradually transforming learning styles and opening new possibilities for distributing educational content to students. Some authors use the term "tablet-learning" to actively encourage the development of new educational materials for tablets, which take advantage of the technology and adjust to the digital and mobile nature of modern students' habits and lifestyles [14].

Previous studies have been done to determine the factors that influence the students' acceptance of digital tablets in educational settings [15]. In 2010, a six-month research study with 40 faculty members at the University of San Francisco experimented with and shared potential uses of the iPad in higher education [16]. The study concluded that educational iPad apps could be used to support teaching and learning, and evaluated the usability of the device in terms of reading, writing, communication, and creation of content.

Not surprisingly, many educational applications are already available for digital tablets. These applications benefit greatly from the mobility, multi-touch capabilities, and 3D interaction offered by the tablet technology. These features are particularly helpful in drawing apps, providing an interesting way to interact with graphic content. An extensive compilation built by [17] in 2011 illustrates the potential of "tablet-learning" for teaching drawing, design and graphic arts.

With the advent of *iBooks Author* (Apple' free authoring tool for *iBooks*) in early 2012, many multimedia educational books are being developed. There are some examples in the area of engineering design graphics, but more work needs to be done to fully exploit the multimedia capabilities.

IV. Design of a Multi-Touch Digital Book for Technical Sketching

As part of this work, we developed a functional prototype of a multi-touch digital book aimed at providing an integrated environment for digital sketching (see Fig. 1, Fig. 2, and Fig. 3). The ability to visualize and interact with three-dimensional models included within the electronic book is a desirable feature, as is the completion of traditional sketching exercises without having to print out any drawing templates.

For this prototype, we selected a representative learning unit present in most engineering design graphics curricula: orthographic projection and multi-view drawing. All exercises included in the eBook simulate traditional freehand sketching activities. The prototype was developed as an iBook (version 3 or higher) for iPad using Apple's *iBooks Authoring* tool.

Fig. 2. 3D widgets in Prototype eBook

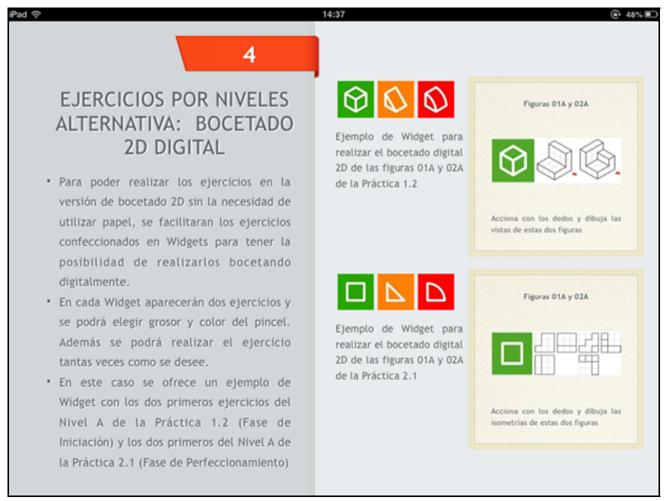

Fig. 3. Interface of Prototype eBook

By default, Apple's *iBooks Author* allows the inclusion of a variety of multimedia elements, such as graphics and video, within the iBook. In addition, custom widgets can be developed to provide extra functionality. Widgets are relatively small pieces of software that provide a specific service within a bigger application. Desktop widgets in personal computers, for example, are used to show the latest news headlines or the current weather. In interactive eBooks, widgets can be used to customize utilities, tools, and other features.

For our prototype, we developed a custom widget to provide a digital sketching environment, where students can "draw" directly on the pages of the electronic book and submit the exercises electronically to the instructor. The following elements were included in the prototype:

- Photo Gallery.
- Custom widgets, designed to simulate a traditional sketching environment.
- 3D models, with solutions to the exercises.

- Videos, with learning materials covering orthographic projection and Multi-View Drawings.
- Email capability, to send exercises and assignments.

V. Preliminary Pilot Study

In order to evaluate the usefulness and effectiveness of our interactive sketching eBook, we conducted a preliminary study with a small group of seven graduate students enrolled in a Master's degree program in Teaching with a concentration in Drawing, Design, and Graphic Arts. Because of their artistic backgrounds, all participants had previous experience with traditional sketching.

For this pilot study, we compared traditional sketching activities, using grid paper and a pencil, versus digital sketching, using our eBook prototype. The digital sketching activities were performed on an iPad tablet with iBooks version 3.1. The study was conducted as part of the workshop "Representation and Analysis of 3D Shapes" available as a multimedia book at http://www.anfore3d.com. The new prototype sketching eBook was provided as supplementary material and made available free of charge in Apple's iBook Store: http://goo.gl/m5obv. The sketching iBook "Maqueta ejercicios 2D" can be viewed with iBooks version 3.0 or higher with iOS 5.1 or higher.

A. Methodology

For the first part of the study, participants were given a traditional drawing template with several exercises and a pencil (see Fig. 4). First, they were asked to sketch the orthographic views of different objects given their isometric views. Next, a second page was distributed where participants were asked to sketch the isometric views of different objects given their orthographic views. In both cases, grids (orthographic and isometric) were available in the template as visual aids.

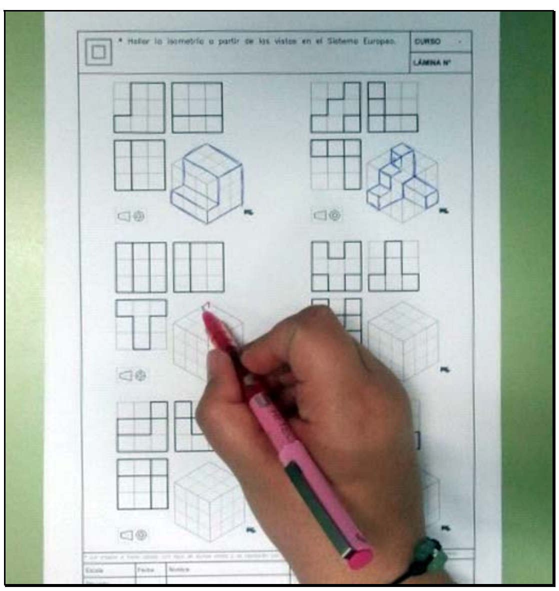

Fig. 4. Drawing Template for Traditional Sketching

In order to test the effectiveness of our prototype, a second series of similar exercises was completed by the participants using an iPad with the interactive sketching book we developed (see Fig. 5). Participants created the drawings freehand either by touching the screen with one finger or with a stylus pen. This was implemented using the Sketchpad widget available at bookry.com. Drawing submission via email was also tested, which participants acknowledged as a valuable feature in terms of saving time and paper when completing the exercises.

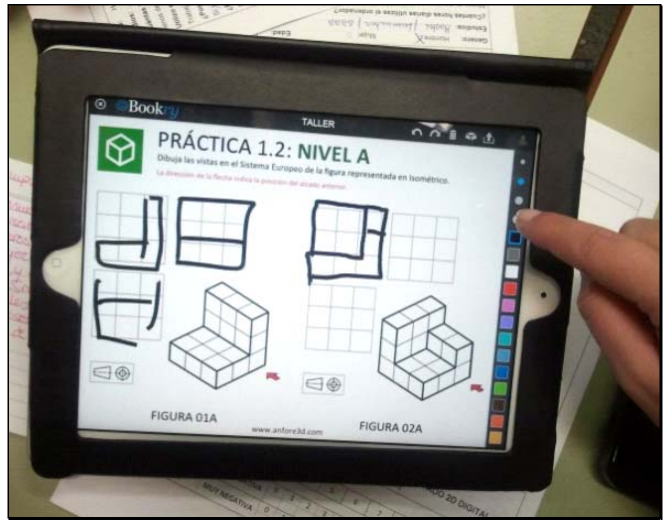

Fig. 5. Custom Widget for Digital Sketching

VI. Results

To estimate the educational value and the level of user satisfaction, we compared our digital sketching prototype with the traditional sketching approach using a simple questionnaire that was distributed to participants at the end of the exercise. Participants were asked to score both sketching experiences (traditional and digital) from 1 (lowest) to 5 (highest) based on a series of questions. The seven questions presented in the questionnaire as well as the mean scores for both sketching experiences are shown in Table I and illustrated in Fig. 6.

TABLE I. Traditional Sketching vs. Digital Sketching

Question	Mean Scores	
	Traditional Sketching	Digital Sketching
Q1. Improves visualization skills	3.43	4.43
Q2. Useful	3.14	4.29
Q3. Intuitive; easy to use	3.14	4.14
Q4. I would like to complete more exercises (Motivation)	2.43	3.71
Q5. Helps with the understanding of technical graphics concepts	2.86	3.86
Q6. Easy to learn	2.57	4.43
Q7. Overall Experience	3.9	4.16

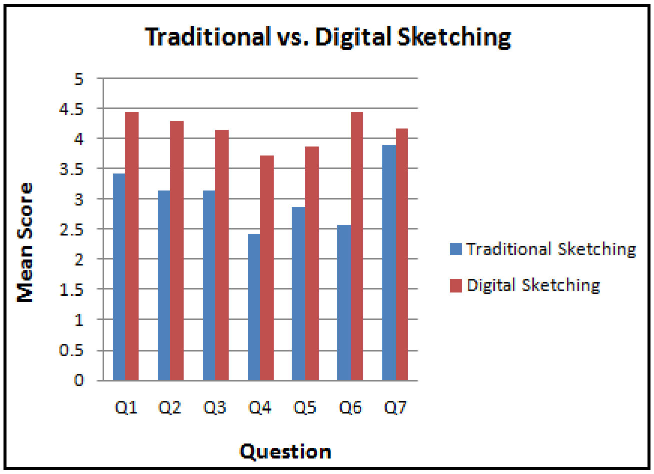

Fig. 6. Comparative results of sketching experiences

Due to the small sample size used in this pilot study, the results regarding user experience with our interactive sketching prototype cannot be considered conclusive. It is interesting to see, however, that this preliminary data show a slight tendency of the participants toward the digital sketching experience.

VII. Conclusions and Future Work

Our work has shown that the use of multimedia elements in electronic books has the potential to enhance traditional teaching materials and learning activities. Interactive three-dimensional visualizations can be easily incorporated to eBooks, providing additional value to plain text and static two-dimensional graphics. This can be particularly useful in technical and scientific areas that are rich in visual information, such as engineering design graphics.

The multi-touch displays in modern tablets provide a natural interface for activities that must simulate traditional paper-based exercises, such as sketching. Additionally, internet connectivity features allow the integration of network services into the electronic book. In our prototype, students use the built-in email client to send their work to the instructors, which reduces de amount of paper in the classroom, reduces time, and facilitates grading and management tasks.

In the future, we plan on expanding our interactive book for engineering design graphics by increasing the number of chapters, exercises, and interactive multimedia content. Although positive preliminary results were obtained in our first pilot study, we would like to conduct a more extensive analysis with larger groups of participants to evaluate the effects of our prototype in the students' performance. We believe interactive books are attractive, engaging, and provide new ways to complement existing learning materials.

Acknowledgments

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A Multi-Touch Application for the Automatic Evaluation of Dimensions in Hand-Drawn Sketches

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***Abstract*—Dimensioning plays an important role in the product development process. It is usually learned through sketching exercises where students add the corresponding dimensions to different parts of an engineering drawing. Nevertheless, being able to self-learn proper dimensioning methods is challenging, as a geometric figure requires a specific number of dimensions to be correctly defined. This paper presents an educational software application for multi-touch tablet devices to support dimensioning activities. Our application uses a multi-touch interface where students can create 2D parametric drawings with dimensions using freehand sketches and receive feedback from the system about the quality of their dimensioning exercises. When a student finishes a sketch, the system reports back the correct and incorrect dimensions. Multi-touch gestures are also used for basic sketch manipulation (panning, zooming, and rotating), similar to the standard functionality found in modern smart phones and tablets. Preliminary experiences show that multi-touch interfaces provide an effective way to capture students' attention. Students found the system very natural, and the time required to learn how to use the application is short. They enjoyed the simplicity of the interface and valued the powerful control of the geometry.**

Keywords—Innovation and technology; multi-touch displays; sketch-based interfaces

I. INTRODUCTION

Sketching and dimensioning are considered important learning outcomes in the engineering curriculum. The Accreditation Board for Engineering and Technology (ABET) recommends a list of eleven outcomes for assessing engineering students, one of which, criterion 3, states that students must possess the ability to communicate effectively [1]. Many engineering programs interpret this ability as encompassing written, oral, and graphical forms. In 2004, a survey [2] conducted by the Engineering Design Graphics Division of the American Society for Engineering Education (ASEE) identified "the ability to sketch engineering objects in the freehand mode" as the second most important graphics skill to be learned by engineering students, while the "ability to create dimensions" was put in the fourth place.

In a classroom environment, students typically practice dimensioning through exercises, where they create the orthographic views of an object and add the corresponding dimensions, or just add the missing dimensions to a given drawing. Dimensioning is a common subject in introductory engineering graphics courses. However, self-learning is difficult as dimensioning exercises are open-ended problems. While a geometric figure requires a specific number of dimensions to be properly defined, there are different sets of correct combinations. In this paper, we present an educational software application for multi-touch tablet devices to support dimensioning activities in engineering graphics courses. Our application uses a multi-touch interface where students can create 2D parametric drawings with dimensions using freehand sketches and receive feedback from the system about the quality of their exercises.

II. RELATED WORK

Different approaches have been taken to teach dimensioning effectively. Some methods are purely methodological. For example, the "Simple Geometry Method (SGM)" developed by [3] involves breaking down a drawing by a process of simplification. A drawing can be understood as complex geometry that is comprised of multiple simple geometric entities such as lines and circles. Students learn to identify these simple geometric forms and provide dimensions for them.

Other methods include the integration of dimensioning and tolerancing topics within CAD modeling courses. As reported by [4], some contents that were traditionally offered as stand-alone courses (e.g. geometric dimensioning, tolerances, and descriptive geometry) can be partially covered in a parametric modeling course, using CAD tools to apply geometric dimensioning and tolerances to 3D models, and drafting and analysis tools to solve descriptive geometry problems.

In previous work by [5], educational modules were designed to illustrate geometric dimensioning and tolerancing examples employing a portable Coordinate Measuring Machine (CMM), which interfaced with a parametric solid modeling software package allowing students to visualize tolerance zones.

McInnis et al. [6] developed an online working drawing review video and online assessment tool. This tool paid particular attention to dimensioning and ASME ANSI Y14

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standards with the objective of improving the quality of the working drawings required in final design project reports.

There is practically no computer software specifically designed to support students with dimensioning activities. Martinez and Félez [7] developed a methodology based on a computer application that uses variational geometry, which allows students to draw a simple shape and obtain the different alternative dimensions, according to the ISO-129 standard. Their system consists of a sketching module that supports the creation of shapes. These shapes are created by combining lines, circles, and arcs. A calculation module outputs a complete set of dimensions for the sketch that are consistent with the rules established by the ISO-129 standard. Although the most suitable set of dimensions is provided, the application is flexible. If the student wants to replace a specific dimension, the algorithm automatically reconfigures the complete dimensioning set and proposes a different one.

III. Dimensioning Technical Drawings

Before an object can be built, complete information about both size and shape must be provided. The process of adding size information to a drawing is known as dimensioning. Dimensioning technical drawings is used to provide a complete description of an object so it can be built and defined. If a part is dimensioned properly, then the intent of the designer is clear to both the person making the part and the inspector checking it.

Additionally, proper dimensioning improves the quality of the 3D models created with parametric CAD packages, since students can also learn to use geometric and dimensional constraints efficiently. If students know how to add dimensions properly, they also understand the concept of degrees of freedom and the fully-constrained sketch paradigm (a fully-constrained sketch is a sketch with zero degrees of freedom, i.e. a sketch in which all degrees of freedom of each geometric element are defined using geometric and dimensional constraints).

The main challenges for students when adding dimensions to a drawing are the following:

- How many dimensions are needed to define an accurate and complete object? In general, dimensions should not be duplicated. Also, only the minimum number of dimensions required to produce or inspect the part should be provided. Over- and under-dimensioned sketches are common errors in students' work. Therefore, many exercises need to be done in order to learn how to fully-dimension a drawing.

- What set of dimensions should be used? There are different sets of dimensions that define a part, but not all of them are correct. A typical selection criterion involves analyzing what information is necessary to manufacture the object. For example, to drill a hole, the manufacturer needs to know the diameter of the hole, the location of the center of the hole, and the depth to which the hole needs to be drilled. These three dimensions describe the hole in complete detail for the feature to be made [8].

Selecting a correct set of dimensions for a drawing requires the correct control and use of the following items:

- Size dimensions (indicate the overall sizes of the object and the sizes of the features).
- Location dimensions (locate features of an object from a specified datum, surface or other feature).
- Dimensions of chamfers, fillets, and rounds.
- Dimensioning of symmetrical parts.
- Dimensions of arcs.
- Dimensions of revolved solids.
- Inclined surfaces.
- Dimensions of standard features and shapes (prism, cylinder, hole, etc).

With the educational objective of assisting engineering students in learning proper dimensioning practices and standards, a computer aided sketching application called eParSketch has been designed. It is described in detail in the next section.

IV. Methodology

A. Software Application for Learning Dimensioning

Our application for learning dimensioning, called eParSketch, is a version of a research application for managing 2D parametric freehand sketches [9] adapted for educational purposes.

The application eParSketch uses a multi-touch tablet where students can create 2D parametric drawings by using freehand sketches to define the geometric elements (line, arc, circle and ellipse). Combined shapes, which are automatically broken down into basic elements, are also supported. These sketches are automatically recognized by the software and converted to parametric entities, such as those usually employed in modern 3D CAD systems. The drawn shapes can be controlled using a set of gestures (symbolic codes) representing geometric constraints (parallel, perpendicular, tangent, vertical, horizontal or concentric), dimensional constraints (linear, diameters or radii) and delete command.

Fig. 1. Inking mode operation: drawing a dimensional constraint.

The application eParSketch uses a single-touch and multi-touch gesture alphabet to distinguish between the two basic modes of operation: inking and visualization. Inking allows the creation of drawing entities, supporting both thick and thin lines. This mode follows technical drawing conventions where thick lines are related to edges and object contours, and thin lines are used for dimensions and other types of annotations. In the context of our application, drawing with a finger on the screen means thin (Fig. 1) and putting two or more fingers together means thick. The whole hand is used to delete elements.

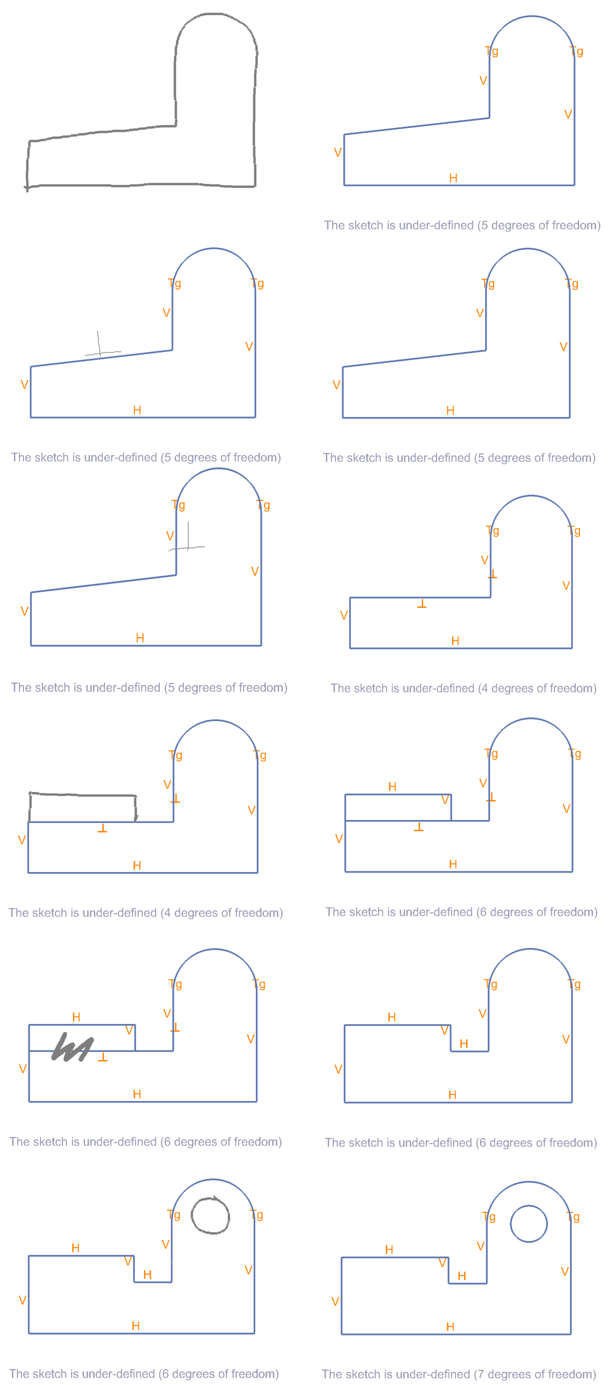


Fig. 2. Sketching sequence in exercise to learn how many dimensions are needed (I): students define, constrain and edit a shape.

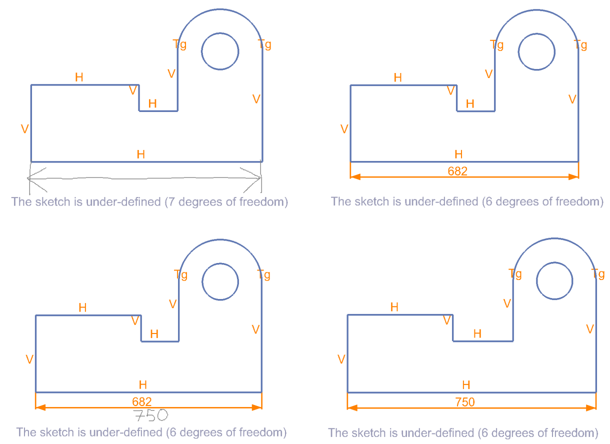


Fig. 3. Sketching sequence in exercise to learn how many dimensions are needed (II): students dimension a given shape (dimensional control).

Visualization mode is controlled by a set of multi-touch gestures where several fingers (pan function) can be used, or two hands at the same time (zoom and rotation). This is similar to the functionality found in modern multi-touch smartphones and tablets. The sketching methodology that is supported by the application follows the typical steps employed by engineers for creating technical sketches. This is an important point, as students do not need to learn any special sketching tools or program commands. They can apply the rules they have learnt previously.

We conducted a pilot study of our application with freshman engineering students to test the usability of the software. We used two types of exercises in this study. The first group of exercises was defined to assist students in finding how many dimensions are needed to fully-define a drawing, and a second group was used to select what set of dimensions is appropriate.

B. Exercises to learn how many dimensions are needed

The first type of exercise is based on drawing creation and dimensioning. As the user is editing, constraining and dimensioning the corresponding sketch, the system reports the current number of degrees of freedom, which is indicative of the number of missing dimensions. The sketching sequences presented in Fig. 2, Fig. 3 and Fig. 4 illustrate the process.

In this type of exercise, the student defines the geometry of the 2D shape (the strokes made by the user are interpreted as geometric entities) which is automatically corrected, adjusted, and connected to other existing elements in the drawing (Fig. 2). Once the user has entered the complete sketch outline, the shape can be edited, dimensioned, and constrained. The user can manage the geometric entities and the geometric constraints using a set of gestures (where the strokes are interpreted as commands). Therefore, if the user wants to generate design alternatives, or adjust some sketch features to reach a specific dimensional condition, the system provides parametric capabilities and handwritten dimensional control to the two-dimensional freehand sections (Fig. 3). The majority of gestures are inspired by the conventional symbols used in technical drafting. During the sketching process, the system provides feedback with the remaining number of degrees of freedom that need to be constrained. This is used to inform the student if the sketch is over- or under-defined (Fig. 4).

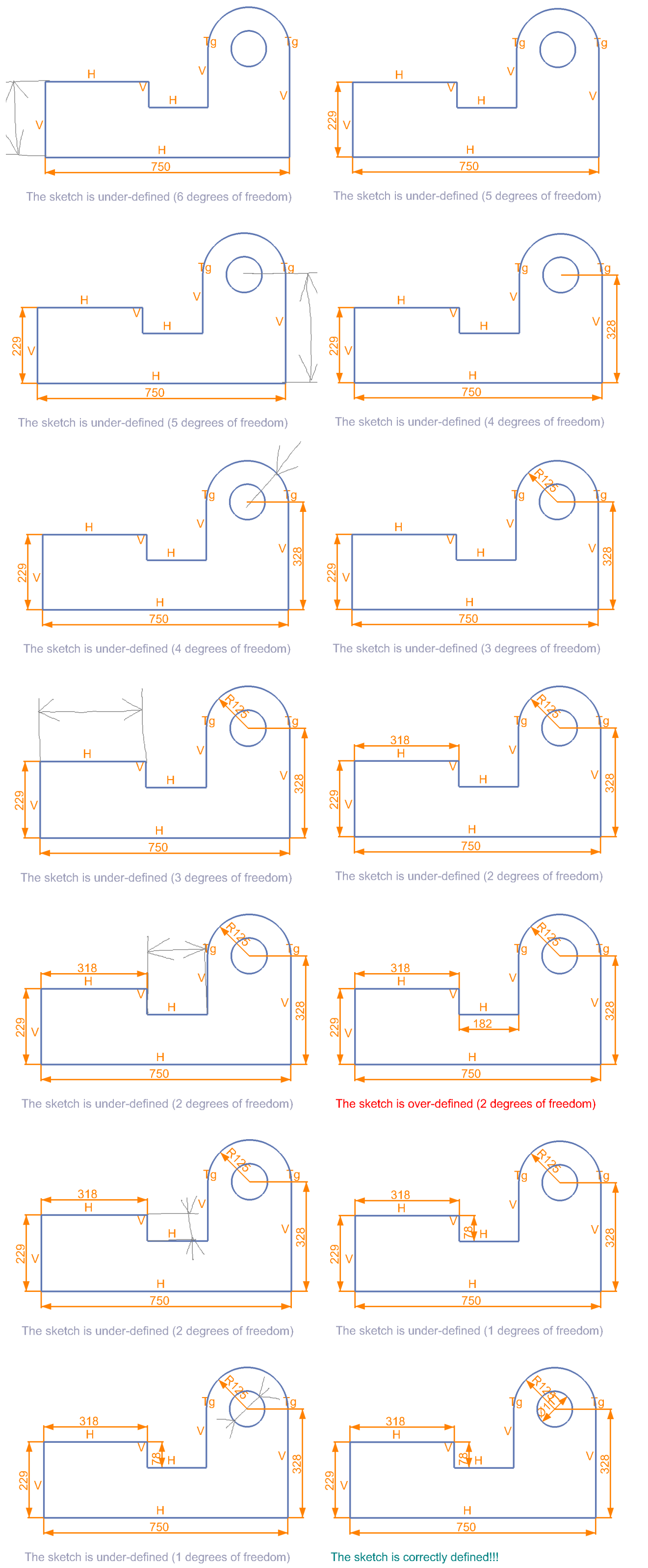
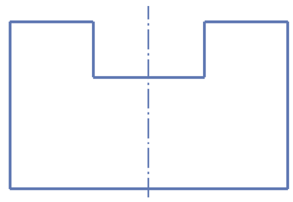


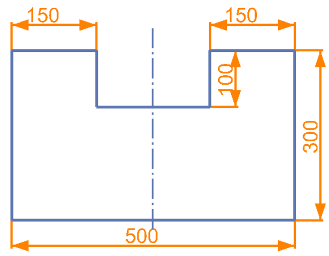
Fig. 4. Sketching sequence in exercise to learn how many dimensions are needed (III): students dimension a given shape.

C. *Exercises to learn what set of dimensions to use*

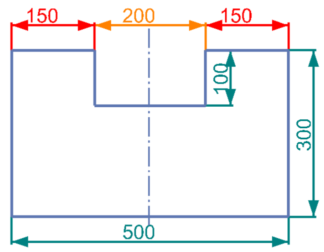
In this type of exercises, a drawing without dimensions is presented to the student (Fig. 5 and Fig. 6). The student is asked to add dimensions. When the student finishes the sketch, the system reports the correct dimensions (in green color), the incorrect dimensions (in red color), and adds the dimensions that were missed by the student (in orange). The application has successfully solved all proposed exercises, and the dimensions drawn by the user are compared with the correct set dimensions of the solution.



a) Sketch presented to the student



b) Dimensions created by the student



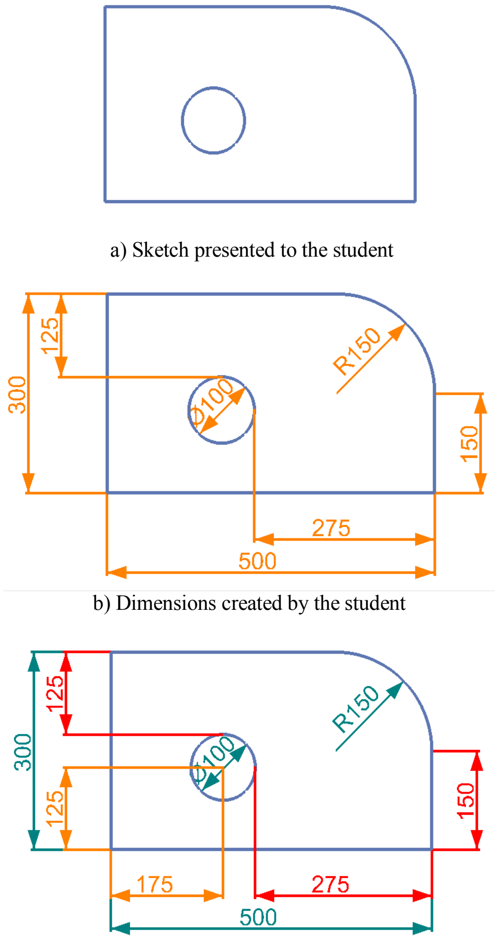
c) eParsketch correction

Fig. 5. Sketching sequence in exercise to select the correct set of dimensions to use (I): dimensioning symmetrical parts.

D. *Preliminary studies*

Our preliminary experience with students shows that multi-touch interfaces are a powerful tool to capture students' attention. They stimulate and build positive attitudes in students toward dimensioning tasks. Initial tests have revealed encouraging results. Students with an engineering background find the system very natural and the learning process very effective. They enjoy the simplicity of the interface and value the powerful control of the sketched geometry.

We have tested our application in multiple Tablet-PC's running Microsoft Windows 7, supporting pen-input using a stylus. The parametric engine used to power the system, Siemens 2DCM, is only available for the Windows platform, which is a limitation in terms of portability to Android and iOS tablets.



a) Sketch presented to the student

b) Dimensions created by the student

c) eParsketch correction

Fig. 6. Sketching sequence in exercise to select the correct set of dimensions to use (II): rounds and location dimensions.

From a usability standpoint, preliminary tests show that a pure tactile management system is not as effective as the combination of pen-input (for sketching) and multi-touch gestures (for visualization tasks, such as zoom, pan and rotate). The screen size is a limiting factor for using a pure multi-touch operation, as users feel less precise in the drawing tasks.

V. Conclusions

In this paper, an educational software application for dimensioning is presented. It was designed for multi-touch tablet devices to assist engineering students in learning proper dimensioning practices and standards. Our application allows students to create freehand sketches, apply dimensions, and receive immediate feedback about the completeness and correctness of their work. The interface was intentionally designed to simulate a traditional sketching environment, and it offers a promising alternative for self-learning complex topics such as dimensioning.

Preliminary results from our tests show that multi-touch interfaces are an effective way to stimulate students, capture their attention, and build a positive attitude toward dimensioning tasks. Participants found the application intuitive and very easy to learn.

Although some manufacturers have decided to exclude pen input from their current models of tablet devices, our experience in the context of this work suggests that, for sketching and technical work, users can greatly benefit from the precision offered by a stylus instead of a pure touch-based drawing.

Acknowledgments

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Low-Cost and Portable Labware for Computing Curriculum Using Scalable Mobile Sensory Platform

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Abstract — **Mobile embedded system is an excellent candidate to provides depth, breadth, and rigorousness for meeting the emerging workforce and education needs in science, technology, and engineering. However, the high requirements of investment in resources and instructors make the mobile embedded system education impractical for universities and colleges that lack the resources and build-ups. This work-in-progress paper presents a novel low-cost and portable labware for hands-on labs and projects using Android smartphones and scalable sensory platform. It is easy-to-adopt, promotes students with authentic and creative learning, and supports wide dissemination.**

Index Terms – Mobile embedded labware, low-cost and portable, modular design, authentic and creative learning.

I. MOTIVATION

The evolution of embedded hardware and software technologies has rendered the embedded systems more and more important roles in all aspects of our society [1]. This importance has been reinforced with the explosive growth of smart mobile device. The mobile embedded systems have expanded the connectivity and functionality of embedded systems to a new era. In addition, there is an emerging trend of enhancing the connection between mobile embedded systems and the physical world via various sensors so that these systems can be more capable to learn, think, and understand the surrounding world [2]. All of these imply great demands for well-trained workforce in mobile embedded system to meet the technology trends and the industry needs.

On the other hand, due to the wide involvement of hardware and software components that interface to various communication and networking processes with real-time requirement, embedded system has been recognized as an excellent candidate to provides depth, breadth, and rigorousness for meeting the emerging workforce and education needs in science, technology, and engineering. Many universities have offered courses related to embedded systems design [3, 4].

A key component in embedded system education is laboratory, which is required in most embedded systems courses [5]. However, existing laboratory models rely on significant investment in resources (e.g., embedded system labs) and high requirement for instructors (e.g., faculty whose expertise is in this area). These prerequisites make the mobile embedded system education impractical for universities and colleges that lack the resources and build-ups. Furthermore, the hands-on lab resources for the emerging mobile embedded system education are even more limited.

II. LOW-COST AND PORTABLE LABWARE WITH SCALABLE MOBILE SENSORY PLATFORM

To overcome the above difficulties and broaden new generation computing education to universities and colleges that have limited resources, this work-in-progress paper presents a new labware to enhance the effectiveness of teaching mobile embedded system and significantly improve the learning outcomes. Taking into account that most students currently have their own smartphones, we developed a novel low-cost and portable labware based on our past successes and experiences on mobile learning environment [6, 7] for hands-on labs and projects using Android smartphones and scalable sensory platform. The labware will be extended to support iOS based smartphones after the completion of the design of the Android based labware. According to the latest statistics [8], the Android based smartphones have 52% market share, while the iOS based smartphones have more than 39% market share. Therefore, the developed labware will support more than 92% smartphones.

In the labware, the sensors are used to collect raw data from physical world. The developed Android apps then convert the raw data to useful digital data, so that the data can be analyzed and used for device control. Currently, most smartphones have built in sensors, such as motion sensors, gravity sensors, gyroscopes, rotational vector sensors, orientation sensors, magnetometers, temperature and pressure sensors, etc. The sensory platform can be extended by integrating external off-the-shelf sensors that are usually only cost a few dollars with mobile devices via microcontroller, USB, Wi-Fi or Bluetooth modules. Figure 1 shows an example of Android-external gas sensory embedded system with Bluetooth that we provided to

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students in the preliminary evaluation. This system can measure the concentration of CO, CH_4, and CO_2 from surrounding environment. The data were acquired by the TI-MSP 430 microcontroller [9] and processed by the embedded program. The microcontroller communicates with Android phone through Bluetooth wireless connection. The total cost for this prototype is $120 (gas sensor: $10, microcontroller: $15, Bluetooth module: $30, Android based smartphone: $50, and miscellaneous items: $15). It is lower than the cost of a typical textbook in science, technology, and engineering areas. If the students use their own Android based smartphone as the learning tool, the total cost can be dramatically reduced to $70.

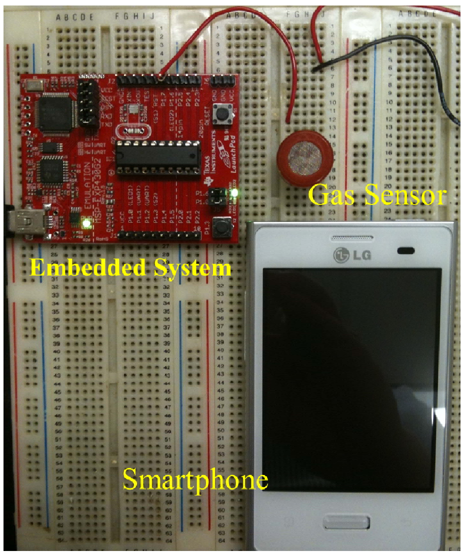

Figure 1. Android external gas sensory embedded system with Bluetooth

The affordable and easy-to-adopt labware is designed to promote students with authentic and creative learning. Through collecting, processing, and analyzing authentic data using the android smartphones and sensors, the hands-on exercises tie the learning process with real-world applications. The open-ended problems in the labware provide a creative learning environment. Consequently, after using the labware, students' skills with hardware and software, comprehensive ability, hands-on and innovation abilities can be better cultivated. Also, students' capacities for employment competitiveness can be strengthened.

The labware is developed using modular approach and has multiple learning levels in each module. This gives instructors the flexibility to adopt the full labware or to integrate selected modules based on their specific needs. Currently, we are developing the following six modules:

- Module 1: Getting started with Android application development.
- Module 2: Getting started with Android sensor management API
- Module 3: Getting started with hardware-software co-design of android-based embedded systems.
- Module 4: Microcontroller (MCU) interface to Android mobile device.
- Module 5: Android apps with built-in internal sensors.
- Module 6: Android apps with external environmental sensors.

Each module in the labware contains three major components, the pre-lab that introduce concepts, theoretical background, and lab preparation; the lab activities that require students to work on internal and/or external sensors for data collection, conversion, processing, and analysis; and the post-lab activities that include student add-on labs and open-end projects.

The labware will support wide dissemination. We will deliver the developed labware as an integrated package and deploy it on a Google site to provide a "ready-to-adopt" model. The Google site is a free service powered by Google Cloud technique. It not only makes anytime anywhere access to the labware possible, but also provides a place for educators to share learning materials, such as sensing related apps, lab manuals, and information for low-cost external sensing devices. Figure 2 shows the main page of this mobile friendly user interface for low-cost and portable labware.

Figure 2. Mobile friendly user interface for low-cost and portable labware

III. CURRICULUM UPDATE

The proposed labware covers basic and advanced computing topics such as programming, networking, hardware software co-design, real-time operating systems, and I/O interface. It can be used as laboratory in a single embedded system course or as selected teaching modules in a sequence of courses in the computing curriculum.

According to the 2004 IEEE/ACM computer engineering model curriculum [10], we are currently revising the curriculum in electrical engineering, computer engineering, and computer science programs by integrating the developed labware to existing courses offered by the authors' departments.

In the revised curriculum, the students will be exposed to mobile embedded system concepts from their freshmen fundamental course by using the developed module 1 and 2 in Introduction to Engineering/CS, Engineering Programming, and Introduction to programming. Then progressing through a sequence of courses, students will build their knowledge and skills to culminate in a senior-level capstone design experience. Module 3 will be integrated to Introduction to Microprocessor. Module 4 and 5 will be integrated to Linear System and Communication Systems. Module 6 will be integrated to Control Systems.

The related concepts and skills among the impacted courses will be emphasized by utilizing previous designs as components in subsequent courses. This vertical integration of concepts and skills of mobile embedded system among courses are expected to significantly increase students' proficiency in mobile embedded system design.

IV. PRELIMINARY EVALUATION

The prototypes of the first five modules have been presented to students for preliminary evaluation. The feedback is very positive and encouraging. Most students enjoy what they learned from the new labware and are excited with the hands-on experience of solving real-world problem with the android-based sensory platform. They feel that experiences with this labware give them confidence and motivation to explore more advanced topics in computing related areas. All of them encouraged us to finish the development earlier.

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Significant Predictors of Learning from Student Interactions with Online Learning Objects

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***Abstract*—Learning objects (LOs) are self-contained, reusable units of learning. Previous research has shown that using LOs to supplement traditional lecture increases achievement and promotes success for college students in the disciplines of engineering and computer science. The computer-based nature for LOs allows for sophisticated tracking that can collect metadata about the individual learners. This tends to result in a tremendous amount of metadata collected on LOs. The challenge becomes identifying the predictors of learning. Previous research tends to be focused on a single area of metadata such as the learning strategies or demographic variables. Here we report on a comprehensive regression analysis conducted on variables in four widely different areas including LO interaction data, MSLQ survey responses (that measure learning strategies), demographic information, and LO evaluation survey data. Our analysis found that a subset of the variables in each area were actually significant predictors of learning. We also found that several static variables that appeared to be significant predictors in their own right were simply reflecting the results from student motivation. These results provide valuable insights into which variables are significant predictors. Further, they also help improve LO tracking systems allowing for the design of better online learning technologies.**

Keywords—Learning Objects, Predictors of Learning, Regression Analysis

I. Introduction

The last 20 years has seen the rapid proliferation of online instructional materials to support distance education and to supplement the traditional classroom environment. One such type of instructional material is learning objects (LOs). LOs are most often described are independent and self-standing units of learning content that are predisposed to reuse in multiple instructional contexts [1]. An example of a LO is a self-contained lesson on a computer science topic (e.g., recursion) with a tutorial, interactive exercises, and assessment questions. LOs have been used to supplement traditional lectures in college-level engineering and computer science courses [2][3]. LOs have two features that can increase achievement and promote success in students:

First, the reusable nature of LOs and the availability of searchable LO repositories mean that the quantity of available LOs is growing, not only in terms of their numbers and content, but also in their usage [4]. This results in a multiplicity of LOs on the same topic but with different content, design strategies, etc. This diversity offers a tremendous potential for providing instructional support for college students with differing attitudes, diverse backgrounds, and prior knowledge on the subject matter.

Second, the computer-based nature of LOs facilitates sophisticated data tracking, which can collect and combine information about the learners, their interactions with the LOs, and their learning efficiency into LO metadata. Tracking is typically based on learner attributes and the content and pedagogical characteristics that are expected to be associated with or predicting learning, but the capability exists for literally every interaction with the LO (i.e. mouse click) to be tracked and time stamped.

However, there is a problem with the data tracking feature for LOs. LO designers have no way of knowing a priori what variables derived from the metadata collected are going to be significant predictors of student learning. Since there is no practical way of redeploying the LOs to collect additional metadata from the same set of students, LO designers tend to err on the side of collecting too much metadata [5]. What results is a tremendous amount of metadata on individual usage of LOs as well as data aggregated across courses, learning strategies such as motivation and demographic characteristics such as gender. This resulting "mountain of metadata" makes it extremely difficult for anyone to benefit from the LO results; for example, instructors will have no idea what metadata to look for when selecting appropriate LOs for their students.

The most common solution to the data tracking problem is an a posteriori analysis of the metadata to determine which of the variables collected are actually significant predictors of student learning. After this analysis is done, the subset of significant predictors is made available and interested groups can take appropriate actions. LO content developers, for example, could improve the tracking system for current and similar LOs to focus on the significant predictors. Previous approaches on analysis of significant predictors tend to focus only on the metadata in a similar area. For instance, Chyung et al. [6] focus on MSLQ survey while Kay & Knaack [7] focused on evaluation survey. These approaches tend to assume that the significant predictors are found in a single area when, in fact, the most significant predictors may be dispersed across multiple areas. Further, they do not consider interactions between variables such as a variable dependent on another variable in a different area and, as such, not truly a significant predictor.

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We report on a regression analysis that involves comprehensive metadata from multiple areas including LO interaction data, MSLQ survey results, demographic information, and evaluation survey results. The metadata analyzed was based on 1335 distinct sessions of student interactions with LOs. These sessions involved 16 different LOs and 134 different students from three different undergraduate computer science courses at two different universities. We used a least-squares regression analysis to identify the variables that are significant predictors of learning based on the LO assessment score from that session. We provide an extensive discussion of the variables found in each area that were significant predictors and also discuss possible interactions between variables.

The rest of this paper is organized as follows. Section 2 describes the learning objects and metadata in more detail. Section 3 discusses the regression analysis. Section 4 discusses the analysis results on the LO metadata including significant predictors of learning while Section 5 provides the conclusions and future work.

II. Learning Objects

Here we provide background on the LOs used in our regression analysis. We start by describing the overall design of the LO. We then discuss, in more detail, the metadata collected during the LO deployment.

A. Learning Object Design

The LOs used in the regression analysis are part of the intelligent learning object guide (iLOG) framework [8]. The iLOG LOs follow the Sharable Content Object Reference Model (SCORM) standard for web-based e-learning. These LOs are designed as self-contained lessons on introductory CS concepts (e.g., searching and sorting). Each of these LOs consists of the same three basic components. First, the LO contains a tutorial with the learning objectives and a set of pages explaining the concept using text and figures (analogous to a traditional textbook). Second, it contains a set of interactive exercises that further explain the concept and provide immediate feedback for students (analogous to homework problems). Third, it contains a set of assessment questions designed to measure whether students have learned the CS concept (analogous to a quiz or test). Students are allowed to freely navigate back and forth between the tutorial and exercises, to allow for review, but once they start the assessment they are locked out of the rest of the LO.

The regression analysis below uses the student score on the LO assessment questions as the measure of whether a student has learned the CS concept. Previous work has shown that assessment scores have a strong connection with actual student learning outcomes [9][10].

B. Metadata Collected

The iLOG framework provides automatic, comprehensive metadata collection for the LOs [8]. Each LO contains software that automatically tracks user interactions with the LO. Examples of the user interactions tracked in LO components are given in Fig. 1. The LOs are also bundled together with surveys designed to collect additional data from the students. There are three different types of surveys: student demographic, motivated strategies for learning questionnaire (MSLQ), and LO evaluation. Students fill out these surveys as part of taking the LOs. After deployment, the iLOG framework automatically "crunches the numbers" and provides statistical metadata based on the data collected; for example, the average time spent on each page. The metadata is provided in a flat file, suitable for further analysis, with a single row for each session between a student and LO.

There are four diverse sets of metadata used in the analysis below: (1) student interaction metadata such as average time spent on a page, (2) demographic metadata such as gender and GPA, (3) MSLQ metadata such as student motivation and self-efficacy, and (4) evaluation metadata such as LO ease of use. Now, we "cast our net" and examine this wide range of diverse metadata for two main reasons. First, we expect variables that are significant predictors of learning to be dispersed across multiple areas. In this event, focusing on a single area of metadata may actually provide an incomplete picture on how the LOs impact student learning. Actions taken based on this incomplete picture are likely to result in unexpected or even unwanted results; for example, actions taken to improve LO content could negatively impact undiscovered predictors resulting in reduced student learning. Second, we expect there to be dependencies between the variable in different areas. In this event, dependent variables appear as significant predictors when only a single area is considered. Actions taken based on dependent variables are, again, likely to have unexpected results.

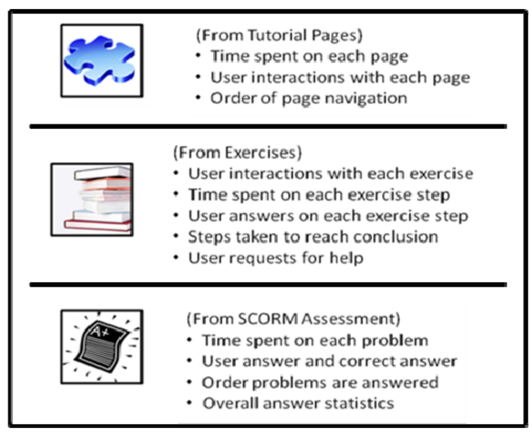

Fig. 1. Examples of user interactions tracked in iLOG LOs.

III. Regression Analysis

Here we provide details on the regression analysis used in our results and discuss previous work using regression to find significant predictors of learning.

A. Methodology

We use a least-squares regression analysis to determine whether a given variable is a significant predictor of learning. This process consists of two separate steps. First, we compute the slope for the least-squares estimate that best "fits" the data:

$$slope = \frac{\sum xy - (\sum x)(\sum y)/n}{\sum x^2 - (\sum x)^2/n} \quad (1)$$

where x contains the session values for the variable in question and y contains the assessment scores on same sessions and n is the number of sessions. The y-intercept is trivial to compute with the slope. Next, we plug the results of the least-squares estimate into an F-test and compute the p-value based on the distribution. If the p-value is less than or equal to 0.05, the variable is deemed a significant predictor of learning.

B. Previous Work

Regression analysis has previously used to find significant predictors of learning for related areas of metadata. First, regression analysis was used in a study by Kruck & Lending [11] to find the significant predictors of learning in an introductory college-level information systems course. This study considered student demographics including gender, major, SAT scores, etc. and student motivation. The authors reported that, based on a regression analysis, GPA and motivation were significance predictors of learning whereas SAT was not. One important detail is that student motivation was measured using homework grades as opposed to the more widely accepted MSLQ used in this study.

Second, regression analysis was used in a study by Chyung et al. [6] to find significant predictors of learning for nine LOs on material science and engineering concepts (e.g., mechanical properties of metals). This study gave students a MSLQ survey to measure motivation, goal orientation, and self-efficacy as well as a pre- and post-test survey to measure student learning of the concepts. Based on regression analysis, student intrinsic goal orientation and e-learning practice were significant predictors of learning but self-efficacy was not. One important detail is that authors were unable to analyze student interactions directly (as we do) since the LOs lacked tracking capability. Instead, the authors relied exclusively on self-reported student knowledge from the pre- and post-test surveys.

Third, regression analysis was used in a study by Kay & Knaack [7], to predict the validity of a wide range of LOs. This study gave students an evaluation survey asking about how much the LOs helped student learning and the quality of the LOs. The authors reported that, based on a regression factor analysis, student responses to the learning questions were significant predictors of learning. One important detail is that the factor analysis was based on a wide range of LOs from different developers. These LOs covered widely different concepts as opposed to the iLOG framework LOs on similar, CS concepts considered in this study.

To summarize, regression analysis has been previously used to find significant predictors of learning for demographic, MSLQ, and evaluation areas. However, to the best of our knowledge, no study exists that *provides a compressive analysis on metadata in all these areas*. Further, analysis to find significant predictors of learning based on actual student interactions with LOs in much more limited.

IV. Results

Here we discuss the results for the comprehensive regression analysis broken down by metadata area.

A. Student Interaction Metadata

Table I shows that nine student interaction variables are significant predictors of learning.

First, assessmentTotalClicks is a significant predictor of learning based on the coefficient and p-value in Table I. In the assessment, students were not allowed to go back to the tutorial but they could go back and change answers to previous assessment questions. We observed that numerous times for each LO, the number of assessmentTotalClicks was greater than the minimum number of clicks required to complete the assessment test. This means that students reviewing and revisiting the test pages had higher assessment scores.

Second, we look at metadata related to student interactions with the LO tutorials. The results for tutorialTotalSeconds and tutorialAverageSecondsOnAPage indicate that a higher assessment score is associated with more time invested by students on each page of the tutorial and the overall tutorial section of the LO. Students need to spend substantial amounts of time to fully understand and comprehend the underlying notion of the LOs provided by these tutorial pages. The more time they spend studying the content on the tutorial pages the better prepared they are for the assessment test, resulting in higher assessment scores. This makes sense given that the assessment questions are designed to evaluate student understanding on the tutorial content. The results for tutorialMinClicksOnAPage show that students who interacted more each page of the LO tutorial received higher assessment scores. The more minimum number of clicks students had on tutorial pages, the higher their test scores. This makes sense because each tutorial page contains a significant amount of information requiring students to click the scroll button a few times to look at all the information provided on the page.

Third, we look at metadata related to student interactions with the interactive LO exercises. The positive results for two variables, namely exerciseAverageSecondsOnAPage and exerciseMinSecondsOnAPage show that students who had visited and spent some time on the exercises did well in the assessment test. Additionally, the results for exerciseAverageEntries, show that students who tried the exercise pages received higher test scores. On the surface, these results make sense given that each exercise is fairly complicated requiring time for students to go through completely. The benefit of the exercises is that they provide active feedback on the LOs which has been shown to improve student learning [10]. However, the other results cast doubt on the effectiveness of the LO exercises. We found that exerciseTotalInterval is a negatively associated significant predictor of learning. The exerciseTotalInterval is the time students spent reading the provided feedback after answering the questions contained in the exercise about the LO topic on an exercise page and clicking the submit button. Further, the exerciseTotalEntries, which is the total number of entries students made in the exercise pages, is also a negative predictor of student learning. Taken together, these two negative predictors seem to indicate that students who struggle with the exercises, as measured by the time spent reading the feedback and making additional entries, also struggle to do well on the assessment questions. In a sense, the exercise questions failed to prepare these students properly for the assessments questions. These results could also result in student frustration from struggling with difficult LOs—we will return to this in Evaluation section. Based on these results, one action to improve the LOs would be to revise the exercises to provide more effective feedback.

TABLE I. SIGNIFICANT PREDICTORS OF LEARNING IN STUDENT INTERACTION METADATA WITH REGRESSION COEFFICIENTS AND P-VALUES.

Student Interaction Var.	Coefficient	p-value
assessmentTotalClicks	**0.1255**	**0.0031**
tutorialTotalSeconds	**0.0028**	**0.0009**
tutorialAverageSecondsOnAPage	**0.0434**	**0.0001**
tutorialMinSecondsOnAPage	**0.2654**	**0.0002**
tutorialMinClicksOnAPage	**7.5953**	**0.0000**
exerciseAverageSecondsOnAPage	**0.0130**	**0.0081**
exerciseMinSecondsOnAPage	**0.0172**	**0.0010**
exerciseAverageEntries	**0.1410**	**0.0336**
exerciseTotalEntries	-0.615	0.446
exerciseTotalInterval	**-0.0001**	**0.0001**

B. *MSLQ Metadata*

Table II shows that eight MSLQ variables are significant predictors of learning.

First, we observe that Extrinsic Goal Orientation (EGO) is a negatively associated significant predictor of learning based on the negative coefficient and p-value in Table 2. Note that EGO refers to student motivation to do well in class for better grades, rewards, evaluation by others, and competition. To further investigate the negative association, we divide the data by courses. We observe that EGO is positively associated predictor with all but one course. On this course, the students were able to take the learning object again and again, with only their last assessment score being used for course grade calculation. As a result, it is possible that those students randomly answered all the questions the first time they took the test, only performing well the second time after they knew the test content. To confirm our suspicious, we found that the time spent was *significantly lower* the last time students took the assessment test compared to the first time they took the test while assessment scores are *significantly higher*.

We think that, after their introduction to the assessment test, these students realized that they could score better when they repeated the test if they learned the test content the first time. That these students were "gaming the system" to achieve higher assessment scores also helps explain the lack of significant results for Intrinsic Goal Orientation (IGO) which has previously been reported to be a significant predictor of learning [6]. Again, if we leave out students in that course, the IGO becomes a significant predictor of learning. Based on these results, one action to improve student learning with the LOs is not allowing students to retake the LO assessment multiple times. Alternatively, if instructors still want this capability, the LOs should be equipped with a larger battery of questions that are randomly presented to students making "gaming the system" less practical for students.

TABLE II. SIGNIFICANT PREDICTORS OF LEARNING IN MSLQ METADATA WITH REGRESSION COEFFICIENTS AND P-VALUES.

MSLQ Variables	Coefficient	p-value
Intrinsic Goal Orientation	0.2717	0.0912
Extrinsic Goal Orientation	**-1.0693**	**0.0000**
Control of Learning Beliefs	**1.2354**	**0.0000**
Self-Efficacy for Learning	**0.9340**	**0.0000**
Task Value	**0.8795**	**0.0000**
Elaboration	0.1245	0.5164
Organization	0.0965	0.4748
Self-Regulation - planning	**1.3040**	**0.0000**
Self-Regulation - monitoring	**0.6859**	**0.0000**
Self-Regulation - checking and correcting	**1.4880**	**0.0000**
Effort Regulation	0.1180	0.6004
Help seeking	-0.0754	0.5382
Problem-Solving	**0.6230**	**0.0006**

Second, we found that Self-Regulation - checking and correcting is a positively associated significant predictor of learning. Self-Regulation - checking and correcting refers to student checking and correcting behavior as they progress through a task. Those students who rated high in this category are more likely to change the way they study to fit course needs and the teaching styles of professors. They are also more likely to attend to feedback and make changes to improve their understanding of the course material.

Lastly, the results for the remaining four variables are expected and consistent with previous work that MSLQ variable are, in general good predictors of learning [12]. Control of Learning Beliefs means that the students control their own learning and their learning outcomes are proportional to their hard work [13]. They believe that results are not affected by the other factors such as teacher or luck. Students who put a high rate in this category strongly believe that the good assessment score they received is because of the hard work they put in. These students are likely to study the material more diligently leading to higher assessment scores. Self-Efficacy for learning is how the students judge themselves on their capability of learning the material [14]. Students who put a high rate in this category are more confident that they can learn the material. These students are likely to work harder at learning the material leading to higher assessment scores [15]. Task Value refers to the student determination about the value of the assessment [16]. The students work on the assessment if they think that the assessment is important to their score in the course. The higher the students rate on Task Value, the more attention they will pay to the assessment and thus they receive better assessment scores. Problem-Solving is a mental process that involves determining, examining, and solving problems [17]. With a high rating in Problem-Solving, it is to say that the students are able to understand the question and are capable of solving the question in the assessment.

C. Demographic Metadata

Table III shows the results for the eight demographic metadata variables. Four of these variables have categorical rather than numeric values so we use the F-test, rather than regression, to determine the p-values. Overall, seven demographic variables were found to be significant predictors of learning.

First, student's ACT score, the student's grade point average, and the student's highest math course taken (i.e., math background) are all positively associated significant predictors of learning based on the regression coefficients and p-values in Table III. These results are expected and consistent with previous work which found that ACT and GPA [18][19][20] and math background [21] are all significant predictors of student learning.

Second, student gender is not a significant predictor of learning. These results are *consistent* with previous research which has shown that gender is not a significant predictor of learning [22][23][24]. To further convince readers, since the influence of gender is still contested [25], we summarize previous work on the iLOG LOs. In the past, female students had more difficulty with these LO assessment questions than did male students [26]. This difficulty led to a systematic revision of the LOs using assessment validation tools from educational research [27]. After this revision, gender was no longer a significant predictor of learning [3].

Third, student's grade level, major, and required course all appear to be significant predictors of learning. These results are undesirable since the LOs are intended to allow students with a wide variety of backgrounds to all learn the CS topics [27].

- To explain grade level, we compared the average assessment scores for each grade level of students against all the other grade levels (e.g., freshmen vs. non-freshmen). We found that the freshmen students achieved significantly higher average assessment scores than all the other years (82.02% vs. 69.34%) based on a Welch's t-test ($p <= 0.05$) contributing to the significance of grade level as a predictor of learning. Looking further, we realized the majority of freshmen were in the CS honors course and, as such, were highly motivated to get good grades (i.e., high EGO motivation). When these honors students were removed, the significant difference between freshmen and non-freshmen students disappeared (71.35% vs. 69.34%). These results seem to indicate a dependency between grade level and EGO motivation in some students.
- To explain major and required course, we looked at the assessment scores broken down by CS students required to take the course and students taking the course as an elective. Surprisingly, non-majors taking the course as an elective achieved significantly higher average assessment scores than majors (84.58% vs. 76.57) based on a Welch's t-test. These results can be explained in terms of IGO motivation. Non-majors taking it as an elective have significantly higher average IGO than non-majors required to take the course (4.81 vs. 4.54 on the 7-point Likert scale). Further, majors with high IGO motivation (>4) achieved significantly higher average assessment scores than majors with low motivation (81.02% vs. 61.85%). These results seem to indicate a dependency between these variables and IGO motivation.

Overall, based on these results, the differences in assessment scores for the students have more to do with motivation than the grade level, major, or required course. In a sense, these dependent variables are simply reflecting the differences between students with high and low motivation. Thus, these variables should not be considered significant predictors of learning. As a result, actions taken to engage lower motivation students are likely to be more effective at improving the LOs than customizing LOs for specific grade levels or majors.

TABLE III. SIGNIFICANT PREDICTORS OF LEARNING IN DEMOGRAPHIC METADATA WITH REGRESSION COEFFICIENTS AND P-VALUES. THE (*) INDICATES CATEGORICAL VARIABLES WHERE F-TESTS WERE USED.

Demo. Variables	Coefficient	p-value
Gender*	N/A	0.0669
Grade Level*	N/A	**0.0000**
College Major*	N/A	**0.0006**
Required Course*	N/A	**0.0000**
ACT	**2.6645**	**0.0000**
GPA	**11.0135**	**0.0000**
Highest Math Course	**4.7810**	**0.0000**
Programming Courses	**-4.2619**	**0.0000**

D. Evaluation Metadata

Table IV summarizes gives the results for the ten evaluation metadata variables. Six evaluation survey variables are significant predictors of learning. The negative regression coefficients for Q8 and Q9 can be explained by the negative wording. On these two questions, students who agreed with these questions (higher survey values) struggled with learning the content more than other students providing the negative coefficients. In general, these results are consistent with previous work which found these questions to be significant predictors of student learning [28]. Based on these results, actions to improve the LOs should focus on improving LO user friendliness. One prime section for such improvements is in the exercises that, as discussed in Section IV.A, are troublesome for the students.

We looked further at the remaining four survey variables. We repeated the regression analysis broken down by course and found that the results were still not significant. To dig deeper, we broke these variables into two natural groups. Group 1 contains Q2 and Q7 that have similar wording and compare the LOs and the professor using traditional lecture. Group 2 contains Q4 and Q6 which ask students about future preferences. For Group 1, we found a significant negative correlation (dependency) between these variables and the MSLQ Self-Regulation – checking and correcting (-0.09 for Q2 and -0.08 for Q7 with DF = 400). Students with high checking and correcting seemed to prefer lectures where they could ask for immediate feedback. For Group 2, we found that non-majors were less likely to use the LOs in the future than majors (3.23 vs. 3.38, p-value 0.12). Based on these results, we have increased confidence that these questions are, indeed, not significant predictors of learning. Therefore, no actions need to be taken to address these questions.

TABLE IV. SIGNIFICANT PREDICTORS OF LEARNING IN EVALUATION METADATA WITH REGRESSION COEFFICIENTS AND P-VALUES.

Evaluation Survey Variables	Coeff.	p-value
Q1- LO was easy to use	**6.2157**	**0.0000**
Q2-LO maintained interest more than professor	1.7167	0.0606
Q3- LO was valuable addition to course	**2.7967**	**0.0014**
Q4-More course material via the web	-0.3622	0.6546
Q5- LO helped me understand this topic	**3.7838**	**0.0000**
Q6-I will use the same LO again in the future	1.1039	0.1580
Q7-Learned more from LO than professor	0.1279	0.8908
Q8-LO material was difficult to understand	**-6.5382**	**0.0000**
Q9-LO needed to go into greater detail	**-4.9595**	**0.0000**
Q10-Overall how would you rate this LO	**4.1535**	**0.0000**

V. CONCLUSIONS AND FUTURE WORK

Learning objects (LOs) are reusable instruction material that support distance education and supplement the traditional classroom environment. The computer-based nature of LOs allows for sophisticated data tracking such as recording user interactions with the LOs. However, such data tracking results in a "mountain of metadata" only some of which are actually significant predictors of learning. This makes it difficult for anyone to utilize the LO results. Previous studies have focused on a posteriori analysis to identify the metadata variables that are actually significant predictors of learning. Unfortunately, these studies tend to focus on metadata in a specific area (e.g., MSLQ or demographic) and, thus, fail to identity variables dispersed across multiple areas. Further, these studies do not take into account variables that are dependent on those in different areas and, as such, not truly significant predictors.

In this work, we found a number of significant predictors of learning based on student interactions with the LOs. Students who spent more time on the LOs and reviewed their answers on the assessment questions received significantly higher scores. Further, students with higher motivation, self-efficacy, and self-regulation also tended to receive higher scores—consistent with previous work. Lastly, student gender was not among the demographic variables found to be significant predictors of learning.

This work has two further general contributions. First, we provide a regression analysis that involves metadata from multiple areas: interactions, MSLQ, demographic, and evaluation. This regression analysis shows that, indeed, significant predictors of learning are dispersed across multiple areas. Second, we further investigate the dependencies between variables that appear (initially) to be significant predictors of learning. This investigation shows that several of variables in the demographic and evaluation areas are, in fact, dependent on variables in other areas such as student motivation.

The above contributions establish the need for more comprehensive analysis on metadata collected for LOs. We see three main avenues for continuing this work in the future.

- First, we intend to make use of the findings (predictors) to improve the LOs. Based on the findings, engaging the students with the LOs may be more effective than customizing the LO content for, say, a given major. One possible way to *further engage* students is to tap into creative thinking. The LO content could be redesigned to engage multiple senses and require imaginative thought as opposed to the current LO content that may be too dry and pedantic—like reading a text book.
- Second, we intend to continue our investigation on the previously collected metadata. This metadata shows clear signs of dependencies between variables in different areas. However, we have likely not found all the interdependencies between these variables. In particular, we still question whether several of the variables in the evaluation and demographic areas are truly significant predictors or simply reflecting other variables.
- Third, we are extremely interested as to whether the significant predictors for these LOs, which are taken individually by the students, are still applicable for students in collaborative learning environments. In particular, we intend to investigate whether motivation and other MSLQ variables remain significant predictors for teams of students working together to write online wikis or essays.

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New National Science Foundation Opportunities for Improving Undergraduate Engineering Education

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***Abstract*—The goal of this mini-workshop is to increase the participants' knowledge of current opportunities at the National Science Foundation (NSF) to support excellence in undergraduate science, technology, engineering, and mathematics (STEM) education. In particular, the discussion focuses on new and current opportunities in the Division of Undergraduate Education as well as highlight examples of project activities that support these opportunities. The mini-workshop uses a highly interactive format, using team-based games and discussion, to engage the participants and to foster the sharing of ideas, to clarify misconceptions, and to potentially initiate new ideas in engineering education innovations and research. This mini-workshop closely encourages the sharing of ideas and interaction amongst peers, and also informs participants about current NSF funding opportunities in STEM education.**

Keywords—funding opportunities; engineering education; National Science Foundation; student learning; curriculum development; faculty development; institutionalization

I. Goals

The goal of this mini-workshop is to increase the participants' knowledge of current opportunities at the National Science Foundation (NSF) to support excellence in undergraduate science, technology, engineering, and mathematics (STEM) education. In particular, the discussion focuses on new and current opportunities in the Division of Undergraduate Education (DUE) as well as highlight examples of project activities that support these opportunities. The mini-workshop uses a highly interactive format, using team-based games and discussion, to engage the participants and to foster the sharing of ideas, to clarify misconceptions, and to potentially initiate new ideas in engineering education innovations and research. The goal of this mini-workshop closely aligns with the goals of FIE because it encourages the sharing of ideas, interaction amongst peers, and inform participants about current NSF funding opportunities in STEM education.

II. Mini-Workshop Topics

In this interactive mini-workshop, participants explore new emphases and opportunities for funding high-impact projects in STEM education. Participants actively engage in learning about new and current opportunities, discussing project activities and elements, initiating the design of potential projects and interventions, and identifying fit with available funding programs.

Recently, several NSF funding programs have used and developed creative new mechanisms to greatly advance knowledge building in engineering education, impact educational practice on a broad scale, and significantly increase the number and quality of graduating engineers. For example, the program Widening Implementation and Demonstration of Evidence-Based Reforms (WIDER) was announced in April 2013. The goal of the WIDER program is to scale up the application of highly effective methods of STEM teaching and learning within and across the higher education sector to achieve improved student learning, increased numbers of students choosing STEM major, and improved retention to graduation of all STEM majors.

A new program Catalyzing Advances in Undergraduate STEM Education (CAUSE) has been proposed and is anticipated to include the goals of past DUE programs (Transforming Undergraduate Education in STEM (TUES), WIDER, and STEM Talent Expansion Program (STEP)), among other goals. Additional undergraduate STEM education programs are highlighted to allow participants to identify potential programs that might match their ideas and goals. Moreover, participants will become familiar with NSF and its goals to put these opportunities into context. Participants also will become aware of the recent revisions in the NSF Proposal & Award Policies & Procedures Guide (PAPPG), which affect proposal preparation, merit review, and reporting.

III. Qualifications of Presenters

All the presenters in this mini-workshop are program directors in the Division of Undergraduate Education at the National Science Foundation. Each presenter has extensive experience in leading and engaging in engineering education and research projects as well as engaging with students in and out of the classroom. The presenters work very closely in developing the STEM education funding programs at NSF. In particular, they are directly involved in writing the program solicitations, reviewing proposals, making funding decisions, communicating expectations to principal investigators, and interacting with potential principal investigators.

IV. WORKSHOP AGENDA

The mini-workshop includes the following topics:

- Introduction and overview of mini-workshop and format
- NSF organization structure and its goals
- Interactive activity on NSF opportunities to improve undergraduate STEM education, using a team-based game and follow-up discussion to highlight key elements of each program
- Summary of STEM undergraduate education opportunities at NSF and follow-up questions and discussion, lead by presenters
- Interactive discussion on project activities
    - This focuses on the types of activities within a potential project and key elements of a successful project.
    - Participants have opportunities to think about and discuss their project ideas
- Revised NSF Proposal & Award Policies & Procedures Guide (PAPPG)
    - Highlights on changes in proposal preparation and reporting
    - Clarification in the merit review criteria
    - Questions and discussion

V. INTENDED AUDIENCE

The anticipated audience of this mini-workshop includes STEM educators who are interested in developing high-impact projects in STEM undergraduate education. This includes instructors, faculty members, and administrators at U.S. college and universities in the engineering, computing, and engineering education disciplines. The content of this mini-workshop would be of interest to the broad FIE audience.

VI. KNOWLEDGE ATTENDEES WILL ACQUIRE

At the end of the mini-workshop, participants will have extended their knowledge about opportunities at NSF for undergraduate STEM education. In particular, the participants should be able to:

- Describe the goals, objectives, and scopes of the programs discussed;
- Identify the program(s) that fit their needs and interests;
- Discuss high-impact project activities that support the goals of the opportunities; and
- Summarize revisions to the proposal preparation guidelines, review process, and project reporting requirements.

Through the highly interactive and engaging activities, participants will have opportunities to increase their knowledge about NSF programs in STEM education, initiate new ideas in engineering education innovations and research, clarify questions and misconceptions related to the opportunities discussed, and share ideas.

Model Collaboration for Advancing Student-Centered Engineering Education

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***Abstract*— The University of Texas at El Paso (UTEP) and the Franklin W. Olin College of Engineering (Olin) are establishing a student-centered hands-on interactive approach to engineering education (similar to Olin's) at UTEP, where it will reside in UTEP's innovative B.S. in Leadership Engineering (LE) program. The goal of the proposed collaboration is to catalyze UTEP's educational innovation through a cross-campus collaboration between the two institutions by incorporating the Olin educational process, both design and features, into the first offerings of the Bachelor of Science in Leadership Engineering (BSLE) program. Specifically, the collaboration includes faculty exchanges between the two institutions; a series of retreats for planning and assessment; curriculum development; and student recruitment practices. The 21st century workplace demands a new engineer — one who effectively contributes to solving problems using innovation, creativity, and strategic foresight. Graduates of the Olin-UTEP developed Bachelor of Science in Leadership Engineering (LE) program will possess these attributes through the program's rigorous yet flexible major in engineering, and in-depth study of leadership and its effect upon technology and society. In this panel we will share the context for our innovative approach, key features of the partnership to date, and acclaim the value of inter-institutional sharing.**

Keywords—student-centered, collaboration, partner, Olin, UTEP, frameworks, engineering education, Leadership Engineering

I. Introduction

A. Motivation for the Project

The need for educating more and diverse engineers is well documented, and the reform of engineering education has been slow and occurring in a piecemeal fashion. Moreover, the National Academy of Engineering issued a report calling for engineers of the 21st century who are broadly educated and see themselves as global citizens [1]. The emphasis in this NAE report was not on whether engineering education should continue to change, but on how, to what degree, and how soon this change should happen. Thus, successful implementation of this proposed BSLE program has significant implications for national reform of engineering education, as it will address NAE concerns. UTEP is a public, urban four-year university serving a majority underserved population of Hispanic students, and Olin College is a small, private and highly selective university. These two institutions are diametrically diverse, and successful adaptation of some of Olin's innovative approaches to curriculum design and implementation at UTEP could pave the way for a broader set of institutions across the U.S. to consider adapting a similar approach.

B. Together Supporting Student-Centered Innovations

The UTEP Leadership Engineering (LE) Program is developing with support from Bob and Diane Malone, and the Halliburton Foundation, under the umbrella of the Center for Research in Engineering and Technology Education (CREaTE) in the College of Engineering at UTEP [2] and the Franklin W. Olin College of Engineering [3].

The Franklin W. Olin College solicits applications from engineering educators and their institutions to participate in the Argosy Collaborative Faculty Exchange program, developed with support from the Argosy Foundation [4]. Olin's Argosy program is designed to catalyze educational innovation through cross-campus collaboration. The exchange creates partnerships — such as the Olin-UTEP partnership — with departments or programs — such as UTEP's College of Engineering — committed to educational change.

Olin evaluates proposals based on the potential impact of change that the projects will have in their home institutions, the level of commitment that the participating institutions make towards actually implementing change, and the participants' professional background, interest and personal commitment to change in engineering education; and the fit with existing Olin activities and resources. Olin and UTEP are embarking on an exciting partnership, and it is an open forum discussion of the partnership in process that is the subject of this Frontiers in Engineering (FIE) 2013 conference panel.

II. Olin-UTEP Partnership

A. Olin-UTEP Partnership Creating Leadership Engineering

UTEP is partnering with the Franklin W. Olin College in the Argosy Collaborative Faculty Exchange program [4]. It is

Sponsored by the Argosy Foundation, Bob & Diane Malone, and the Halliburton Foundation.

this program that has led to the Olin-UTEP model for student-centered engineering education.

The partnership includes collaboration between Olin and UTEP over at least a two-year period, with opportunity to extend the partnership as needed or desired. Our joint approach (as partners) and the work completed to date will be shared at the FIE workshop. The types of engagement include Olin-run workshops for UTEP faculty, visits to the Olin and UTEP campuses ranging from short trips to semester and year long faculty exchanges, and joint assessments of both the partnership and of the outcomes of the BSLE degree.

The goals of the Olin-UTEP partnership are very well aligned with the Argosy Faculty Exchange program, and the engagements described above are the types of activities outlined in the Argosy Program guidelines [3].

The Olin program, funded by the Argosy Foundation, is designed to catalyze educational innovation through cross-campus collaboration. The exchange creates partnerships — such as the Olin-UTEP partnership — with departments or programs committed to educational change, embedding faculty from partner schools for year-long residencies at Olin College, and providing participants with time, space and support for planning transformative activities at their home campuses. Partnerships are typically expected to include two consecutive years of residencies at Olin, with varying faculty participants. The multi-year program includes a comprehensive assessment of the exchange's impact on the partner schools as well as Olin.

Participating institutions, such as UTEP, are invited to nominate pairs of senior and junior faculty who will work on the proposed projects. The pairing of senior and junior faculty is designed to provide a coalition for change in engineering education at the partner institution. Senior faculty members have deep understanding of their institution's culture, students and facilities. Junior faculty will drive the innovation as they advance their careers and serve as future leaders of change.

During the residency period, partner faculty work with Olin faculty and engage in collaborative curricular creation and innovation. Teaching opportunities – such as co-teaching in some of Olin's distinctive courses – are strongly encouraged and may also include piloting of courses developed during the residency for the home institution. Olin faculty and students will benefit from the fresh perspectives that visiting faculty will offer. As a part of the program, Olin faculty also spend time on the UTEP partner campus, to help focus, guide, and positively influence faculty and staff teams at UTEP in implementing the planned Leadership Engineering curricular innovations.

B. *Maintaining the Integrity of the Olin Approach at UTEP*

The characteristics of Olin's approach to curriculum design most relevant to the UTEP LE Program are:

- Frameworks and approaches for student-centered curriculum design
- Development of intrinsic motivation, self-direction, and autonomy through authentic project and leadership experiences.
- Culturally and socially responsive curricula, where students creatively investigate and solve social problems through innovative technological design.

The first class of BSLE students begins in the fall of 2014, and the goal is to incorporate this model for curriculum development and innovation into the first offerings as part of this new program.

III. Leadership Engineering Education

Integration of engineering and liberal arts education is central to developing the engineer of the conceptual age. The art and science of engineering is key to providing engineers with the technical and system thinking capacity needed to achieve leadership in our complex modern society. The US is at a tipping point regarding global competitiveness in technological innovation, and to a very large extent, humanity is critically dependent on the duopoly of technological innovation and liberal thinking for improvement of quality of lifestyle.

Leadership Engineering (LE) is defined as an emerging engineering sub-field that integrates disciplinary knowledge and practice with communication, business, and leadership skills. This innovative approach to engineering has emerged as a direct result of industry's immediate and long-term need for a new kind of engineer: one with a new skill set to work in complex 21st century contexts. LE is about creating engineers, who have the technical competence and leadership acumen to play vital roles in the future wellbeing and success of the US and all it stands for, and the citizens of the US, and thereby the future of the world.

The Olin-UTEP development of the LE program seeks to visualize and actuate a new paradigm for engineering education by responding to the call from students, alumni, businesses, and civic organizations. To address these needs, the new program features problem-based, student-focused learning across disciplines and situated learning through professional practice experiences.

A. *Details of Planning*

Details of planning for the new undergraduate program in Leadership Engineering at UTEP will be shared at the FIE panel. We will overview inputs from key stakeholders. Included is the contextual development of the program, the parameters considered as key, and the finalized degree plan. The program features are explained including engineering accreditation, and tracks and stems that provide flexibility for students. Balancing the competing demands within the curriculum, proved challenging but attainable given the strong administrative support and leadership for this program, and UTEP's desire to provide innovative undergraduate engineering education that leads toward increased retention and advancing opportunities for serving underrepresented populations.

Sponsored by the Argosy Foundation, Bob & Diane Malone, and the Halliburton Foundation.

B. Olin-UTEP Sharing of Lessons Learned

At the FIE panel faculty from Olin and UTEP will share lessons learned in development of this program, which revolve around curriculum determinations, development, and accreditation. A delicate balance is achieved with balancing the number of credit hours in the program, the general education core mandated as a public institution, and providing the needed LE coursework, internships, professional practice experiences, and flexible tracks in business, education, and technical specialization. Of paramount importance is that all LE courses provide student-oriented, practice-/problem-/project- based learning with intrinsic motivation, self-direction, and autonomy achieved through authentic project and leadership experiences. The result is a challenging, engaging, and exciting new program that promises to push the boundaries what it is to undertake engineering education at UTEP.

C. Final Comments – Our Panel Process

The sharing of the Olin-UTEP partnership FIE 2013 is appropriate since the forum provides an opportunity for discussion at a major international conference about educational innovations and research in engineering and computing. The Olin-UTEP panel being presented at FIE 2013 continues a long tradition of disseminating results in innovative areas of engineering education. It is an ideal forum for sharing ideas; learning about new partnerships, and developments in engineering and technology education, and interacting with colleagues in these fields.

Given the unique individual Olin and UTEP history and culture, panel discussion and focus areas will include:

- Innovation in approach and implementation of engineering education, across regions, and institutions.
- Diversity initiatives, and matters of regional development through community engagement.
- Interdisciplinary programs, at the interface between engineering, technology and society.

The panel make-up includes input from Oliin and UTEP faculty, including clinical professors (or professors of practice), and stakeholders. It is noteworthy that the Olin-UTEP LE program creation includes inputs from students, who as key stakeholders are participating as integral partners in the programmatic development. This initiative follows that process used at Olin in establishment of the first cohort curriculum.

The panel seeks to serve participants at FIE 2013 who are themselves involved in innovations in engineering education, and to provide mentoring and support for their efforts.

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Assessment of a Sustainability Program in Graduate Civil and Environmental Engineering Education

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***Abstract*—The engineering professions are becoming increasingly international and oriented towards a sustainability mindset. To enable graduate students in the Civil and Environmental Engineering (CEE) Department at Michigan Technological University to prepare to meet these demands, the National Science Foundation awarded the University a "Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM)" grant that enabled 45 students in six CEE degree programs to receive $5,000-$10,000 scholarships in 2008-12. The Michigan Tech S-STEM Program was designed to advance a global outlook of economic and social prosperity that protects the environment through various means. A complementary goal was to advance intercultural competency. The S-STEM scholars' knowledge of and attitudes toward sustainability and intercultural competency was assessed during the grant period. Pre-/post-intercultural competence assessment results were similar, however, through coursework, one sub-group of scholars displayed increased intercultural competence in pre/post assessment. Emergent content analysis of scholar written materials suggests that maturation in scholar perspectives, balancing engineering with community, economic, and environmental realities, occurred during the scholarship periods.**

Keywords—STEM education; engineering; sustainability; intercultural competency

I. Introduction

The engineering professions are becoming increasingly international and oriented towards a sustainability mindset. While sustainability conceptualizations in other fields incorporate the necessary "human" element as the governing factor in subjective design decisions, sustainability in engineering is rarely perceived in this light. Furthermore, the social and cultural dimensions of sustainability are not present in the majority of sustainable engineering courses in higher education institutions [1]. To enable graduate students in six degree programs in the Civil and Environmental Engineering (CEE) Department at Michigan Technological University to prepare to meet these demands, the National Science Foundation awarded the University a "Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM)" grant.

The Michigan Tech S-STEM Program was designed to advance a global outlook of economic and social prosperity that protects the environment. A complementary goal was to advance intercultural competency. A key means to advance this outlook was the creation of a novel mentoring scheme that engaged scholars, faculty in CEE and eight additional units of Michigan Tech, as well as off-campus experts from academic, government, non-government, and tribal organizations (inter)nationally.

The grant enabled 45 students in six degree programs (MS Civil Engineering, MS Environmental Engineering, MS Environmental Engineering Science, Peace Corps Master's International MS, PhD Civil Engineering, PhD Environmental Engineering) to receive $5,000-$10,000 in annual scholarships during the 2008-12 grant. Scholars gained experience in conduct of research in a two-semester reciprocal mentoring project on a sustainability topic in groups composed of at least one MS and one PhD scholar, and one faculty member. Scholar education activities included required enrollment in a course on life cycle assessment, in which the scholars conducted a life cycle assessment project. Scholars were also required to enroll and participate in the Environmental Engineering graduate seminar. Their participation involved facilitating colloquia discussions on the topic of their reciprocal mentoring projects (described below) with faculty and graduate students in the CEE Department (and others who attended the colloquia), and in-so-doing informing and engaging the skills of those who attended who were not directly involved in reciprocal mentoring projects. The colloquia provided means to extend reciprocal mentoring to those attending.

Scholar research activities included reciprocal mentoring projects. Scholars participated in reciprocal mentoring projects for the duration of their scholarship. The reciprocal mentoring model was created through the S-STEM Project as a way to improve the traditional model in which there is one-way flow of knowledge and information from a faculty member to a student. According to the model, research development is based upon two-way knowledge transfer among all participant pairs: groups of faculty participate with scholar researchers to share a broader perspective of science, engineering and sustainability expertise. Doctoral scholars integrate sustainability knowledge at new research interfaces, then share with the faculty, and transfer research methods to masters scholars; masters scholars share the subtleties of implementing research with doctoral scholars and applications in practice with faculty. Using this novel reciprocal mentoring model, the program facilitated increased mentoring relationships among students as well as faculty within and outside CEE and off-campus.

Programmatic activities included regular program meetings in which scholars provided updates on reciprocal mentoring projects, discussed papers and documentaries covering a range of sustainability science and engineering topics, and encounters with professionals in sustainability science and engineering from outside the University. These encounters included listening to formal presentations, discussion in informal groups or individually on topics related to sustainability science and engineering, and career path mentoring. In addition, doctoral scholars had the opportunity to apply for funding to travel to conferences or to work with MS scholars in developing countries on sustainability projects. While knowledge, skills, attitudes, and identity may evolve through participation in any sustained learning environment, two attributes were of main interest to this program: cultural and sustainability competencies. Two research questions posed were: Did individual CEE graduate student scholars or certain groups of scholars demonstrate advancement in intercultural competence during the program? Did these scholars/groups demonstrate progress in understanding of environmental, economic, and social aspects of sustainability? Methodologies used to assess cultural and sustainability competency and key findings are discussed, followed by presentation of the results of the research.

II. Methods

A. Assessment of Intercultural Competence

Cultural competency is a relative measure of one's ability to interact with people from different cultures [2, 3]. The value of cultural competency in engineering is grounded in enhancing the effectiveness in working on teams with engineers, scientists, etc. from diverse races and cultural backgrounds. Its value is also evident in understanding the needs of worldwide clients who will use the engineered product or project, define problems differently, and work across cultural boundaries. Many learning through service experiences, especially those related to international efforts (such as Michigan Tech's Peace Corps Master's International (PCMI) Program), require students to work in a culture entirely different from their own. The impact of such efforts on how students work in a different cultural norm is of value to understand their learning. There were two critical motivations for attempting to assess intercultural competency in our S-STEM scholars:

1. our program design required reciprocal mentoring research teams; each were inherently multi-cultural regardless of their makeup; and
2. our program focused on sustainability; past evidence [4] suggests that engineers tend to give least attention to the social domain of sustainability in their project work as compared to environmental or economic concerns.

The Intercultural Development Inventory (IDI) is a cross-culturally valid and reliable method to assess intercultural competence development [5]. The IDI is suggestive of a student's proficiency at working with others who view the world differently. The IDI is available as an online 50-question tool but requires a qualified administrator for use. While the IDI provides quantitative data, its results are difficult to interpret without further awareness of the test subject (e.g., from observation, examination of project documentation, and assessment of peer-mentoring feedback). Due to its cost ($11/test) and time for completion (30-60 minutes), the IDI was administered in a pre/post S-STEM program involvement. The IDI yields quantitative results, placing the student along a spectrum of intercultural sensitivity from ethnocentrism to ethnorelativism in stages of denial, defense, reversal, minimization, acceptance, and adaptation [6]. The IDI produces two scores, a perceived orientation (PO, i.e., where the student thinks they are on the spectrum) and a developmental orientation (DO, i.e., where the student actually lies on the spectrum). Our evaluation plan focused primarily on the DO, although the gap between PO and DO was also examined as a measure of progress.

B. Assessment of Advancement in Understanding of Sustainability

Although sustainability initiatives have infiltrated engineering curricula and research over the past decade, many engineering faculty are not certain of the meaning of sustainability in the context of engineering, or how educational experiences should be designed (let alone assessed) to address the issues [7]. While sustainability conceptualizations in other fields incorporate the necessary "human" element as the governing factor in subjective design decisions, sustainability in engineering is rarely perceived in this light. Furthermore, the cultural and social dimensions of sustainability are not present in the majority of sustainable engineering courses in higher education institutions [1]. The S-STEM Program introduced a project-based learning experience and multi-level mentoring network to address some of these concerns.

To assess understanding of sustainability among S-STEM scholar participants, we took advantage of an instrument currently under development [8]. This tool, Sustainable Engineering through Service Learning (SESL), is being developed through NSF sponsored research and assesses three dimensions of sustainability mastery: self-efficacy (e.g., choices, efforts, and persistence), value (e.g., beliefs and interests), and affect (e.g., attention, character, conscience). SESL is available as a two-part evaluation, a forty-question online survey and an open-ended essay to a sustainable engineering design challenge scenario. For our program, due to a limited number of trained scenario essay evaluators and assessment time and resources, only the online survey portion of SESL was used in our evaluation strategy in a pre/post approach.

To further assess potential connections between learning experiences and outcomes, an emergent content analysis was performed on all final reports submitted by scholars on their reciprocal mentoring project research (n=25; reports were written by project teams). The nearly 80,000 words contained in the reports were examined for frequency. Those words used

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more than ten times were included in the analysis. These (132 resulting) keywords were thereafter binned into one of three sustainability categories: environment, economics, or society. The total frequencies of words in those bins were summed and normalized to the category with the maximum frequency.

III. RESULTS

A. Demographics

Fractions of female scholars were 33%, 43%, 52%, and 50% in Years 1-4, respectively, for an average of 48%. Over the entire project minorities represented 13% of all scholars, with one scholar of Asian race and five scholars who were of Hispanic or Latino ethnicity. The fraction of scholars who were Hispanic/Latino (8%) was half the fraction of the U.S. population that was Hispanic in 2010 (16%), the year a spike in college enrollment of Hispanics of 24% occurred [9]. The program exhibited higher diversity over the grant period than the Michigan Tech CEE Department. Department percentages for race and ethnicity were relatively constant over the grant period, whereas for gender there was an increase in the fraction of female graduate students from ca. 30% to ca. 40%, for a 4-year average over this period of 32% in comparison with the 48% of all scholars who were female in this period. The fraction of S-STEM female faculty mentors was lower at 20%. The fractions of scholars that were Asian or Black/African American was lower than those of the Department (2% as compared to 5% and 0% as compared to 1%, respectively); however, the fraction of Hispanic/Latino scholars was 8%, four times higher than that of graduate students in CEE (2%) and faculty mentors (0%). The greater gender and ethnic diversity of the scholars as compared to their faculty mentors provided opportunities for faculty mentors to interact with scholar mentors with a broadened scope in world views and experiences in the reciprocal mentoring experiences.

B. Intercultural Diversity Inventory

While sample pools were too small to draw statistically significant conclusions, information can be gathered about sub-cohorts for semi-quantitative comparisons. The findings for intercultural competency, as expressed by the IDI, are given in Table 1 for scholars who completed the pre- and post-program evaluations. Changes in intercultural competency are computed as the difference in post- and pre-program evaluations divided by the average of the two scores. While percent changes were small (for all scholars, an average increase of 1.8%), past work suggests changes in the > ±5% range are difficult to manifest without a significant experience (either planned major intervention, or unplanned culturally disruptive event). In general, women increased in intercultural competency, whereas men decreased; PCMI scholars increased, whereas MS/PhD scholar counterparts decreased; civil engineering scholars increased more, with environmental engineering scholars having higher competency. The 11.6%

Table 1. Intercultural competency as determined by the Intercultural Development Inventory, developmental orientation (DO) scores. Only scholars with pre and post scores were included (n=29).

Sub-cohorts	IDI (pre)	IDI (post)	Change (%)
Female (n=17)	92.4	96.8	4.4
Male (n=12)	92.4	90.5	-1.9
PhD (n=3)	96.3	84.7	-11.6
MS (n=2)	93.7	92.2	-1.5
PCMI (n=24)	89.8	96.0	6.2
Civil Eng. (n=7)	86.6	90.1	3.5
Env. Eng. (n=22)	94.2	95.5	1.3

decrease in pre/post IDI for the small group of PhD scholars may be meaningless. For example, the result could be explained by one scholar making an error on the post test. The most recent PCMI cohort had more information/knowledge in the form of a required curriculum including a new course on Cultural Dimensions of International Immersion and Research. (A separate, unpublished examination of the 22 (of the 24 in Table 1) PCMI scholars in that course showed a 9% increase in IDI over the one-semester course intervention.)

Using Hammer's IDI scale [5; Figure 1], plotted as a group, most scholars in this S-STEM cohort were found to have a minimization cultural view; effectively, they see the commonalities among cultures as their main feature. (The three PhD scholars that completed pre/post evaluation would be categorized as possessing a defense mindset, a view that one cultural perspective is better than others). Through their involvement in the S-STEM Program, most scholars moved somewhat to the right in the spectrum, inching toward an acceptance framework (a cultural view towards accepting that various cultural perspectives are present and relevant; Table 1). These results suggest that this group of engineers progressed in intercultural competence during the scholarship period.

C. Sustainable Engineering through Service Learning

Changes observed in pre- and post-program scores for the three independent SESL sub-scales (sustainable engineering self-efficacy, value, and affect) provide some clues to program impacts: self-efficacy changed little, value decreased, and affect increased dramatically (Table 2).

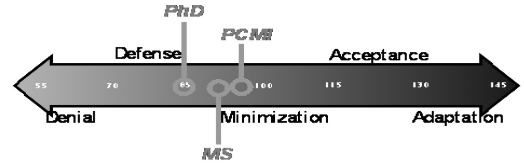

Figure 1. Intercultural Development Inventory score spectrum mapped to Bennett's [6] developmental model of intercultural sensitivities and the scale of Hammer et al. [5]. Approximate positions of S-STEM degree objective sub-cohorts are presented.

Table 2. Normalized sustainable engineering index sub-scores (sub-scores sum to unity). Only scholars having pre and post scores were included (n=26).

	Self-Efficacy	Value	Affect
Pre	0.346	0.434	0.228
Post	0.358	0.391	0.251
Change	3.41%	-10.4%	9.60%

In other words, on a group average basis, these students claim to have little change to their sustainable engineering abilities (self-efficacy), care less about sustainability (value), but are more attuned to sustainability. The change in value sub-scores may seem contradictory, but an explanation may be found in the high initial score (pre) and in a common observation of more experienced students that "nothing is sustainable". This view may simply indicate maturation of perspective, balancing engineering with community, economic, and environmental realities. It may also indicate an increased pessimism of the scholars in regards to the potential for the public to make lifestyle changes that promote sustainability.

Stepping away from group averages, Figure 2 displays the pre- and post-program positioning of each scholar (n=26) in a three-dimensional space representing the SESL sub-scales. As hinted at by the table above, the general movement is to the right, indicating a dominant shift in the affect sub-scale, and a decrease in value.

Comparisons of SESL assessment results by gender, program (PCMI, MS, PhD) and degree (civil/environmental engineering) cohorts did not yield significant results due to small sample sizes. Self-reported self-efficacy results (not shown) were for the most part stable. Male scholar self-efficacy was generally lower pre but similar to female self-efficacy post (9.8% increase overall in males). Lower (than MS and PhD scholars) and similar pre/post scores were reported by PCMI scholars. Comparisons among the sub-cohorts for sustainable engineering value indicated that women finished with bigger decreases (-9.2%, but still higher scores) than their male counterparts. PCMI scholars decreased more than other majors (-9.9%), whereas civil engineering majors decreased the most among all sub-cohorts examined (-14.4%). Women and PCMI scholar groups started with the highest scores, and may simply be "re-calibrating" their perspectives on sustainability after an academic year of wrestling with real projects, interacting in group discussions, and better appreciating multiple disciplinary perspectives through mentoring. Civil engineering, women, and PCMI scholar groups made large gains in affect (35.5%, 21.1%, and 20.0%, respectively), suggesting these students became more attuned to sustainability during the scholarship period. While the S-STEM participants are certainly influenced by other academic forces, by the end of the S-STEM Program, these groups all reported dramatic gains in their abilities to be aware of and act on sustainability issues within their work and lives.

D. Emergent Content Analysis

Scholars explored mostly environmental, then economic, and lastly, societal aspects of sustainability in their research projects (Figure 3). Terms related to economics were used at 77% the frequency of terms related to environment, whereas societal terminology was used less than half as frequently, 45%. This data is aligned with the assessment findings above and with curricular coverage for many graduate scholars in civil and environmental engineering. However, further research is needed to determine whether the lack of societal focus found in the scholars, as expressed by these research communications, is a result of lower cultural/awareness competencies, or of limited exposure to these domains in college education. It is likely even more challenging for the general engineering populace to base engineering practices on social, economic, and environmental aspects of sustainability. These scholars are pre-disposed to be interested in sustainability, and in the case of PCMI scholars, in community development as well.

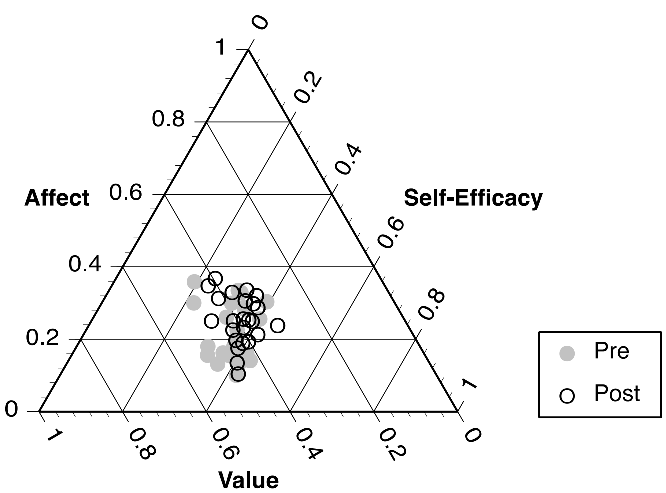

Figure 2. Representation of sustainable engineering index by its three sub-scales (self-efficacy, value, and affect). Only scholars having pre and post scores are displayed (n=26).

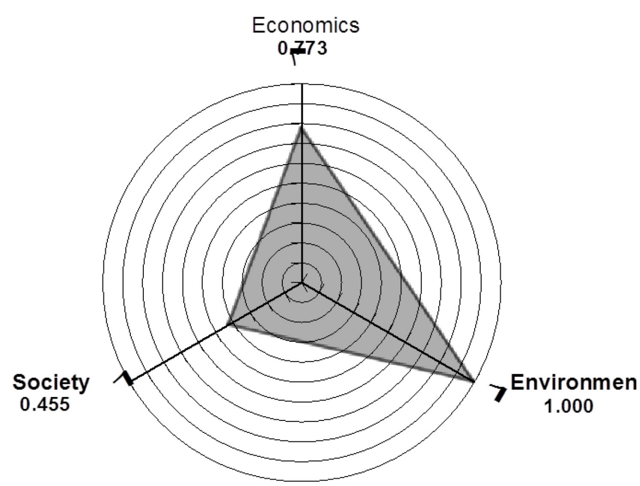

Figure 3. Sustainability content frequency analysis of final research project reports submitted over all years of the S-STEM Project (n=25; 79,769 words). Frequency numbers are normalized to frequency over maximum sector (Environment).

IV. Conclusion

Comparison of the results presented here and CEE Department-wide results would be of value in order to assess how these cohorts view cultures and consider the dimensions of sustainability differently. Such a comparison might lead to the finding that, during the project, the S-STEM cohort progressed in these areas relative to all CEE students. If we are to promote development of engineers having balanced worldviews of cultures and a sustainability mindset as the world demands [10-13], assessment of intercultural and sustainability competency in education programs is essential.

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Engineers Transforming the Environment for Betterment of Life

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Abstract *— Knowledge in Basic Sciences, Basic Sciences of Engineering and Specifics of Engineering are fundamental for the education of an engineer. However the insertion in labor market demands sometimes some practice or experience that should also be provided by the engineering schools. Taking this into account, the Engineering Education Research Team of COPEC – Science and Education Research Council has designed a program for an engineering school which main goal is to prepare engineers for the future work market, the engineer for the future. It is an interdisciplinary environmental engineering program that intends to offer students an exciting opportunity to focus their technical capabilities on evolving science that affects human quality of life in an international scale and can simultaneously help preserve and restore areas in which they work. Emerging issues challenge environmental engineers in public health, conservation and restoration of natural systems, water and wastewater treatment, pollution prevention, and more.*

Keywords *— global education perspective; PhD program; technical skills; regional environmental issues; growing economies*

I. Introduction

It is currently common to watch the innumerous achievements of so many engineers all around the world in TV shows, who have diligently built and transformed the environment to make men's life better. The number of prominent professionals who have been referenced by their accomplishments is uncountable. Based on this, it is possible to say that the education of engineers is fundamental to keep the level of development of humanity in order to achieve social development similar to technological development. However the present challenges of engineering education institutions are not limited to the education of a professional for an international work market, but also to defeat the crises of education in which they are inserted.

It is accurate to state that engineers are responsible for the development of science and technology once they design tools, systems and instruments that make the acquisition of knowledge in a vast amount of fields possible. Engineering is responsible for the deep transformation of human relations in the first decade of 21st century, changing both education as well as business paradigms. A new era in working environment has started, which characteristics are peculiar due to new communications, mobility and globalization. These aspects lead to the fact that now it is also important to provide engineers with tools that enable them to act in a working environment that demands a very flexible and innovative mind in order for them to be fully inserted and to keep up with the work market [1].

The expanding global population has brought with it a growing concern about the environment and the impact of technological development on it. The goal of this work is to show the engineering program developed with the objective of training engineers to enter and remain in the future labor market. The choice of a PhD program is due to the investments that are being done in the region and the future possibilities for civil engineers. It is a region where petrol has been found in a great amount and also where the enlargement of the seaport for 2020 is being planned, two big endeavors that require many constructions.

The present program is an interdisciplinary environmental engineering program that intends to offer students an exciting opportunity to focus their technical capabilities on evolving science that affects human quality of life in an international scale and can simultaneously help preserve and restore areas in which they work. Emerging issues challenge environmental engineers in public health, conservation and restoration of natural systems, water and wastewater treatment, pollution prevention, and more. Students in this program acquire the professional skills to manage these complex issues and help their planet. This is also the opportunity for young people who are seeking for a career and a job.

II. Some Discussions About Engineering Education

The globalization phenomenon is here to stay and scientists, educators and politicians worldwide have been searching for sustainable development with social promotion of individuals and society. Despite the efforts of so many sectors of society, the present status of Education plays an important role in the development of peoples worldwide. It is the key factor to fight ignorance and consequently poverty. The growth investment in education is fundamental for all. Education in every level in western world is not yet as good as it should be. However many efforts are taking place at governmental level, because it is not enough to invest in the development of science and technology, it is necessary to have good researchers and good professionals applying the achievements of technology.

Technological power is an asset pursued by nations worldwide. Fortunately the achievements will spread and bring some balance in terms of political play in global economy. It will also contribute for the adoption of free market, highly trained workforce and innovation in the use of natural resources, and University is still the cradle of science and technology development.

The innumerous achievements of so many engineers all around the world who have diligently built and transformed the environment to make men's life better are also visible. The number of prominent professionals who have been referenced by their accomplishments is uncountable. Based on this, it is possible to say that the education of engineers is fundamental to keep the level of development of humanity in order to achieve a social development level similar to the technological development.

However the present challenges of engineering education institutions are not only limited to the education of a professional for a new global work market, but also to defeat the crises of education in which they are inserted. It is crucial to rethink the kind of education that has fragmented knowledge which drives people to not being able to articulate its several parts. Education must promote the natural ability of the mind to set and to solve problems and by inter-relation to stimulate the full usage of general intelligence [2].

The role of teachers at the higher level is drastically being changed and challenged to move from the holder of knowledge to the Master who will illuminate the path, as a backlight, so that the student can find and construct his/her knowledge and acquire the capability of applying the knowledge and build a career. The future teacher will be more of an adviser than a professional who just delivers some knowledge. It is imperative to prepare the future educators to take on this new role in order to make education advance.

o *II.1 The education for the Future*

The present work market in general is extremely complex and demanding for both professionals and enterprises, and mainly to the educational institutions - the universities - that prepare the high-qualified professionals. In the engineering field, the challenges are enormous. It became more and more necessary to prepare the engineer for a much more changing world full of complex issues of global and regional dimensions.

For engineering colleges the task is huge, once above all it is imperative to deliver a professional capable to enter and keep up with the work market, working in companies, in governmental organizations, as entrepreneur or consultant.

The actions towards the quality of a program have to be taken by the engineering college members responsible for the creation and development of an engineering program that fits the new demands [3]. It is necessary to:

- create a balanced program that integrates technical skills and professional practices;
- provide professional development and opportunities that enable faculty to teach effectively in an integrated curriculum;
- implement an integrated curriculum that meets diverse student populations;
- develop a rigorous assessment program that balances indirect and direct measures;
- establish and maintain an active research community with a research agenda that completes a feedback loop to strengthen engineering.

It is generally agreed that the engineers that universities train gain tremendous professional advantages if they write and speak well, work in teams and manage projects effectively, and listen carefully. Their communication needs to be technically complete and accurate, logically organized for the audience, visually appealing, and interesting; it also needs to be mechanically and grammatically conventional, and it must say something worthwhile. This is the recipe for success in any field and so any engineering program should include courses to enhance these skills.

III. Environmental Engineering Program developed by COPEC Engineering Team

Environmental engineers are a hybrid of an engineer and a scientist, thus making them the best profession to deal with environmental issues and problems; it is a branch of engineering that is more broadly defined and multi-disciplinary by nature, as it encompasses issues from other branches of study ranging from science, arts, mathematics and engineering. The broadness explains why there is such a wide variation between the courses of study.

Environmental engineering basically involves assessing, managing, preventing and controlling the impact of human activities on the environment. The environment can be defined as the nature surroundings, air, land, water, humans, and all non-living and living things. It entails the planning and designing of systems, equipment and technology for the management and protection of the environment, meaning that the environment is top priority in every decision-making processes [4].

The necessity of sustainable development regionally and the opportunity brought by political and geological aspects have started a new era. It has led to the need of creating a program in environmental engineering. The Engineering Education Research Team of COPEC – Science and Education Research Council has designed a program for an engineering school which main goal is to prepare engineers for the future work market, the engineer for the future. The program has been designed in detail in accordance to the present labor market of engineers, with its particular characteristics and considering a growing need for engineers. The success of the program depends on the ability to inspire the students by showing engineering as an exciting career, a personal upward path, and a way to affect local social and economic well being. The implementation of the program is meant for 2014.

The possibilities are increasing for environmental engineers. They have been employed by universities and research enterprises, government agencies, and also by major corporations.

Environmental Engineers can work in a wide variety of industries, including chemical, pharmaceutical, water/wastewater treatment, mining and manufacturing, and can be involved in hazardous waste remediation, air pollution control, facilities planning, and environmental consulting.

IV. Aspects of the Program

It is an interdisciplinary environmental engineering program that intends to offer students an exciting opportunity to focus their technical capabilities on evolving science that affects human quality of life in a global scale and can simultaneously help preserve and restore areas in which they work. Emerging issues challenge environmental engineers in public health, conservation and restoration of natural systems, water and wastewater treatment, pollution prevention, and more. Students in this program acquire the professional skills to manage these complex issues and help their planet [5].

It is a PhD level program with topics for research ranging from power storage to water quality preservation, and opportunities to work in outdoor settings and communities as well as in laboratories. Following the world trend educational model of theory and practice, student projects provide unique, hands-on opportunities to explore the multifaceted considerations surrounding environmental engineering problems at local and global levels, and to improve living conditions in the subject areas.

It offers a unique depth in this specialization, with educational options that supply the comprehensive understanding swiftly transforming field demands. It is a full-time PhD program that lasts two years, offering classes conducted on an undergraduate-type schedule.

It has a curriculum that addresses the time-crunch problem by integrating professional practices into the technical curriculum — that is, professional practices are contextualized in engineering in ways that reinforce and strengthen students' understanding and their ability to apply that understanding to address engineering problems. Throughout their graduate program, students work to master the engineering body of knowledge and simultaneously become skillful communicators, ethical decision makers, team leaders, creative thinkers and problem solvers.

It is has been designed for an engineering School of a private university in Santos, Brazil. There is no other program of environmental engineering in the region at present time. Taking this fact into account and also the fact that it is a need for this kind of engineers, this particular university is investing a great deal in this program.

This is a new kind of program because the students have out of class lecturers and meetings with project developers groups of enterprises that have agreements with the school. The students will also have classes in environment research centers located in the region.

Today, engineers must keep up with emerging technologies and understand the financial and strategic impact of their decisions. The program strongly focuses in career development fostering the accumulation and cultivation of skills and knowledge that enable a professional to advance or grow in the field of his or her choice [6].

The two-year program (120 ECTS) consists of courses amounting to 90 ECTS, followed by a Degree project (30 ECTS). The system is compatible with ECTS credits, the European credit system. Although the system of the country is in credit hours, the choice of having the European credit system is due to the fact that it is a trend for the future. It makes no difference as in terms of credit hours the amount is in accordance with the demands of the Ministry of Education.

At the end of the program the students receive a diploma registered and recognized by the Ministry of Education of the country.

V. The Courses

The choice of courses is based on the global and regional demand for engineers capable to work in projects taking into account the environmental issues and to enhance the practice of engineering for the betterment of whole community, nature and human groups impacted by projects.

The courses are dimensioned to explore the content pertinent for the development of a mind focused on research.

The courses are as follows:

ENVIRONMENTAL STUDIES: The study of environmental problems and their solutions requires an interdisciplinary approach. This course examines current environmental issues from the intersection of several key disciplines including: environmental philosophy and history, environmental policy, and science. The course develops these different approaches for analyzing environmental problems, explore the tensions between them, and present a framework for integrating them. Topics such as environmental justice, developing nations, globalization, and climate change policy are explored.

GEOGRAPHIC INFORMATION SYSTEMS: This course introduces Geographic Information Systems (GIS) as a powerful mapping and analytical tool. Topics include GIS data structure, map projections, and fundamental GIS techniques for spatial analysis. Laboratory exercises concentrate on applying concepts presented in lectures and focuses on developing practical skills. These exercises include examples of GIS applications in environmental modeling, socio-demographic change and site suitability analyses. Although the course is computer-intensive, no programming background is required.

ENVIRONMENTAL POLICY AND ETHICS: In this course, we will examine some of the important moral, legal, and public policy concerns which are raised by the interaction of human beings with the natural environment. How are policy frameworks, the beliefs and actions of environmental activists, and your views guided by deep seated notions of who has standing in the moral community? The course considers a range of moral perspectives including: anthropocentrism, biocentrism, egocentrism, animal rights and others, and examines them in the context of various contemporary public policy case studies [7].

GOVERNANCE, TECHNOLOGY, AND INNOVATION: This course examines how public policy models have the capacity to shape technological change and social innovation in a time of ecological crisis. With global attention dominated by environmental catastrophe and despair, it spotlights new work that has brought together scientists, environmentalists, engineers, and artists to tackle the most serious problems facing communities. It explores the political ecology implications of control over essential resources and the positive consequences of rethinking and democratizing basic social needs for a more sustainable future [8]. Recent exciting case studies feature examples of simple solutions that inspire elegant, transferrable, and inexpensive applications of technological design. It examines the role and obligation that scientists have to collaborate with interdisciplinary and public policy efforts that benefit people with sustainable approaches to architecture, food, energy, transportation, and infrastructure.

HUMAN BEHAVIOR AND ENVIRONMENTAL PROBLEMS: This course examines how people think about and behave toward the environment. Environmental problems can ultimately be attributed to the environmental decisions and actions of human beings. These behaviors can in turn be understood as resulting from the nature and limitations of the human mind and the social context in which behavior takes place. Knowledge of the root causes of environmentally harmful behavior is essential for designing effective solutions to environmental problems. The goals of the course are:

- to provide students with the basic social science knowledge needed to understand and evaluate the behavioral aspects of such important environmental problems as air and water pollution, global warming, ozone depletion, preserving biological diversity, and hazardous waste and
- to help students identify and improve shortcomings in their knowledge and decisions related to the environment.

Topics include, but are not limited to:

- environmental problems as tragedies of the commons;
- public understanding of global warming and global climate modeling;
- folk biology;
- risk perception;
- intelligent criticism of environmental claims;
- making effective environmental choices;
- strategies for promoting pro-environmental behavior;
- human ability to model and manage the global environmental future.

ENVIRONMENTAL PROBLEMS IN GROWING ECONOMIES: Environment and development are often seen as incompatible, in part because many poor people in the developing world depend directly on natural resources for their livelihoods. At the same time, poor people are often seen as responsible for causing environmental degradation because they lack the knowledge, skills and resources to manage the environment effectively. The vicious circle is completed as environmental degradation exacerbates poverty. However, optimists argue that poor people can and do contribute positively to environmental outcomes, that states and organizations can facilitate their efforts and that environmental interventions can coincide with development [9]. This course examines these different perspectives on environmental problems in the developing world through the insights and critiques of social science. Subjects covered include sustainable development, population, environmental risks, gender, urbanization, environmental decision-making and non-governmental organizations (NGOs). The goals of this course are to think critically about the various links between environment and development and the role of governmental and non-governmental organizations in promoting sustainable development in the developing world.

ENVIRONMENT & RISK COMMUNICATION: Environmental risks consist of incidents or trends, either man-made or natural in cause, that have potential to inflict harm to human health and/or ecosystems and could include physical assets or the economy (i.e., business and social disruption). Communication of environmental risks can be divided into two distinct categories, according to the time-sensitivity of the need for sharing information:

- events that might occur in the future where prevention is the focus, and
- emergency scenarios where an event has occurred, and there is a need for immediate notification and deployment of mitigation actions.

Moreover, the consequences of these events can produce either acute or chronic effects. The communication process is at the heart of effective environmental risk communication because it establishes the policies and procedures under which individuals and organizations will operate. Another requirement for effective communication is the ability to disseminate risk information in a timely, reliable and targeted manner. Reaching the proper audience through the proper means at the proper time is a prerequisite to effective environmental risk communication [10]. This course examines the needs of an effective communication in case of environmental risks. It provides a series of case studies in order to allow students to acquire knowledge on effective ways of communications in case of environmental risks to the wide environmental risk stakeholders.

ORIENTED CAREER DEVELOPMENT: Reflect, plan and chart a future career becomes vital condition for professional success in a globalized world. Plan a career is not just choosing a profession or an undergraduate course to follow, but also an industry segment and a performance for which the young or trader should prepare by preparing himself/herself with all the necessary tools that will bring competitive desired expertise and differential [11]. The goal of this course is to foster students with the search for career development in terms of niche choice and entrepreneurial initiatives.

ENVIRONMENTAL STUDIES SEMINAR: The course is designed to integrate each student's educational experience (e.g., core environmental courses, environmental electives, and environmental projects) in a capstone seminar in Environmental Studies. Through seminar discussions and writing assignments students will critically reflect on what they learned in their previous courses and project experiences. In teams, students will prepare a final paper and presentation that critically engages their educational experience in environmental studies and anticipates how their courses and experiences will translate into their future personal and professional environmental experiences.

The content delivery of each course is up to the teacher who can sense the development of the students and make adjustments in order to cover the topics. The choice for this more liberal approach aims to provide the students with comprehension and application of the learnt concepts in practical works [12].

VI. PROGRAM GOALS

The goals of the program are to position graduates to:

- use their knowledge and understanding of engineering sciences and design to advance their professional career;
- think critically when solving and managing tasks;
- communicate effectively in multidisciplinary, professional environments;
- exercise professional responsibility and sensitivity in the context of the social, economic, ethical and environmental implications of their engineering work;
- function effectively and efficiently as an individual and as a part of a team; and
- pursue life-long learning to earn relevant professional credentials.

VII. FINAL CONSIDERATIONS

Environmental engineering has become an important area and will be in the future, as environmental problems are worsening and cannot be eliminated, only controlled. Considering this reality, there will be a higher demand for more environmental engineers as they become more scientifically and technically prepared to find solutions to environmental problems. There is a demand for more environmental engineering programs which have the character that a proper education and training demand, as well as a well-structured and well-designed curriculum. There is no doubt that education is the key to solving global problems, contributing to global sustainability and achieving better policies for environmental issues.

If environmental engineers have all the skills and knowledge needed, they can perform their best in order to find solutions to control environmental problems and thus promote a better future for generations to come. The proposed program has the possibility to provide the students hands-on work and case studies due to the current regional scenario and the geographical location in the country besides belonging to a historical moment of a growing economy country. It is a PhD program of high quality in order to fulfill the work market's demand.

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Monitoring F2F Interactions through Attendance Control

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This work explores the use of interactions between teachers and students as a basis to infer the students' learning status and generate suitable feedback for them. We propose a system that lets teachers and students register the interactions face to face, so they can be capitalized for improving traditional teaching/learning. The recorded interactions will be exploited in a similar way to how teachers infer the knowledge status of their students from their interventions. In order to discover the teachers' strategies and, specially, their necessities regarding the interactions with their students, we have run a questionnaire and verified some previously stated hypotheses. The design of the PresenceClick system is a first result. It has a double aim: to show teachers the knowledge status of their students, so that they can adapt their teaching; and to show students their progresses and the one of the overall class so they can compare them. PresenceClick incorporates an Attendance module, which automatically collects the list of students attending the class with no effort from the teacher. This paper presents the results of this study, the PresenceClick architecture and the Attendance module, as an essential component to help and complete traditional F2F, blended or e-learning scenarios.

Student centered learning, F2F interactions, presence monitoring, attendance control, student model

I. Introduction

Current educational trends consider students as principal actors of their learning processes instead of being passive knowledge receivers. Thus, learner centered methodologies must involve continuous evaluations and control of the student's activities, which significantly increases teachers' workload during the whole course presence sessions. Therefore, new educational methods and supporting student-centered tools [1] are required.

Concerning students' competencies and learning achievements, many studies in the adaptive education field have been conducted about student modeling [2]. Most of them present different approaches for modeling the student: his or her acquired knowledge, and even interests, goals and tasks [3]. Recent works point out the relevance of enriching the student model to improve personalization and adaptation to the learner. They propose to consider new aspects such as learning styles [4] or cognitive styles [5]. Other works try to go further and investigate the modeling of the learning context: user platform [6], user location [7], environment and human dimension [8] or affective states of the students [9]. So far the study of interactions has been mainly focused on the student-system learning flow, despite the fact that the most successful and used way of tutoring is the traditional face-to-face interaction (F2F), as stated in the Interaction Hypothesis [10]. This hypothesis predicts also that the effectiveness of tutoring increases monotonically with the degree of interactivity: the more interactive the tutoring is, the more the student learning [11]. Chi et al. proved also that the one-to-one tutoring is the best way to learn [12]. However, currently this is practically impossible to be carried out in the schools, institutes or at university level. Nevertheless, tutorial sessions could be used to support attendance classes, but they are not used as often as they should.

Taking these aspects into account, a clear question arises to us: *How can we exploit to the maximum the interactions between teachers and students to take advantage from them and improve learning*? The answer is not that simple. Therefore, starting from modeling traditional interactions on the basis of didactic communication according to [13][14], our final aim is to create a tool that helps both teachers and students to manage their interactions, moving a step further towards the student-centered learning. Accordingly, we propose to monitor the F2F interactions. From the teacher's point of view, the main goal is to build an in-situ interactions acquisition system that provides them with valuable information about students' presence characteristics. This will be useful for improving the overall learning process, and for making lighter the teachers' workload. From the students' point of view, the system will allow them to incorporate their perceptions of these interactions, for example misunderstood concepts, problems with exercises, or the correct progress in the subject.

On the one hand and as a founding base, we are exploring how teachers obtain, use and exploit their knowledge about the student's learning process from F2F interactions. As a first step, we have carried out an empirical inquiry process to obtain information about teachers' expertise and necessities concerning direct interactions with students. In a similar way, a survey was conducted to discover the teachers' needs [15]; however, this study focused on tracking the interactions arisen between students and computer systems, instead of those between teachers and students. A questionnaire was passed out at the Computer Science and Engineering centers of the University of the Basque Country. In next future, we will carry out a parallel study with students to squeeze the

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interactions from both points of view.

On the other hand, we have started to develop the PresenceClick system by considering the results of the questionnaire. The system aims to provide with agile and intuitive means for teachers and students to record information about F2F interactions. These interactions are related to presence learning activities, e.g. exercises assignment, evaluations, annotations of questions and answers, etc. The PresenceClick architecture assumes some meta-knowledge structures from classical Intelligent Tutoring Systems such as the Domain and the Student models. In addition, it incorporates an Attendance module that automatically collects the list of students that attend class. Data from students' interactions are used to enrich the attending students' models, what will allow teachers to provide students with more adapted feedback. In summary, the system should be: (1) *intuitive*, to make an understandable tool with just a glimpse, no matter the user's background; (2) *simple*, to motivate teachers and students to use it, and (3) *agile*, to avoid waste of time in class to register the interactions and to decrease workload outside class.

The paper is structured as follows. Section 2 summarizes the questionnaire, the previously stated hypotheses and its results, which highlight the interest of the majority of the teachers to be helped by an educational tool. Section 3 describes the PresenceClick tool which allows teachers to register and manage just-in-time information about students' presence interactions in a flexible and easy way. Finally, Section 4 draws the conclusion and future work.

II. OBTAINING TEACHING EXPERTISE

A first step to spread student-centered learning in traditional environments is to discover the current and desired mechanisms that run the interactions among teachers and students. We believe these mechanisms will allow to derive new learning tools capable of providing both teachers and students with more adapted and contextualized help. Thus, we have conjectured that there exist different aspects of presence classes and their actors that determine the set of possible teaching strategies, material and technological tools to be applied. Besides, we presume teachers infer interesting feedback from the spontaneous class behavior.

Therefore, in order to discover these aspects, their inter-relationships and the actual teachers' perspective, we run a questionnaire about classroom teaching activities. This questionnaire promoted an introspection process oriented to reflect on the students' learning conditions in order to help teachers to specify, articulate and identify that deal of information.

We designed the questionnaire by means of an iterative process. First, we identified a meaningful question set that was gradually tested, corrected and improved. A pilot test was carried out with thirteen teachers. After analyzing their responses and interviewing all of them, we finally obtained an understandable and agile inquiry process. The resulting questionnaire is composed of 26 questions categorized in four item blocks: (1) *Teaching context* –e.g. teacher's age, number of students in class; (2) *Planning of learning sessions* –e.g. type of session, week or course plan made, and different aspects included in the plan; (3) *Interactions with students* –i.e. attendance classes, tutorial sessions and evaluation; and (4) *Teachers collaboration* –e.g. about the student workload and progress in other subjects.

The questionnaire is mostly composed of two types of question: scaled and multiple-choice. The latter facilitates answering while maintains the motivation, whereas the former aims at discover the interest of teachers about some proposals. In addition, two open-ended questions were included for teachers to deeply explain their behavior. Besides, every block includes an open entry question to freely record teachers' opinions or suggestions. TABLE I. shows an excerpt of the questionnaire entailed by two scaled questions and a multiple-choice question, the three of them concerning to block 3 (*Interactions with students*).

Once finished the refining process, the questionnaire was presented at some centers of the University of the Basque Country, where 69 Computer Science and Engineering teachers took part voluntarily. The statistical and inferential study of the teachers' answers allows us to corroborate some of our conjectures and beliefs. We have analyzed four hypotheses whose statements and results follow.

***Hypothesis H1**: The number of students in class influences the teaching strategies, i.e. material and tools used, information registered, etc.*

Teachers were divided into three groups depending on the number of students in their classes: Gsmall (less than 25 students), Gmedium (from 25 to 59 students) and Glarge (more than 59 students). Groups were balanced, so Gsmall group included 24 teachers, 22 teachers were in Gmedium, and 23 in Glarge. We found significant differences on the behavior of the groups in the following cases:

TABLE I. FRAGMENT OF THE QUESTIONNAIRE

16. Regarding the activities and the interactions in class, identify the types of information you register, you would like or you consider irrelevant.

	I register	**I'd like**	**Irrelevant**
Given concepts	○	○	○
Solved exercised	○	○	○
Proposed exercises	○	○	○
…	○	○	○

17. Choose the communication types you employ to interact with your students outside the classroom.

A. *E-mail*	B. *Individual tutorials*	C. *Collective tutorials*
D. *Forum*	E. *Chat*	F. *Others*

25. Regarding the students' behavior in non-specific , identify the types of information you register, you would like or you consider irrelevant.

	I register	**I'd like**	**Irrelevant**
Particpation in class	○	○	○
Activities performance	○	○	○
…	○	○	○

- *Teaching context –Functionalities on teaching tools (e.g. Moodle)*. Teachers in Glarge group significantly seek more supporting functionalities than teachers with less than 25 students ($p=1.2e^{-07}$), especially for *evaluating exercises*: p=0.02 between Glarge and Gsmall, and p=0.01 between Gmedium and Gsmall.

- *Interactions with students –Recording of information, e.g. assessment of presentations*. Teachers in Gsmall record information significantly more than teachers in Gmedium (p=0.03) or Glarge (p=0.001). Obviously, as the number of students increases it is more difficult to assess presentations because of time demands.

- *Interactions with students –Tutoring communications types, e.g. collective tutorials or forum*. Students in large groups require more *collective tutorials* or communication outside class than those in small ones (p=0.002). We also found a positive correlation between the use of *forum* and the number of students. TABLE II. shows usual communication types between teachers and students, and the percent of teachers that normally employ them. This information has been inferred from the answers to the 17th question of the questionnaire (see TABLE I. TABLE III. shows p-values when comparing the distributions of the communication types employed by teachers and considering the number of students in their classes.

- *Interactions with students –Content of tutorial session and its implication*. Demands of theoretical knowledge and exercises during tutorials correlate with the number of students enrolled in the class. As it was expected, students in small groups tend to ask more doubts about practice tasks or laboratories during class time. But teachers in Glarge take advantage of tutorial sessions in different ways, like *individual or class monitoring*. So, they especially *generalize* in the class those *questions* that students ask in tutorial sessions (there is a difference between Gsmall and Glarge p=0.02).

TABLE II. STATISTICS ON THE USE OF COMMUNICATION TYPES

Group	n	Communication Types				
		Email	*Individual Tutorials*	*Collective Tutorials*	*Forum*	*Chats*
Gsmall (<25)	24	96%	96%	29%	38%	4%
Gmedium (25 to 59)	22	100%	96%	55%	45%	5%
Glarge (>59)	23	96%	96%	79%	52%	0%

[a] Group=group by number of student; n=number of students in each group

TABLE III. P-VALUES COMPARING THE USE OF COMMUNICATION TYPES

p-value comparing the employment of communication types		
distribution x	*distribution y*	*p-value*
Gsmall (<25)	Gmedium (25 to 59)	0.51
Gsmall (<25)	Glarge (>59)	0.001
Gmedium (25 to 59)	Glarge (>59)	0.38

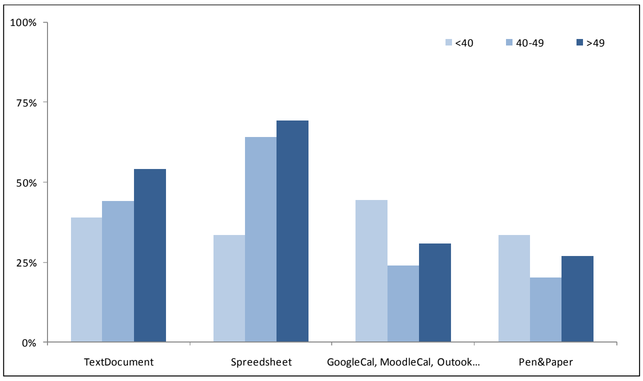

Fig. 1. Use of planning tools depending on the teachers' age

Hypothesis H2*: Non-digital natives are more reluctant to use technology in learning, so they need some kind of motivation to lose this fear.*

For this hypothesis, teachers were divided into three groups depending on their age: G40- (less than 40), G49- (from 40 to 49) and G49+ (more than 49). We found significant difference on the behavior of these three groups in the following cases:

- *Planning of learning sessions –Planning tools*. Teachers in G49+ tend to use text documents or spreadsheets to plan, while teachers in the G40- start to use other kind of tools like MoodleCalendar, GoogleCalendar, Outlook, etc. (p=0.004 between G40- and G49+, and p=0.01 between G40- and G49-). Almost the half of the youngest teachers uses this kind of tools, while teachers older than 40 use much more spreadsheets or text document (Fig. 1). This leads us to think that young people are more open minded to new tools that the older ones, who could need some kind of motivation or extra help to start using them until they feel comfortable.

- *Interactions with students –Registration of interactions*. We have found significant differences in some aspects like students' mistakes, where the youngest teachers (G40-) try to record them while the oldest ones (G49+) just express their possible interest in doing it (p=0.002). This could be related to the fear of technology in the non-digital native people, who being used to well-established tools don't like to try new applications, even being computer scientists. The teacher's experience seems to be important in other aspects: older teachers pay attention to some factors like *students' answers to questions* made in class. The youngest teachers think these aspects are not relevant (p=0.03), despite the fact that they could be hints about the individual or general knowledge level of the class.

Hypothesis H3*: Teachers are interested in registering some interactions aspects of the class in order to receive feedback.*

- *Interactions with students –Registering spontaneous aspects in class*. Fig. 2 shows the results of the 16th question (see TABLE I. They establish that the majority of the teachers (>75%) already register concerns related to planning, such as given concepts, exercises solved in class and exercises proposed for the next learning session. However, less than 50% of teachers register the non-planned aspects related to the interactions, such as students' mistakes, spontaneous questions and answers, evolution of the work, etc. Nevertheless, they show big interest in doing it.

- *Interactions with students –Registering students' behavior in class.* Fig. 3 shows that the majority of the teachers already register a set of defined and evaluable aspects of the student behavior, like the tasks they do individually or in groups, the work they develop in laboratories or the resolution of exercises. In all these cases, more than 60% of teachers record this kind of information. However, less than 25% register more abstract aspects of the students' behavior, such as participation in class, performance of activities, suitability of questions posed in class, perseverance in daily work or personality features (learning style, leadership skill, etc.), although an important percent of teachers show their willingness to do that. We consider this interest from teachers really motivating for improving our tool with this kind of interactions.

***Hypothesis H4**: Teachers are interested in coordination aspects with other teachers in order to obtain valuable information about their students.*

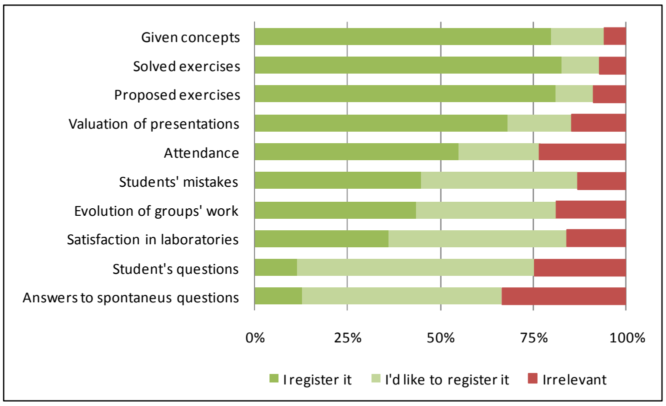

Fig. 2. Teachers' interest in registering class interactions

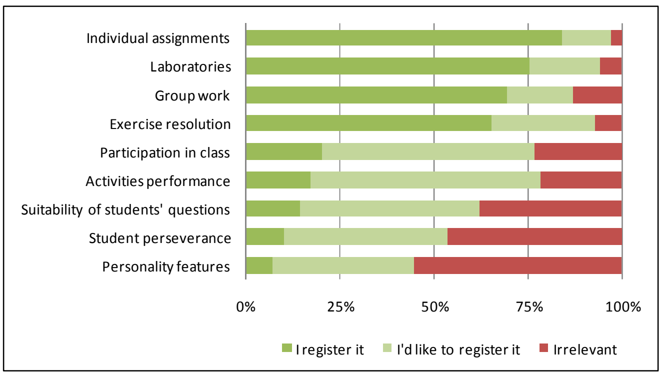

Fig. 3. Teachers' interest in registering students' behavior in class

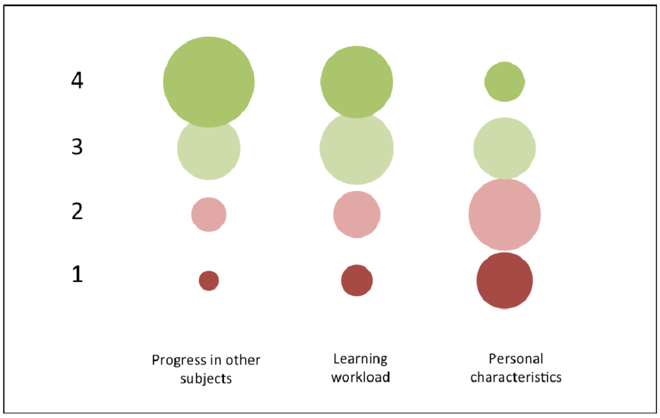

Fig. 4. Teachers' interest in coordination between colleagues

The questions about "coordination among teachers" aim for examining teachers' willingness to share information about their students with their colleagues. The issues were: learning workload, progress in the subject and personal characteristics. Fig. 4 shows the teachers willingness to coordinate with peers. The circles represents the number of teachers who valued from 1 to 4 depending on their interest, from low to high. Thus, teachers show big interest in knowing the students' workload and progress in other subjects. This positive response could open future collaboration mechanisms through exchange of non-private information.

This questionnaire has let us know how teachers interact with their students: the strategies and tools they use, how they register the information, etc. Therefore, we can derive some conclusions from these hypotheses and their results that are relevant for designing our system. First, ***H1*** results indicate that big groups of students provoke that their teachers seek more support in learning tools, and also restrict their registering of some kinds of interactions. This confirms that teachers of big groups need extra help in order to follow the students' evolution in the subject, which reinforces our purpose. In addition, it brings the prerequisite of *agility* for not increasing teachers' workload. Second, ***H2*** leads to build an *intuitive* and *easy to use* system; that is, a motivating and engaging tool for all teachers, no matter the age, that helps more experienced teachers to lose the fear of technology and lets them share their teaching strategies. Third, ***H3*** confirms that teachers are interested in registering the interactions with their students for getting feedback, which supports our system objective. This enlightens *simplicity* as the most important system requisite in order to fully explote teachers' interest in registering all interactions (see Fig. 2 and Fig. 3). A too complex system will cause teachers give up using it. Finally, if ***H4*** is taken into account, teachers could collaborate at subject level by accessing an open student model, what would increase the knowledge at course level, and would improve the skills to detect students' problems.

Taking all this into account, we are designing a system, named PresenceClick, to support registering of the teacher-student interaction information flow. Currently it is devoted to give feedback to teachers, and the obtained results have defined the teachers' necessities to fit with.

III. A PROPOSAL: PRESENCECLICK

This section thoroughly presents the main ideas underlying PresenceClick. Its main functionalities are to record the interactions in F2F sessions, to explicitly visualize them and to provide useful feedback for improving the learning process. The overall environment is devoted to two types of user, i.e. teachers and students, and so it collects the most relevant interactions that arise between them in the typical F2F learning sessions. Then, these interactions are exploited by extracting and showing valuable information for them. The teachers' goal is to know "*what happens*", i.e. the events and evolution of each student in the learning sessions. Thus, PresenceClick helps teachers to monitor their students through different aspects, such as students' (or groups') interest or participation, problems derived from exercises, theory comprehension, probable giving up of the subject, etc. The students' goal is to know *"how does my learning go"*, i.e. his/her learning progress and its comparison to the one of the overall class. PresenceClick helps students to be aware of their own subject knowledge regarding peers, and also to increase their motivation.

In summary, three main user requirements can be derived from the survey results: intuitive handling, simplicity and agility. For this purpose, the system has been designed by following an agile and user-centred interactive software development methodology [16].

A. General PresenceClick behavior

As mentioned, the tool must gather the greatest deal of information in the fewest clicks, and must collect just-in-time interactions in the shortest possible time. In addition, getting technology close to the non-digital natives in an easy to use way will increase motivation of older teachers (see ***Hypothesis H2)*** and then their willingness to use the system. Fig. 5 shows graphically the PresenceClick proposal. Teachers and students introduce different kinds of F2F information in the system (*arrow 1 and 2*). Then, the system provides them with feedback, such as global statistical attendance information, progress of group or each student, interest on topics, problem detection, etc. (a*rrows 3 and 4*).

On the one hand, teachers record any kind of incidence or student participation that can be considered relevant (see ***Hypothesis H3***), e.g. assigned tasks, given grades, questions or other spontaneous aspects arising in class (*arrow 1*). On the other hand, students may give their opinion about theory and exercises, express their satisfaction about different aspects, respond just in time any question of the teacher, or even make new questions.

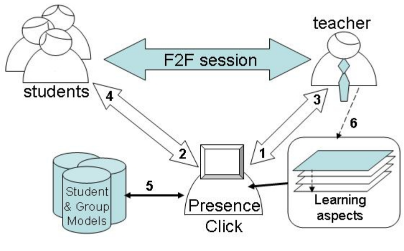

Fig. 5. PresenceClick approach

The students' procedure will be similar to that of Audience Response Systems, where they show their knowledge during presence sessions by using 'clickers devices' to answer teacher's questions just in time. These systems have proved to be a big advantage for improving the learning process [17] by increasing some students' aspects, such as attendance, motivation, attention or interaction.

This way, students make teachers aware of the class knowledge status by indicating which exercises they have done (in class or outside), and so on (*arrow 2*). Thus, the tool accesses to actual information about students' current status, which allows updating their student models, and so infering the group model of the attending students. That is, PresenceClick will feed the Student and Group Models (*arrow 5*) with the interactions' information that teachers and students include. And these models, in turn, will provide PresenceClick with updated information that will allow it to generate suitable feedback for the teachers' and students' issues (*arrow 3 and 4*). Also other functionality is needed by teachers, i.e. the authoring characteristics that allow them to specify those learning aspects they consider worth to monitor (*arrow 6).* In order to record all the relevant class interactions just in time, while doing other teaching activities, teachers need the list of attending students in an agile way. For this purpose, we have built the Attendance Module.

B. PresenceClick architecture

The PresenceClick architecture (Fig. 6) assumes some meta-knowledge structures from classical Intelligent Tutoring Systems, such as the Domain and the Student models. The Domain meta-knowledge enables teachers to plan the learning sessions and to define the relevant learning aspects of interactions to be record. In the same way, the Student Model meta-knowledge defines the significant student learning aspects to be noted. In addition, PresenceClick includes an Attendance Module that automatically collects the list of students that attend to class. Other functionalities allow teacher and students to provide the system with the interactions occurred in the F2F sessions, which feeds the databases hosting the Student and Group Models. Besides, users can visualize both kinds of models. This tool is aimed to be a helping component for the traditional F2F teaching method, or even as a complement for blended-learning scenarios in which the F2F communication line is usually under-represented (e.g. Magadi [18]) or e-learning (e.g. moodle[1] or blackboard[2]).

A plan for a F2F learning session includes aspects such as *subject*, *lesson*, *concept*, *example*, *exercise*, etc. All these meta-knowledge terms are used to define the subject domain, i.e. the activities and the concepts to be worked in a specific learning session. They enable teachers to express learning aspects of the interaction to be recorded. In addition, although plans are not compulsory, if a session plan has been provided by the teacher to the system (*arrow 6 in Fig. 5*), a more agile process of recording interactions is offered in the F2F session, i.e. *the more planning the less clicks*.

[1] https://moodle.org/
[2] http://blackboard.com/

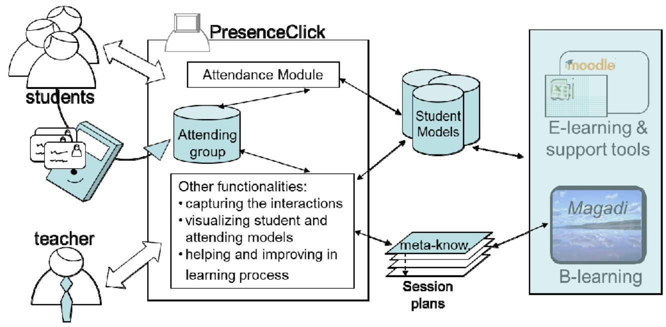

Fig. 6. PresenceClick architecture

For example, if the teacher has previously defined a plan for a specific day −e.g. *lesson 2* and *exercises 4* and *5*, this information will be automatically included in the model of each student attending the class, just when the teacher confirms it with one click. If no previous plan exists, the teacher can add the planning aspects once finished the class session. In any case, although PresenceClick is thought to be used in presence sessions, teachers always can visit the sessions to edit or add new information. This functionality may be merged or integrated within the planning characteristics of blended or e-learning platforms, in such a way that their authoring/edition interfaces be re-used for this purpose. The system is being developed incrementally and, currently, planning aspects are not being considered. The focus is on visualizing attendance information without previous planning effort from teacher.

C. Attendance Module

PresenceClick provides teachers with an agile and just-in-time snapshot of the students attending class so that teachers can personalize their activities. This Attendance Module provides teachers with this list without any effort, forgetting the piece of paper where they usually note these aspects and avoiding the waste of time it generally involves (as much as in class as later when they have to transfer it to their own documents). According to the ***Hypothesis H3*** this module can reduce teachers' workload and help teachers of large groups (see ***Hypothesis H1***). The main functionality is to record the students' arrivals to class. This module uses a presence control device together with the students' identification cards provided by the university (Fig. 6 left part)—the University of the Basque Country provides teachers and students with an identification card that is valid for various services, such as access to buildings, library loans, parking lot, etc. This device is connected to the university network through TCP/IP or WIFI, while a server is waiting to receive the calls. Each time a student passes his/her card, the device stores the marking time. The server asks for new stored markings every time slot. Then, PresenceClick's database is filled with the metadata related to the marking: student's card code, device code, marking time, IP of the connecting device, etc.

In order to just-in-time visualize the attendance information of one specific class, its starting and finishing time and device code must be provided to the system. Then, PresenceClick generates and shows the list of the students in class together with other statistically enriched information (Fig. 7 left). In case that a student has forgotten the card or the system fails, teacher may add students manually to the attendance list. Teachers may also view general information about the group (Fig. 7 right): (1) student attendance to each session and percent of attendance; statistical information about (2) the medium attendance of the group (global view and by type of session) through pie charts, and (3) detailed percent of attendance by session through bar diagrams.

The information attendance streamlines the capturing of valuable information during the F2F learning sessions. Similarly, students in [19] indicate their position in class and have the possibility to include their affective state, respond to questions or make new ones. However, our main idea is to include also all this information in the Student Model in real time, so they can get feedback from these interactions. The attendance registration will also let teachers and students know the student daily attendance as reflecting the evolution of the interest of the class during the whole course. In addition, both teachers and students will be able to configure the advice management by means of an advice module [20]; depending on the number of unjustified absences or the allowed minimum attendance percent, the advice mechanism will allow teachers to identify those students at risk for losing whatever chance related to attendance, for instance a continuous evaluation. Students will be also aware of that loss and will be able to mend it.

So far we have evaluated incrementally this module with two registering devices, which were tested with different teachers, groups of students and locations (buildings and classrooms). The aim of these evaluations was to register different parameters, such as: time to start-up the device and connect with the computer, cards marking process and database update, unforeseen events, etc. The tests were well received by the participants, with curiosity and enthusiasm. The obtained and updated database is 100% reliable.

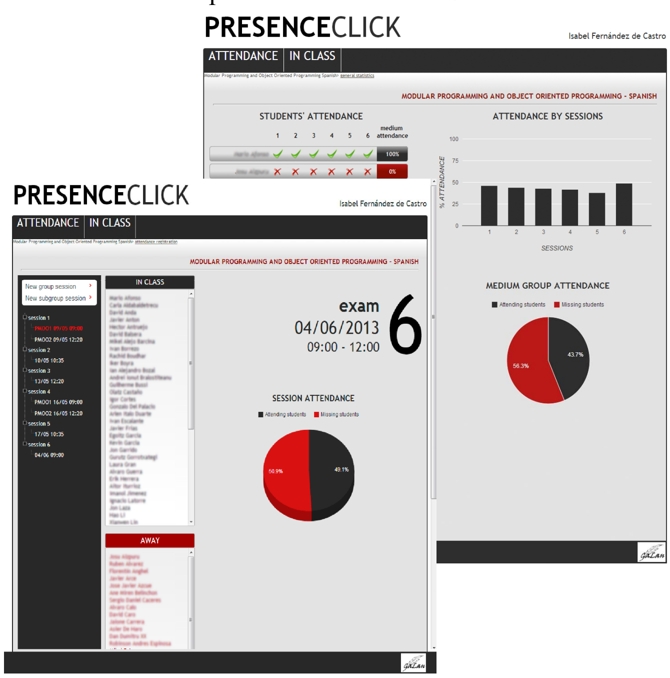

Fig. 7. Session and group interfaces for the Attendance module

The next objective is to incorporate this system in the daily routine for the first year students of the Computer Science Faculty at the University of the Basque Country. The experiment will be developed during the 2013-2014 academic year, with a device assigned to each classroom (6 to 8 devices will be needed). As the schedule will be already defined for each classroom (subject, teacher, students), the system will include automatically the students' attendance in the corresponding models, with no teacher participation. Although this tool is thought to be used just in time during presence sessions, it is also possible to use it offline to visualize or edit its information.

IV. Conclusion and Future Work

The final purpose of the work here presented is to build a tool that provide teachers with relevant information about each one of their students regarding their learning processes and knowledge status, with no workload increment. Concerning students, the tool will give them feedback about their learning progresses and the possibility of comparing their results with those of the class. This information will be obtained by exploiting different kinds of face to face interactions that arise in presence class, in a similar way to teachers use to do. These interactions will be recorded by teachers and students in a just-in-time manner. The designed tool is endowed with simple and agile authoring and recording means that allow defining and registering the learning aspects to be considered.

Up to now, we have designed a questionnaire for teachers to identify main functionalities of a software learning tool by means of an introspection process. A total of 69 Computer Science and Engineering teachers of three centres of the University of the Basque Country carried out this questionnaire. They expressed different needs related to the traditional learning method, i.e. face-to-face classes. The results of this survey have given us the basis for designing and implementing PresenceClick, a tool aimed to support teachers and students in F2F learning tasks. Currently, PresenceClick collects just-in-time the attendance information with no teacher effort, which is the first step in order to gather interactions arisen in class in an agile way. The agility of the system is a big premise aimed to decrease teachers' workload and get technology closer to non-digital natives.

The next evolution of PresenceClick will include advice module and the possibility for teachers to record just-in-time the students' interactions. We propose to give them the possibility to include valuable information in their Student Model about the tasks they do, and to express the learning aspects of the interactions to be recorded in F2F sessions. Planning and coordination will be also considered.

Acknowledgment

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The Appalachian Cohort for Engineering: An Evaluation of S-STEM Strategies for Success

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***Abstract*—The Appalachian Cohort for Engineering (ACE) at Ohio University is an NSF S-STEM funded scholarship program for students in Engineering and Computer Science that combines intensive early intervention approaches (i.e., learning communities, peer-led team learning, midterm progress reports, and purposeful selection of academic advisors) with peer advising and cohort building activities. The intent of this program is to help academically capable but financially insecure students from the economically disadvantaged Appalachian counties of Ohio and surrounding states to complete important early milestones in their academic careers. The ultimate goal of this project is to build evidence-based approaches for encouraging retention and early academic milestone completion for a broad range of undergraduate students in the STEM disciplines. The research component of this project seeks to determine which services are most effective at encouraging and supporting these students to reach early academic milestones to promote long-term retention and degree completion. This component involves substantial data collection that includes observational field notes and one-on-one contact records, along with the required NSF data elements. Much of the data collection is provided by trained peer advisors; capturing the following dimensions of academic wellness: personal/transitional, social, academic, financial, health and stress-coping, study sessions and tutoring, goal setting, follow up data, and academic reviews by course. In addition, field notes are collected that describe the setting, attendees, acts, and reflections on specific events that happen throughout the year. This project is in its first year of implementation. In this work-in-progress paper, we report on the design of the project, early successes and challenges, the data collection strategy, and the preliminary results of this project. In this first year, early observational results indicated that this body of students needed both social and academic support; with both being equal emphasis. Furthermore, this body of students indicated that one-on-one support and goal setting were important components of their early success.**

Category

Keywords—retention strategies; cohort building; peer advising

I. Introduction

Retention in the STEM disciplines is viewed as a significant problem nationwide. According to a recent report by the President's Council of Advisors on Science and Technology [1], "Fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree." Since nationwide production of STEM graduates is seen by many as crucial to continued economic growth in the U.S., improving retention rates among students who are initially interested in the STEM disciplines has become a national priority. With that being said, the factors involved in retention issues in the STEM disciplines are complex and multi-faceted, and local influences likely play an important role. At Ohio University, we face similar STEM related retention challenges and are in the beginning stages of project that aims to provide an understanding of these issues among our unique blend of students. Many of our strategies follow recommendations laid out in a recent STEM related retention study [2]. Our project is called the Appalachian Cohort for Engineering (ACE).

The ACE program is a collaborative effort including three Ohio University entities: the Russ College of Engineering and Technology (Russ College), the Voinovich School of Leadership and Public Affairs (Voinovich School) and the Office of Multicultural Student Access and Retention (OMSAR). Faculty from the Russ College serve as project leadership providing and coordinating recruitment, retention, and academic cohort building activities. Faculty from the Voinovich School provide technical assistance related to educational research and evaluation as well as cultural competence. Administrators and staff from OMSAR provide the backbone of the student support services.

This work-in-progress paper describes the design of the project, early successes and challenges, the data collection strategy, and preliminary results from this project.

II. Project Design

ACE is an NSF S-STEM funded scholarship program for students with demonstrated financial need who reside in the Appalachia and have chosen majors in Engineering or Computer Science. It is important to note that ACE is more than a scholarship, it is a *program.* Each student in the program receives a scholarship that covers roughly 80% of the yearly tuition at Ohio University. These scholarships are then renewable for up to four years under the condition that students achieve satisfactory academic progress, maintain a 3.0 GPA, and remain in a STEM major in the Russ College of Engineering and Technology.

Faculty and staff associated with the project provide a variety academic support programming for the students. The first component of the program is the *first year student learning*

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community. In order to make sure that students are connected with their majors and the Russ College of Engineering and Technology, ACE students are required to enroll in a one-credit semester Learning Community course. These courses provide students with academic guidance regarding their specific major and provide students with an engaging atmosphere in which to meet and connect with other students in their academic major.

A second component of the program is the *All ACE Meetings*. To foster cohort building, ACE students were required to meet once a week as a group. The All ACE Meetings evolved over the first year. The first semester, the goal of the meetings was primarily cohort building and the activities were structured by the program staff. Beginning second semester, responsibility for planning the All ACE Meetings became a shared venture; the project staff planned half of the sessions and the ACE scholars planned half of the sessions. Throughout the year, the All ACE Meetings covered a variety of topics, including: co-op and internship opportunities, resources for academic success, curricular and career paths, entrepreneurship, and leadership opportunities within their majors. These discussions helped supplement and reinforce topics that were also covered during the Learning Community courses.

A third component of the program was *academic support*. ACE scholars were strongly encouraged to attend Supplemental Instruction (SI) and Peer-Led Team Learning (PLTL) sections of specific mathematics and science courses, when available. Furthermore, ACE scholars are paired with selected well-qualified academic advisors (faculty) who work with them on academic and career related issues throughout their academic careers. ACE students are evaluated by the instructors in their courses at the mid-point of each semester, and their academic advisors are provided with Academic Progress e-reports. Finally, ACE scholars had access to free tutoring from through OMSAR.

The final component of the program was *peer mentoring*. ACE students are required to meet once a week with a peer mentor who works with that student on academic, social, and other adjustment related issues. Student peer mentors associated with the ACE Scholars program received training through the OMSAR. The usual peer mentor training consists of a seven week program, where mentors receive two hours of training each week on a range of topics that explain the role of the peer mentor. (Our first peer mentors received a compressed version of this training, due to the late start of the project.) The topics covered include understanding diversity, supporting academic success, providing personal support, working as an advocate and ally for the student, providing social support, and the best practices for peer mentoring. The peer mentors are also provided with a 25 page training manual that covers many of the procedural aspects of the peer mentor program. Peer mentors also meet bi-monthly with OMSAR staff to debrief about the ACE scholars that they peer mentoring. In addition, the peer mentors meet monthly with Russ College and Voinovich School faculty to discuss any concerns or successes the ACE scholars may have as well as provide input on program planning.

III. Data Collection, AnALYSIS, and Relevant Research Questions

The initial cohort of ACE scholars consisted of 8 students from Appalachian counties in Ohio. The STEM disciplines chosen were as follows: Electrical Engineering (N = 1), Computer Science (N = 1), Industrial and Systems Engineering (N = 1), Mechanical Engineering (N = 1), Chemical Engineering (N = 2), and Civil Engineering (N = 2).

This project was approved by the Ohio University IRB, Protocol 12X147. ACE scholars were provided with an informed consent process prior to entering the program. All ACE scholars who were minors at the start of the program were required to have parental consent to participate in the program.

The evaluation design includes both formative and summative assessment, using a mixed-methods approach to describe and measure the progress of the ACE scholars as well as the ACE program. Quantitative measures include demographic profiles, student achievement data, and student questionnaires. Qualitative methodologies include observations, interviews, focus groups, and document review. The evaluation design facilitates interaction between qualitative and quantitative components and permits the close examination of both the processes associated with and the impact of the ACE program.

For this work in progress paper, the following data were utilized: data collected from a facilitated session with the ACE scholars and a document review of the first semester one-on-one meeting reports.

Artifacts from the facilitated session (i.e., chart paper activities and meeting notes) and one-on-one interviews were coded using MAX-QDA, a software package for qualitative data analysis [3]. Content analysis was used to analyze the information collected; Patton [4] describes content analysis as "searching for recurring words or themes." Text was analyzed to see what phrases, concepts, and words were prevalent throughout the data. During this stage of the analysis, coding categories were identified. Through the coding process, data were sorted and defined into categories that were applicable to the evaluation questions at hand. Codes were defined and redefined throughout the analysis process as themes emerged. At the end of the analysis, major codes were identified as central ideas or concepts, as explained in Glesne [5]. These central ideas were assembled by pattern analysis for the development of major themes. From the major themes, we drew conclusions. To ensure credibility of both the procedures and the conclusions, we used analyst triangulation. Patton [4] defines analyst triangulation as "having two or more persons independently analyze the same qualitative data and compare their findings." Teamwork, as opposed to individual work, is likely to increase the credibility of findings, as noted by Lincoln & Guba [6].

For the purposes of an early assessment, we examined the following evaluation questions:

1. What did students actually receive in terms of the ACE program? What were their primary activities? What did they experience? To what extent were those services culturally

competent? What was the evidence of cultural competence? How was the ACE program tailored to meet the needs of individual students?

2. What did the students like and dislike about the ACE program? Did they "buy into" the program's goals and intended outcomes?

IV. Early Challenges and Successes

Formative evaluation is essential with any new project. By utilizing qualitative data techniques, we were able to acquire and analyze data in real time to make course adjustments and corrections. With a strong focus on the evaluation questions, throughout the academic year, we were able to develop the program with feedback from the project team, faculty advisors, OMSAR staff, peer advisors, and the ACE scholars themselves.

As can be expected with any new project, we experienced a few initial challenges. For example, we experienced some early challenges related to *academic support*. Through the formative evaluation process, we realized that there was some disconnect between the college-wide advising provided to all incoming freshmen and the specific course expectations (e.g., PLTL sections of Chemistry) for the ACE students and their specific majors. This will be corrected in Year 2.

During the facilitated session with the ACE scholars we learned that the *peer advising* component was perceived to be very important to the scholars. They like to have a weekly meeting scheduled with their peer advisor as they found the reflection time helpful. That said, the scholars felt as if the meeting could be shortened to 30 minutes from an hour. We made that change for the second semester.

Having the peer advisors meet with the Russ College faculty advisors monthly was also a modification made using formative evaluation data. During the first semester, many of the faculty advisors had weekly contact with their ACE Scholars through the first year student learning community. It was realized early second semester that many of the faculty advisors would have little or no contact with their ACE scholars. As such, the faculty requested they meet with the peer advisors monthly to get updates on the "pulse" of the program. This strategy has proven to be very successful at keeping the faculty members engaged with the program.

The increased responsibility the ACE scholars took during second semester for the *All ACE meetings* was also a result of the formative evaluation process. After the facilitated meeting, it was evident that the ACE scholars had coalesced as a group. The project staff was also faced with the question: What would be the role of the Cohort 1 ACE scholars when the Cohort 2 ACE scholars came to campus in the fall? At the facilitated meeting, two main themes were uncovered: the ACE Scholars were (1) very interested in shaping the program and being connected with the future ACE scholars and (2) craving more "engineering specific" information. To meet both of those needs, the project staff decided to share the responsibility of preparing for the All ACE meetings with the ACE scholars. During second semester, project staff designed seven sessions to promote a greater understanding of the engineering opportunities available during college and beyond. For the remaining 7 sessions, the ACE scholars worked with the current peer advisors to develop 7 sessions that they would facilitate with the Cohort 2 ACE next academic year. This was well received by project staff, faculty advisors, and ACE scholars alike.

V. Conclusions

Overall, we believe that the experience provided for the first cohort of ACE scholars was a success. By the second semester, we succeeded in helping these students form a cohesive group who were able to talk and laugh with each other. Overall, retention of these students was good for the first year, with 75% (6) students achieving important academic milestones and remaining in their selected STEM programs. However, we did not retain one electrical engineering and one mechanical engineering student. The electrical engineering student chose to leave the university in order to pursue other career opportunities, whereas the mechanical engineering student decided to leave engineering and to pursue another major. We have collected the appropriate exit data to try to learn from these students who were not retained in STEM-related majors.

While only in the first year of a multi-year project, we are beginning to collect enough data through field observations and other means to create a picture of the diverse issues involving retention among the unique STEM-related student mix at Ohio University. Early results suggest potential retention strategies that we will discuss further in later works.

Acknowledgment

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The Nature of Learning in a Guided Inquiry Classroom

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***Abstract*— Active learning approaches are becoming of increasing importance within engineering education, and it has been established that an active learning environment leads to improved student outcomes. What is less known is the ways in which these classes support student learning. Our study takes place in the context of a Process Oriented Guided Inquiry Learning (POGIL) classroom. We use grounded theory to answer the research question: How do students construct knowledge in a POGIL classroom? Constructivist grounded theory was used to code student interview data and develop a theory of how student learning occurs. The resulting theory shows that the use of POGIL results in a concept-focused class, as opposed to focusing on discrete aspects of knowledge (facts). This concept-focused class provides for both conceptual understanding and improved retention of information. The findings illustrate one way to design a class for deep conceptual understanding and suggest broader implications for curriculum design.**

***Keywords*— active learning, guided inquiry, grounded theory**

I. Introduction

Recently there has been an increasing awareness of the effectiveness of various types of active learning approaches. Within engineering, a number of active learning approaches have been developed, including cooperative and collaborative learning, problem-based classes [1-6], and guided design [5]. Prince & Felder have provided a comprehensive review of the effectiveness of various types of active learning methods, both within engineering and in education more generally [7]. Their review shows that, while there may be differences depending on the type of method chosen, the experience of the instructor, and the characteristics of the students, in general active learning techniques result in improved student outcomes, particularly when deep learning is the goal.

Various models of learning also support the use of active learning methods, including constructivism [8-10], social construction of knowledge [9,11], cognitive models of learning [7,12], and the learning cycle [13,14]. One particular approach that applies the learning cycle model is Process Oriented Guided Inquiry Learning (POGIL). Despite several studies that show the effectiveness of POGIL [15,16], there is little known about how student learning occurs in a POGIL classroom. The purpose of this study is to examine the ways individual students learn within this collaborative environment. Therefore, this study was undertaken to answer the following research question: How do students construct knowledge in a POGIL classroom? The focus was on the specific aspects of the class that they used for learning. This study does not address issues of the course design or implementation; these issues have been discussed in other papers [15,16].

II. POGIL Classroom

The POGIL approach was originally developed for the chemistry curriculum, and is now used in a variety of STEM disciplines including biochemistry, math, computer science, and materials engineering. In a POGIL class, the instructor does not lecture. Rather the goal of the class is to have the students develop their own understanding of the material through a set of guided questions. During class students work in groups to complete activities containing the following elements: 1) Data or information as background material; 2) Critical thinking questions, which are designed to lead the students to understanding the fundamental concepts represented by the data, and 3) Application exercises, which provide the students with practice in solving problems using the concepts they have derived. The instructor's role is to guide the students, walking around the room and probing them with questions to check their understanding.

III. Methods

This study was conducted at a small liberal arts college in the Rocky Mountain region of the US. All students (17 total) in a second semester general chemistry class were invited to participate. A total of 11 students agreed. Students were interviewed using a semi-structured interview format which focused on identifying aspects of the class that helped or hindered their learning. Students were compensated with US$20 in cash. Each interview lasted 20-30 minutes and was recorded. Students are identified with pseudonyms.

All interviews were transcribed verbatim. Analysis was conducted using the approach of constructivist grounded theory [17,18]. Analysis was conducted by coding each significant statement in the transcript with a brief descriptive tag. A typical transcript thus resulted in 50-70 individual codes. Initial codes were grouped into focused codes by identifying those codes which addressed similar issues, with reference to the original data as necessary. Focused codes were then examined to identify the theoretical codes that they represented, as well as the connections between focused codes. Again, the original data was consulted throughout this process. The resulting

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connections were illustrated with a diagram that shows the grounded theory developed by the analysis. The trustworthiness of the analysis was ensured through the involvement of multiple researchers who worked together until a consensus was reached on the codes and their relationships.

IV. FINDINGS

Figure 1 shows the grounded theory resulting from the data analysis. The major finding is that the POGIL class is a concept-focused class which results in both improved retention of knowledge and a conceptual understanding of the material. Improved retention and conceptual knowledge are mutually reinforcing, with each benefiting the other. Additional aspects of the class provide the support needed to realize these goals.

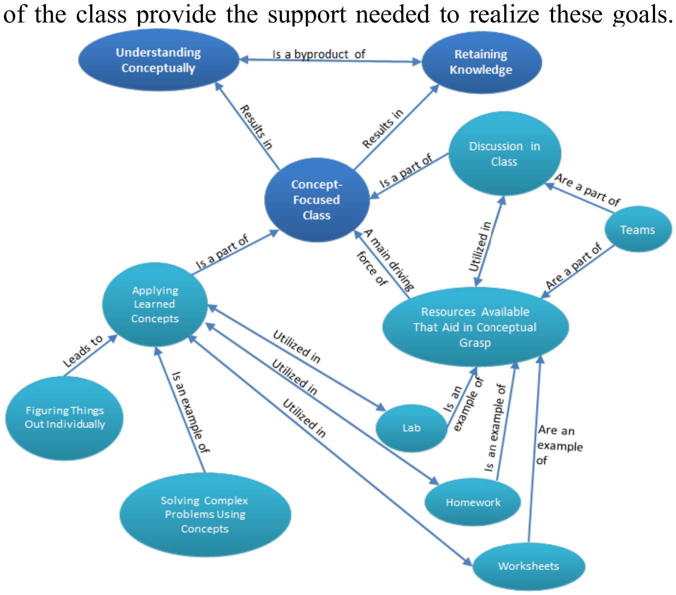

Fig. 1. Grounded theory of student learning in a POGIL classroom.

A. *Concept-Focused Class*

Fundamentally, students see the POGIL class as focused on concepts rather than facts. This approach to knowledge results in the other two theoretical codes, Understanding Conceptually and Retaining Knowledge. Students describe the class as heavily focusing on concepts and derivation of knowledge rather than on memorization and recitation. Tom contrasted the two types of learning: "It gets you thinking, thinking you know, the why, how. In my Linear Algebra class right now it's, you know, I just read the textbook and then kind of plug things in where they need to go and I don't always understand why and so it's kind of hard to ask more questions about a concept you don't, you know, understand why 100%. So with a greater understanding of the concept you can see how it relates to you know, anything else or in the real world."

B. *Understanding Conceptually*

"Understanding Conceptually" is a direct result of a concept-focused class, since students are exposed more to concepts than to memorization and recital. Cheri cited this as one of the key elements of this class, stating that an important element is "making sure you understand where the formulas come from before you use them and then being able to apply those." In this view, understanding conceptually is correlated to the ability to derive equations, and understanding behavior of certain interactions as opposed to simply memorizing them. Tom provides one specific example of this where he learned about equilibrium constants for acids and bases: "…like to come up with K_A for example, like first we found, we knew the equation for K_W and then we knew the equation for K_C and then we combined those to find like K_A and K_B for example, like to derive those equations."

C. *Retaining Knowledge*

"Retaining Knowledge" is also a direct result of a concept-focused classed, since the class takes a different approach to the retention of content. Instead of having students directly memorize certain concepts and be able to recite them, a concept driven class results in not only a deeper conceptual understanding of the subject, but also a more permanent retention of the knowledge acquired mainly because the students can, at any point, derive that knowledge themselves if needed. As pointed out by Brett, "Because it makes us think more about it and you know, and then I feel like when I figure it out for myself I understand it better and I don't just forget it when I walk out of the classroom." Patty added that "retention" goes beyond just remembering, it includes an active understanding of the material: "Because, I think if you just watch it or read it there's a lot more chance that you're going to zone out and you're not going to actually, you might think you know what's going on but when it comes down to actually doing it yourself when you get to the homework, you probably didn't." Retaining knowledge is therefore a by-product of conceptual understanding itself.

V. DISCUSSION AND CONCLUSIONS

The findings point to the power of the constructivist model of learning. In this setting, the learners recognized the benefits of social construction of knowledge. When Susan said "Like each one of us kind of throws out a brainstorming idea and like okay, yeah, that makes sense and then from there we'll try to approach it this way," she was talking about the initial social interaction. This social interaction led ultimately to what Vygotsky called inner speech [11], or as Anna put it "Because if we think of it ourselves then it's, I feel like it's more permanent." Through this inner speech students were able to achieve deep understanding of the material beyond simple memorization of disconnected bits of knowledge. Instead, they were able to create their own conceptual understandings. The findings also point to the power of the learning cycle in developing the deeper understanding required for "learning", and provide guidance as to what students see as needed to support that learning. The learning cycle is not the only approach to develop effective learning, but the findings here show that when it is applied it can result in deeper learning than a lecture class. In addition, while the findings were obtained in a POGIL classroom, they point to broader implications for pedagogical design. There are a number of similar approaches based on constructivist models of learning, including collaborative and cooperative learning, problem-based learning, and guided design. For any of these approaches, ensuring that the classroom is "turned", so that responsibility for teaching by the instructor becomes responsibility for learning by the student, is likely to lead to the same kind of deep learning observed here.

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Development of a Reliable, Valid, Multi-Dimensional Measure of Student Engagement in Group Projects

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***Abstract*—Student engagement is widely explored, but there is no specific measure of student engagement in group projects. This paper presents a Student Group Project Engagement Questionnaire (SGPEQ) instrument and discussed its reliability analysis, validity exploration, and further validity verification. Explanatory factor analysis revealed four dimensions of student engagement in group projects that were distinct and reliable: effort, teamwork, motivation, and organization. Relationships were found between these factors and self-reported engagement and endorsement of self-theories.**

Keywords—student engagement; group projects; measures' reliability and validity.

I. Introduction and Background

A. Measuring Student Engagement

"Student engagement is generally considered to be among the better predictors of learning" [3] and research on this construct date to the mid-1980s [16]. Search on student engagement research revealed there are higher education studies that assess student engagement at institutional and program level, such as: the Higher Education Research Institute (HERI) [6]; the National Survey of Student Engagement (NSSE) [15]; the Community College Survey of Student Engagement (CCSSE) [5]. There are also studies at course level and particularly for online courses. For example, Handelsman at al. developed a measure of in class college student engagement [9]; Molinari & Huonker studied student engagement in business school classes [14]; Robinson & Hullinger, studied student engagement in online classes [17]. However, no reliable and valid measure of student engagement in group projects was identified.

B. Student Engagement in Group Projects

Group projects are essential for graduate level programs and the question is not: Should we have graduate level group projects? The question is rather: How should we optimize students' learning experiences from group projects, as well as the projects' outcomes? Student experiences in immersive vs. traditional group projects were examined during two consecutive semesters in 2011 at University of Maryland University College (UMUC), and "student engagement in group projects" was identified as a distinguishable construct, worth to be studied further [1].

C. Developing a New Measure

Research on constructs that are relative to attitudes, emotions, and opinions involve the use of Likert-type scales [12]. To quantify a not directly measurable construct such as "engagement", a summated ratings scale was developed [1]. The scale has multiple items – each related to a quantitative measurement continuum, having no right answer, and being a statement that can be rated [18]. To capture the many potential dimensions of "student engagement in group projects", an inductive approach was applied. Focusing on student engagement definitions, students and faculty were asked to describe what engaged in group projects students *do*, *feel*, and *think*. The responses were used to develop a preliminary scale for a new Student Group Project Engagement Questionnaire (SGPEQ) instrument, which was further discussed and refined by a focus group. The preliminary SGPEQ is shown in Table I.

TABLE I. PRELIMINARY SGPEQ SCALE

To what extent do the following behaviors, thought, and feelings described you in this group project? Please rate each of them on the following scale: 1=Very little; 2=Some; 3=Quite a bit'; 4=Very much
Q1 Worked on project on regular basis
Q2 Put forth effort
Q3 Preferred to work on my own
Q4 Took detailed notes during discussion meetings
Q5 Wished my teammates were working harder than me
Q6 Completed all assigned tasks on time
Q7 Rehearsed for project presentation
Q8 Was motivated and enthusiastic
Q9 Found project activities relevant to my life
Q10 Thought about project activities between meetings
Q11 Found ways to make project interesting to me
Q12 Was inspired to learn and contribute
Q13 Felt presence of team members during meetings/ presentations (as if in person)
Q14 Found project academically challenging
Q15 Would like to have similar projects in other classes
Q16 Fulfilled the assigned role
Q17 Contributed to discussions with ideas and opinions
Q18 Got to know teammates' strengths
Q19 Had fun during team activities
Q20 Incorporated teammates ideas and opinions
Q21 Helped/ tutored teammates during project activities
Q22 Preferred team-work than working on my own
Q23 Experienced sense of discovery and accomplishment
Q24 Trusted teammates will do well on their project parts
Q25 Found ways to involve non-participating team members
Q26 Stepped in when a teammate was not performing (+ N/A option if everybody participated)
Q27 Was organized and prepared
Q28 Communicated clearly and effectively
Q29 Attended all group meetings
Q30 Applied critical thinking and problem solving
Q31 Did good work on my part
Q32 Was creative and productive
Q33 Developed leadership skills
Q34 Presented final research product clearly and effectively
Q35 Was confident we can learn and do well on the project

The presented in this paper research was conducted in 2012 and focused on the theoretical development of SGPEQ as a reliable, valid, multi-dimensional measure [10] of student engagement in group projects. A study on the SGPEQ initial data reliability and validity was conducted in accordance with established psychometric principles for use in survey research. Initial item reduction and factor identification [13] on SGPEQ was performed through exploratory factor analysis and examination of reliability estimates. The validity of the measure was further verified through a study on relationships between the SGPEQ factors and students' self-reported engagement and endorsement of self-theories [8].

II. The Study

A. Purpose

The purpose of the study was to assess SGPEQ reliability and internal consistency and establish criterion-related and construct validity for the measure to be usable with confidence for quantitative analysis.

B. Data

Students from 40 sections of Information and Technology Systems (ITS) courses were invited to participate. Data was gathered from 260 students (gender: 25% female, 75% male; age: 16% in 20-30, 35% in 31-40, 36% in 41-50, 10% in 51-60, 3% over 60 years old), which reflects the composition of the ITS UMUC student body. The overall response rate was 82%.

C. Method

First, a study on SGPEQ initial data reliability and validity was conducted. Then, initial item reduction and factors identification through exploratory factor analysis was performed. Finally, verification of validity through a study on relationships between the factors and students' self-reported engagement and endorsement of self-theories was obtained.

III. Initial Data Reliability and Internal Consistency

Reliability refers to the ability of a measurement instrument to give similar results for similar inputs. The IBM SPSS guide [9] elaborates that "Ideally, to obtain a good estimate of reliability, a survey should be administered twice to same group of people and then correlate the two sets of results." However, as some bias may be introduced the second time or students may not be willing or able to take the survey twice, often other solutions are needed. The IBM SPSS guide suggests "to compute Cronbach's alpha" or "to split the instrument into two and then to compare the results as if they were separate administrations of the same survey" [9].

Following these suggestions, the reliability analysis for SGPEQ was conducted based on two models: Cronbach's Alpha ("model of internal consistency, based on the average inter-item correlation") and Split-Half ("model that splits the scale and examines the correlation between the two parts") [9].

The Cronbach's alpha (0.940) and Split Half (0.894 | 0.884) values for SGPEQ confirms high level of reliability – Table II.

The presented research was completed in Spring and Summer 2012, under the sponsorship of the UMUC's Faculty Research Grant Program.

TABLE II. SGPEQ Reliability

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.941	.945	35

Cronbach's Alpha			
	Split Half - Part 1	Value	.894
		N of Items	18
	Split Half - Part 2	Value	.884
		N of Items	17
	Total N of Items		35

The inter-item correlations also confirm suitability of the data for factor analysis, as 64% (783 from all 1225) inter-item correlations are larger than the recommended level of 0.30.

TABLE III. SGPEQ Inter-Item Correlation Matrix
(Note: Not al values are shown due to space constraints.)

	Q1	Q2	Q3[a]	Q4	Q5	Q6	Q7	…
Q1	1	0.667	-0.09	0.453	0.246	0.291	0.44	…
Q2	0.667	1	-0.08	0.5	0.187	0.422	0.479	…
Q3[a]	-0.09	-0.08	1	-0.04	0.214	0.102	0.072	…
Q4	0.453	0.5	-0.04	1	0.176	0.316	0.582	…
Q5	0.246	0.187	0.214	0.176	1	0.138	0.246	…
Q6	0.291	0.422	0.102	0.316	0.138	1	0.314	…
…	…	…	…	…	…	…	…	…

a. Q3 is with inverted meaning.

IV. Explanatory Factor Analysis and Reliability Estimates

The SGPEQ factor structure was tested through explanatory factor analysis and construction of reliability estimates.

A. Item Reduction and Factors Identification

Principal axis factoring with Varimax rotation was performed on the 35 SGPEQ items. The questions were: "How many components (factors) are needed to represent the variables?" and "What do these components represent?"

Six-factor and four-factor extractions were performed via a principal components analysis with Kaiser's criterion, retaining only factors with eigenvalues of 1.0 or more; and Scree test plot of eigenvalues, retaining all factors above the "elbow".

The communalities extracted via Principal Axis Factoring are shown in Table IV. Initial communalities are "proportions of variance accounted for in each variable by the rest of the variables" [9]. "Extraction communalities are estimates of variance in each variable accounted for by the factors in the factor solution – small values indicate variables that do not fit well with the factor solution, and should be dropped from the analysis" [9].

The SGPEQ extraction communalities are acceptable, except the low value of Q26 shows it should be dropped; the lower values of Q20 and Q29 (in both factor solutions) show they do not fit as well as the others. Note that mean responses for Q26 – 10.6%, 19.3%, 12.9%, 25.0%, 32.2% – show the "N/A" option is not defining for the low communalities.

TABLE IV. SGPEQ COMMUNALITIES

Question	Six-Factor Solution		Four-Factor Solution	
	Initial	*Extraction*	*Initial*	*Extraction*
Q1	.615	.577	.615	.481
Q2	.695	.818	.695	.550
Q3	.517	.562	.517	.275
Q4	.545	.525	.545	.474
Q5	.420	.402	.420	.349
Q6	.544	.403	.544	.400
Q7	.572	.573	.572	.443
Q8	.718	.657	.718	.655
Q9	.679	.667	.679	.605
Q10	.663	.658	.663	.650
Q11	.670	.637	.670	.638
Q12	.721	.699	.721	.708
Q13	.648	.593	.648	.537
Q14	.595	.533	.595	.533
Q15	.711	.648	.711	.640
Q16	.601	.524	.601	.526
Q17	.667	.601	.667	.568
Q18	.708	.623	.708	.620
Q19	.723	.708	.723	.710
Q20	.449	**.367**	.449	**.364**
Q21	.616	.610	.616	.470
Q22	.651	.628	.651	.491
Q23	.752	.736	.752	.738
Q24	.590	.590	.590	.570
Q25	.553	.517	.553	.492
Q26	.329	**.150**	.329	**.139**
Q27	.774	.657	.774	.653
Q28	.750	.640	.750	.641
Q29	.479	**.389**	.479	**.388**
Q30	.695	.649	.695	.650
Q31	.740	.689	.740	.688
Q32	.763	.692	.763	.687
Q33	.663	.592	.663	.544
Q34	.646	.589	.646	.581
Q35	.569	.488	.569	.451

Low values in both factor solutions are shown in bold

The total variances explained are shown in Table V. For the six-factor solution, 12 iterations were required. The first part shows "the variance explained by the initial solution" [9]. There are only six factors in with eigenvalues greater than 1; altogether they account for 65% of the variability in the original variables. This suggests that six latent influences are associated with student engagement in group projects, but there remains room for a lot of unexplained variation. The second part shows "the variance explained by the extracted factors before rotation" [9]. The cumulative variability explained by these six factors in the extracted solution is 58%. This is a difference of 7% from the initial solution, which means that 7% "of the variation explained by the initial solution is lost due to latent factors unique to the original variables and variability that simply cannot be explained by the factor model" [9]. The last part shows "the variance explained by the extracted factors after rotation" [9]. The rotated factor model makes adjustments to factors 1, 2 and 3; some small adjustments to factors 4 and 5, but factor 6 is left virtually unchanged – the changes between the unrotated and rotated factor % of variance show how the rotation affects the interpretation of the 1 to 5 factors. The picture is better with the four-factors solution, for which 5 iterations were required.

The six- and four-factor matrices, extracted by Principal Axis Factoring, are shown in Table VI. The relationships in the unrotated six-factor matrix, show that only some questions are associated to only one factor – for example, Q8 has only factor 1 greater than 0.2. However, there are a lot of questions that have correlations greater than 0.2 with multiple factors, which muddies the picture. A rotation is used to clear it up – "a rotation method gets factors that are as different from each other as possible, and helps interpret the factors by putting each variable primarily on one of the factors" [9].

TABLE V. TOTAL VARIANCE EXPLAINED FOR SIX-FACTOR AND FOUR-FACTOR SOLUTIONS
(*Note*: The not shown rows are not essential for the discussion.)

Factor	Six-Factor Solution								
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*
1	13.398	**38.280**	38.280	13.012	37.178	37.178	6.812	**19.463**	19.463
2	3.863	**11.037**	49.316	3.463	9.894	47.072	4.557	**13.020**	32.483
3	1.909	**5.455**	54.771	1.455	4.156	51.228	4.533	**12.951**	45.434
4	1.531	**4.374**	59.146	1.143	3.265	54.493	1.958	**5.594**	51.028
5	1.123	**3.209**	62.354	.696	1.988	56.481	1.540	**4.399**	55.427
6	1.041	**2.974**	**65.329**	.624	1.784	**58.264**	.993	2.838	58.264
7	.932	2.662	67.991						
…	…	…	…						
34	.142	.405	99.699						
35	.105	.301	100.000						

Factor	Four-Factor Solution								
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*
1	13.398	**38.280**	38.280	12.979	37.082	37.082	6.891	**19.690**	19.690
2	3.863	**11.037**	49.316	3.420	9.770	46.852	5.040	**14.401**	34.091
3	1.909	**5.455**	54.771	1.410	4.029	50.881	4.092	**11.692**	45.783
4	1.531	**4.374**	**59.146**	1.097	3.135	**54.016**	2.882	**8.233**	54.016
5	1.123	3.209	62.354						
…	…	…	…						
34	.142	.405	99.699						
35	.105	.301	100.000						

TABLE VI. FACTOR AND ROTATED FACTOR MATRICES FOR SIX- AND FOUR- FACTOR SOLUTIONS

Question	Six-Factor Solution												Four-Factor Solution							
	Factor Matrix						Rotated Factor Matrix						Factor Matrix				Rotated Factor Matrix			
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	1	2	3	4
Q1	.611	.170	.307	-.027	-.121	-.255					.496		.607							.433
Q2	.686	.263	.203	-.127	-.039	-.468	.508				.663		.673				.525			
Q3	**-.229**	**.491**	**.073**	**.169**	**.468**	**.122**						**-.635**		**.453**				**-.407**		
Q4	.601	.009	.294	.170	.155	-.152					.436		.600							.527
Q5	.162	.343	.422	.180	-.096	.197				.527					.411					.491
Q6	.538	.312	-.110	.023	.036	-.047	.577						.539				.588			
Q7	.586	.069	.250	.236	.294	-.142					.437		.581							.517
Q8	.783	-.116	.082	-.142	-.057	.006			.555				.784						.546	
Q9	.684	-.263	.171	-.213	.180	.150			.701				.682						.620	
Q10	.662	-.159	.322	-.280	.048	.099			.726				.662						.705	
Q11	.695	-.167	.199	-.284	.040	.072			.691				.696						.676	
Q12	.750	-.126	.085	-.337	.013	.026			.681				.751						.679	
Q13	.544	-.423	-.181	.191	.184	-.126		.715					.542	-.420				.688		
Q14	.615	-.321	.095	-.194	.060	.035			.597				.616					.416	.566	
Q15	.653	-.458	.002	-.047	.016	.099		.552	.538				.654	-.459				.614	.474	
Q16	.560	.378	-.251	-.062	-.021	.018	.706						.561				.709			
Q17	.644	.369	-.126	-.074	-.125	.120	.719						.643				.701			
Q18	.663	-.232	-.190	.289	-.046	-.087		.651					.664					.661		
Q19	.690	-.370	-.125	.267	-.040	-.077		.710					.691					.734		
Q20	.528	-.180	-.203	.099	.058	.042		.491					.528					.503		
Q21	.539	-.025	.292	.365	-.205	.240				.674			.534							.588
Q22	.516	-.458	-.027	.193	-.324	-.090		.553				.460	.511	-.441				.619		
Q23	.752	-.384	-.009	-.143	-.028	.048		.512	.603				.753					**.588**	**.566**	
Q24	.372	-.537	-.373	-.002	.154	-.024		.691						-.536				.714		
Q25	.550	-.104	.248	.346	.091	.117				.517			.549							.575
Q26	**.313**	**.049**	**-.197**	**.003**	**-.027**	**.100**														
Q27	.678	.414	-.118	.064	-.009	-.084	.735						.679	.417			.744			
Q28	.667	.399	-.188	.019	.010	.027	.753						.668	.402			.758			
Q29	.476	.388	-.009	.086	-.025	-.065	.550						.476				.554			
Q30	.720	.347	-.019	-.086	.041	.023	.690						.721				.698			
Q31	.621	.465	-.271	-.104	.034	.044	.808						.622	.469			.816			
Q32	.724	.373	-.089	-.118	-.055	.065	.751						.724				.748			
Q33	.707	.120	.037	.176	-.132	.168	.516			.423			.705				**.494**			**.414**
Q34	.648	.303	-.259	.047	-.072	.045	.713						.649				.708			
Q35	.606	-.187	-.222	.055	.170	.066		.542					.605					.535		

Q3 is with inverted meaning
Low values in both factor solutions are shown in bold

TABLE VII. SGPEQ FACTORS SOLUTION

Item	Factor 1 (Effort)	Item	Factor 2 (Teamwork)	Item	Factor 3 (Motivation)	Item	Factor 4 (Organization)
Q31	0.816	Q19	0.734	Q10	0.705	Q21	0.588
Q28	0.758	Q24	0.714	Q12	0.679	Q25	0.575
Q32	0.748	Q13	0.688	Q11	0.676	Q4	0.527
Q27	0.744	Q18	0.661	Q9	0.620	Q7	0.517
Q16	0.709	Q22	0.619	Q14	0.566	Q5	0.491
Q34	0.708	Q15	0.614	Q8	0.546	Q1	0.433
Q17	0.701	Q23	0.588				
Q30	0.698	Q35	0.535				
Q6	0.588	Q20	0.503				
Q29	0.554	**Q3**	**-0.407**				
Q2	0.525						
Q33	0.494						

Q3 is with inverted meaning

The rotated six-factor matrix is computed from the original (unrotated) factor matrix using Principal Axis Factoring as extraction method and Varimax with Kaiser Normalization rotation method, where rotation converged in 7 iterations. However, the relationships in the unrotated four-factor matrix and the rotated four-factor matrix, where rotation converged in 7 iterations, shows clearer and better interpretable picture.

Based on the analysis of the six- and four-factor solutions and the inspection of a scree plot (please refer Fig. 1), four factors were retained. After four factors, interpretability of factors was difficult, confirmed by the scree plot slope decreasing by only a small amount after four factors. The four factors accounted for 59.15% of the variance. The first factor consisted of 12 items that were labeled “Effort” (19.69% of the variance) – "Did good work on my part", "Communicated clearly and effectively", "Was creative and productive", etc. The second factor consisted of 10 items that were labeled “Teamwork” (14.04% of the variance) – "Had fun during team activities",

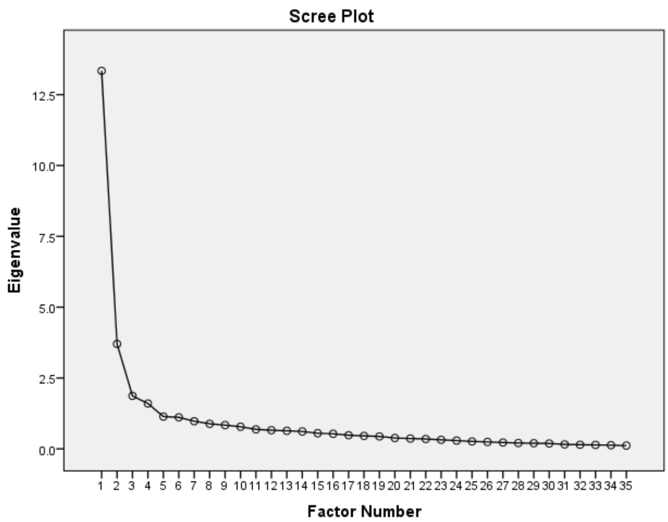

Fig. 1. Scree Plot

"Trusted teammates will do well on their project parts", "Felt presence of team members during meetings/ presentations (as if in person)", etc. The third factor consisted of six items that were labeled “Motivation” (11.69% of the variance) – "Thought about project activities between meetings", "Was inspired to learn and contribute", "Found ways to make project interesting to me", etc. The fourth factor consisted of six items that were labeled “Organization” (8.23% of the variance) – "Helped/ tutored teammates during project activities", "Found ways to involve non-participating team members", "Took detailed notes during discussion meetings", etc. Table VII shows the factor solution and the items (questions) for each factor. Only one question, “Q26 Stepped in when a teammate was not performing”, was dropped due to low communality and low loading on all factors.

B. Factors Reliability and Preliminary Validity

The four SGPEQ factors show reasonable reliability (Cronbach's alphas are .926, .838, .889, .766) and the inter-factor correlations (the highest is .088) support the discriminant validity of the measure – Table VIII.

TABLE VIII. SGPEQ FACTORS CORRELATIONS

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1.000	.004	.039	.072
Factor 2	.004	1.000	.088	.035
Factor 3	.039	.088	1.000	.064
Factor 4	.072	.035	.064	1.000

V. FURTHER VERIFICATION OF VALIDITY

SGPEQ validity was further verified through a study on the relationship between the identified factors and students’ self-reported engagement and endorsement of self-theories. The questions were added to the same SGPEQ instrument.

A. Self-Reported Engagement

Factors predicting absolute engagement (engagement in this group project) and relative engagement (engagement compared with other group projects) were determined. For that two analyses that regressed each of the two dependent variables on the four factors of SGPEQ were performed.

- *Absolute engagement*

Dependent variable: “How engaged were you in this group project? (1=not at all, 6=extremely).”

Regression of relative engagement on the four factors shows that the factors account for 63.1% (R Square in Table IX) of the variance in absolute engagement; 70% of absolute engagement was explained by the model: $F(4, 166) = 70.81$, $p < .001$ (F and Sig. from ANOVA table). Factor 1 “effort” (β = .611); Factor 2 “teamwork” (β = .174); Factor 3 “motivation” (β = .325); Factor 4 “organization” (β = .236) are all positive predictors of absolute engagement. ANOVA tests the acceptability of the model from a statistical perspective – a significant F statistic, indicates that using the model is better than guessing the mean.

TABLE IX. MODEL SUMMARY, ANOVA, COEFFICIENTS (ABSOLUTE ENGAGEMENT)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.794	.631	.622	.66386

ANOVA: Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	124.841	4	31.210	70.817	.000
	Residual	73.159	166	.441		
	Total	198.000	170			

Model		Unstandardized Coefficients		Standardized Coefficients
		B	Std. Error	Beta
1	(Constant)	4.988	.051	
	REGR factor score 1	.686	.053	.611
	REGR factor score 2	.206	.056	.174
	REGR factor score 3	.395	.058	.325
	REGR factor score 4	.290	.058	.236

Relative engagement

Dependent variable: "How engaged were you in this group project compared to other group projects you worked on during the same semester? (1=less engaged, 6=more engaged)".

Regression of relative engagement on the four factors shows that the factors account for 44% of the variance in relative engagement (R Square in Table X); 33% of relative engagement was explained by the model: $F(4, 166) = 32.54$, $p < .05$. Factor 1 "effort" ($\beta = .387$); Factor 2 "teamwork" ($\beta = .259$), Factor 3 "motivation" ($\beta = .326$), Factor 4 "organization" ($\beta = .233$) are all positive predictors of relative engagement.

TABLE X. MODEL SUMMARY, ANOVA, COEFFICIENTS (RLATIVE ENGAGEMENT)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.663	.440	.426	1.00489

ANOVA: Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	131.614	4	32.903	32.584	.000
	Residual	167.626	166	1.010		
	Total	299.240	170			

Model		Unstandardized Coefficients		Standardized Coefficients
		B	Std. Error	Beta
1	(Constant)	4.624	.077	
	REGR factor score 1	.534	.080	.387
	REGR factor score 2	.377	.085	.259
	REGR factor score 3	.487	.088	.326
	REGR factor score 4	.352	.088	.233

B. *Incremental and Entity Self-Theories*

Dependent variable: "You have a certain amount of intelligence and you cannot do much to change it. (1=do not agree, 6=strongly agree)"

Regression of belief in incremental theory on the four factors shows that the factors account for 59% (R Square in Table XI) of the variance in absolute engagement; 3% of the variance in incremental theory beliefs was explained by the factors: $F(4, 166) = 2.6$, $p < .001$. Factor 2 "teamwork" ($\beta = .141$) and Factor 4 "organization" ($\beta = .171$) are positive predictors of belief in incremental theory. Factor 1 "effort" ($\beta = .024$) is probably too small to be considered a predictor. Factor 3 ($\beta = -.112$) shows "motivation" is not a predictor of belief in incremental theory.

The results indicate that effort, teamwork, motivation, and organization are all related to self-reported global ratings of absolute and relative engagement. However, while teamwork and organization are related to incremental self-theories, effort is almost not related to it and motivation is surely not related to it.

TABLE XI. MODEL SUMMARY, ANOVA, COEFFICIENTS (INCREMENTAL AND ENTITY SELF-THEORIES)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.244	.059	.037	1.52935

ANOVA: Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	24.476	4	6.119	2.616	.037
	Residual	388.260	166	2.339		
	Total	412.737	170			

Model		Unstandardized Coefficients		Standardized Coefficients
		B	Std. Error	Beta
1	(Constant)	2.160	.117	
	REGR factor score 1	.038	.122	.024
	REGR factor score 2	.241	.130	.141
	REGR factor score 3	-.196	.134	-.112
	REGR factor score 4	.302	.134	.171

VI. CONCLUSION

The conducted research resulted in creation of a reliable, valid, multi-dimensional measure of student engagement in group projects (SGPEQ) – Table XII. Evidence was found of four interpretable and internally consistent factors: effort, teamwork, motivation, and organization. The low correlations between variables suggested initial evidence for discriminant validity of the measure. Evidence of convergent and discriminant validity was obtained by relating SGPEQ scores with students' self-reported engagement and self-theories – it was confirmed that students who are engaged in learning, presumably believe this engagement will increase their capacity for learning. Evidence was obtained also for the reliability of the measure – all factors have reliabilities above recommended level. As a result, empirical evidence of the usefulness of SGPEQ was obtained, so it can be easily administrated while providing a comprehensive snapshot of students' engagement in group projects.

The SGPEQ instrument can be utilized as a diagnostic tool. Group project results from one course section can be benchmarked against those of other course sections. Benchmarking can be done against sections taught by the same faculty, by other faculty, by all faculty teaching the same course, or by all faculty teaching in the department. Then benchmarking can be further detailed for each of the four SGPEQ factors, and for each of the items comprising each factor, to get additional insight into student engagement and take actions to improve performance in next group projects. The SGPEQ instrument can be utilized and comparisons can be done on class, department, school, university, and even country level.

TABLE XII. VALIDATED SGPEQ SCALE

To what extent do the following behaviors, thought, and feelings described you in this group project? Please rate each of them on the following scale: 1 = Very little; 2 = Some; 3 = Quite a bit'; 4 = Very much
Effort
Did good work on my part
Communicated clearly and effectively
Was creative and productive
Was organized and prepared
Fulfilled the assigned role
Presented the final research product clearly and effectively
Contributed to discussions with ideas and opinions
Applied critical thinking and problem solving
Completed all assigned tasks on time
Attended all group meetings
Put forth effort
Developed leadership skills
Teamwork
Had fun during team activities
Trusted teammates will do well on their project parts
Felt presence of team members during meetings/ presentations (as if in person)
Got to know teammates' strengths
Preferred team-work than working on my own
Would like to have similar projects in other classes
Experienced sense of discovery and accomplishment
Was confident that we can learn and do well on the project
Incorporated teammates ideas and opinions
Preferred to work on my own
Motivation
Thought about project activities between meetings
Was inspired to learn and contribute
Found ways to make project interesting to me
Found project activities relevant to my life
Found project academically challenging
Was motivated and enthusiastic
Organization
Helped/ tutored teammates during project activities
Found ways to involve non-participating team members
Took detailed notes during discussion meetings
Rehearsed for project presentation
Wished my teammates were working harder than me
Worked on project on regular basis

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The Impact of Project-Based Service Learning in a Native American Community on Student Performance in Civil Engineering Capstone Design

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***Abstract*—Three educational institutions in South Dakota are collaborating to develop pre-engineering courses to increase the enrollment and success of students transferring from Oglala Lakota College (OLC) to 4-year bachelor degree programs in science and engineering at South Dakota School of Mines and Technology (SDSMT) and South Dakota State University through a grant from the National Science Foundation Tribal Colleges and Universities Program (TCUP). Activities of this grant have led to a partnership with the native-led Thunder Valley Community Development Corporation (TVCDC) and have provided significant opportunities for students at OLC and SDSMT in the areas of civil engineering and sustainability. The most recent opportunity includes incorporating TVCDC's plans for an 800-person net-zero regenerative community on the Pine Ridge Indian Reservation into the Capstone Design course at SDSMT. The project includes sustainable design objectives in wastewater treatment, rainwater harvesting, and the use of straw bale and compressed earth walls as renewable building materials for phase I of the planned community. Four teams of students working on the regenerative community and four teams of students working on a more traditional capstone design project completed proposals and their first progress reports during the Fall 2012 semester. The Comprehensive Assessment of Team-Member Effectiveness (CATME) instrument was administered twice during the semester to evaluate team functioning. A comparison of the data for the two capstone projects is presented. Results from these surveys indicate students working on the regenerative community project were more positive and consistent with the behavioral and satisfaction categories within the peer evaluation survey.**

Keywords-Capstone Design; regenerative community, CATME peer evaluation

I. Introduction

The Pre-Engineering Education Collaborative is an effort by Oglala Lakota College (OLC), South Dakota State University (SDSU), and the South Dakota School of Mines and Technology (SDSMT) to develop a pre-engineering curriculum that will enable students graduating from OLC with associate degrees to transfer to 4-year engineering programs at the junior level. Summer research and service learning projects are incorporated into the program to provide a hands-on introduction to science and engineering topics, promote community service, and to stimulate student interest and motivation to pursue engineering. One of the specific project goals is to transform classical engineering program curricula to follow the constructivist philosophy of learning through vertical integration of the first two years of introductory engineering topics.

University-level curricular materials have typically been designed to improve understanding of topics in a linear but not interrelated or integrated fashion. The linear cognitive development model [1] has become a very popular and well used model within STEM disciplines, while Bloom's Taxonomy [2] has provided the active-voice language for developing, assessing, and evaluating the success of STEM programs of study in the linear cognitive development model [3]. STEM curriculum design has also typically followed the linear development pattern of a Piagetian [1] theoretical framework [4]. That is, material designed to specifically improve understanding in one area typically is not assessed for its impact on other areas.

In contrast to the Piagetian learning model, other researchers [5] focused on the structure of the field explaining that the "grasping of the structure of a field" is understanding it in a way to permit many other meaningful relationships to be established. Student learning experiences need to be facilitated in a manner that allows them to construct complex interrelated understandings of STEM fields. The development of knowledge is a complex process including stimulation, reflection, abstraction, and experimentation [4] [6]. In general, constructivist pedagogy emphasizes the importance of knowledge gained through experience [7]. Also, it has been stressed that one of the most important ideas is that students must construct their own knowledge structures and that basically correct preconceptions can be used to help the student learn [8]. Thus, the integration of learning activities is important because mastery of the fundamental ideas of a field involves both the grasping of general principles and the development of an attitude toward learning and inquiry, guessing and hunches, and the possibility of solving problems on one's own [5].

A partnership between the OLC/SDSU/SDSMT Pre-Engineering Education Collaborative (OSSPEEC) and the Thunder Valley Community Development Corporation (TVCDC) has provided an opportunity to vertically integrate the Civil and Environmental Engineering design process through a proposed 800-person regenerative community. Phase 1 of the development was used to provide real-world civil engineering design problems set in a sustainability framework at SDSMT during the Fall 2012 semester. An effective and unique integration will be achieved as the service learning and research projects continue through OSSPEEC and the regenerative community is introduced in engineering and sustainability courses taught at OLC and SDSMT. We describe the successes observed through completion of the Fall 2012 semester Capstone Engineering I course at SDSMT as

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measured by the Comprehensive Assessment of Team-Member Effectiveness (CATME) instrument [9] and discuss the results.

II. Capstone Design Projects

Students were given two project statements created during the Fall 2012 semester for Capstone Design to choose from: Phase 1 at Thunder Valley, and a proposed Research Building on SDSMT's campus. Introductory descriptions of the projects as presented to students from which they based their preferences in August of 2012 are included below.

A. Thunder Valley Regenerative Community (TVRC)

The Thunder Valley Community Development Corporation is developing an 800-person community ¼- mile north of Sharps Corner, SD (~70 miles SE of Rapid City). Objectives of the development include creating a net-zero community through maximizing water reclamation and energy efficiencies. An architectural rendering of the development is shown in Figure 1. Phase I of the development includes construction of five single-family houses, a Youth Empowerment Center, and two apartment buildings. The initial development phase will accommodate 70-100 people. All design concepts must be scalable to meet the needs of the final 800-person community. Design tasks must consider principles of sustainability, life cycle costs, and environmental impacts and include a cost estimate for construction. Design aspects of the project include:

- Design treatment systems for waste and greywater. Various innovative and sustainable methods will be compared between different design teams.
- Design rainwater harvesting and greywater recycling systems and identify applications for the recycled water (e.g., greenhouses, greenway).
- Design of a water distribution system
- Design of storm water and erosion control systems
- Site layout and roadway design. Concrete, pervious concrete, and asphalt pavements will be considered.
- Structural design of the Youth Empowerment Center. Steel and wood structures will be compared between different teams.
- Foundation design of the Youth Empower Center. Deep and shallow foundations will be compared between different teams.
- Employment of LEED design principles.

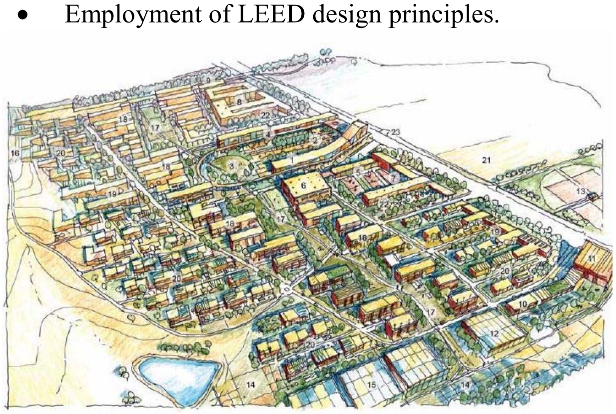

Figure 1. Thunder Valley Regenerative Community

B. SDSMT Research Building (SRB)

The South Dakota School of Mines & Technology is developing plans for a \$40-60 million, 120,000 ft^2 3-story research facility in support of the university's growing research efforts. The building will be located somewhere on campus (Figure 2. . Key features of the research facility design are: a central area with a meeting location; a central auditorium with a 600 person capacity; separate institute areas with clusters of specific institute-associated research laboratories; and a single cluster of institute directors' offices with joint administrative staff areas.

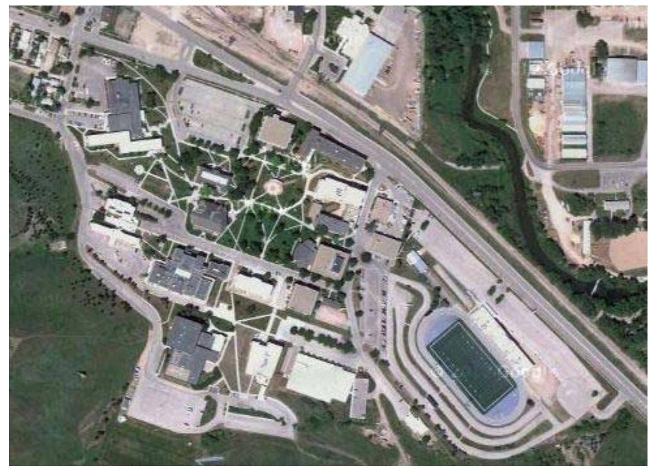

Figure 2. SDSMT Campus

Designs must consider principles of sustainability, life cycle costs, and environmental impacts and include a cost estimate for construction. Aspects of the project include:

- Site selection considering the recently published campus master plan and other factors.
- Design of rainwater harvesting and greywater recycling systems and identification of applications for the recycled water.
- Design the water piping system
- Design storm water and erosion control systems
- Site layout and parking area design. Concrete, pervious concrete, and asphalt pavements will be considered.
- Structural design of the research building. Steel and concrete structures will be compared between different teams.
- Foundation design of the research building. Deep and shallow foundations will be compared between different teams.
- Apply LEED design principles.

C. Team Assignments

The instructor assigned teams based on student's heterogeneous GPA which was obtained from transcripts and homogeneous interest in the project based on their initial preferences. This method of assigning groups resulted in better attitudes at the end of similar courses [10]. The instructor applied a third criterion distributing student contributions to a multi-disciplinary teaming component across the four teams.

Four teams for each project were assigned and are shown in TABLE I. The number of declared disciplines shown represents all areas of Civil Engineering students were interested in and therefore can exceed the number of team members.

TABLE I. CAPSTONE DESIGN TEAM ASSIGNMENTS

Team	Team Members	Average GPA	Number of Declared Civil Engineering Disciplines: Environmental	Water Resources	Geotechnical	Structural	Project Preference: SRB	TVRC
SRB-1	4	3.00	1	1	1	4	3/4	
SRB-2	5	2.88			2	2	4/5	
SRB-3	5	2.93		1	2	3	5/5	
SRB-4	5	3.05		1	2	2	3/5	
TVRC-1	4	3.45	1	2	1	1	2/4	2/4
TVRC-2	4	3.27	2	2		2	1/4	3/4
TVRC-3	4	3.43	2	2		1	1/4	3/4
TVRC-4	4	3.18	1	3	1	1	1/4	3/4

The GPA disparity for the two teams was greater (53% vs. 12% higher) for women than the class as a whole. Five of the 35 students enrolled in the Capstone Design course were women, three of which selected the TVRC project as their preference. Female student average GPA was 53% higher than the students preferring the SRB project. The average GPA for students preferring the Thunder Valley project was 12% higher than those for the SRB teams. All SRB team members received their preferred project or indicated no preference, while five students were assigned to TVRC teams had a preference for the SRB project.

III. DATA

Independent and pair-wise comparisons of student responses to the CATME behavioral categories [12] and the team satisfaction [13] results were performed using SPSS software [11]. Levene's test was used to test the assumption of equal variance before performing the t-tests. Pre-test TVRC student behavior (M = 4.3, SD = 0.33) was significantly different from the SRB group behavior (M = 3.9, SD = 0.47) at the 99% confidence interval, $t(33) = 2.9$, $p = 0.006$. Pre-test TVRC student satisfaction (M = 13.7, SD = 1.74) was not significantly different from SRB group satisfaction (M = 12.2, SD = 2.45) at the 99% confidence interval, $t(31) = 2.0$, $p = 0.051$. Post-test TVRC student behavior (M = 4.5, SD = 0.24) was significantly different from the SRB group behavior (M = 3.9, SD = 0.39) at the 99% confidence interval, $t(33) = 4.9$, $p < 0.000$. TVRC student satisfaction (M = 13.9, SD = 1.95) was significantly different from the SRB group satisfaction (M = 11.2, SD = 2.91) at the 99% confidence interval, $t(31) = 3.1$, $p = 0.004$. Pairwise comparisons between pre and post-tests for the TVRC and SRB groups were not significant at the 99% confidence interval, $t(15) = 0.59$, $p = 0.56$, $t(15) = -1.565$, $p = 0.138$. These data are summarized in TABLE II.

IV. ASSESSMENT RESULTS

The CATME Smarter Teamwork is a web-based instrument that allows instructors to effectively manage and assess student teams [9]. The standard peer evaluation method was used with five questions related to the following behavioral characteristics: 1) Contributing to the Teams Work, 2) Interacting with Teammates, 3) Keeping the Team on Track, 4) Expecting Quality, and 5) Having Related Knowledge, Skills, and Abilities [12]. Students were asked to rate themselves and their teammates based on a description of behaviors provided. An example with fictitious names is shown in Figure 3.

TABLE II. CATME RESPONSE COMPARISON SUMMARY

	Pre-survey		Post-Survey	
Student Behavior	M	SD	M	SD
TVRC	4.3	0.33	4.5	0.24
SRB	3.9	0.47	3.9	0.39
Student Satisfaction				
TVRC	13.7	1.74	13.9	1.95
SRB	12.2	2.45	11.2	2.91

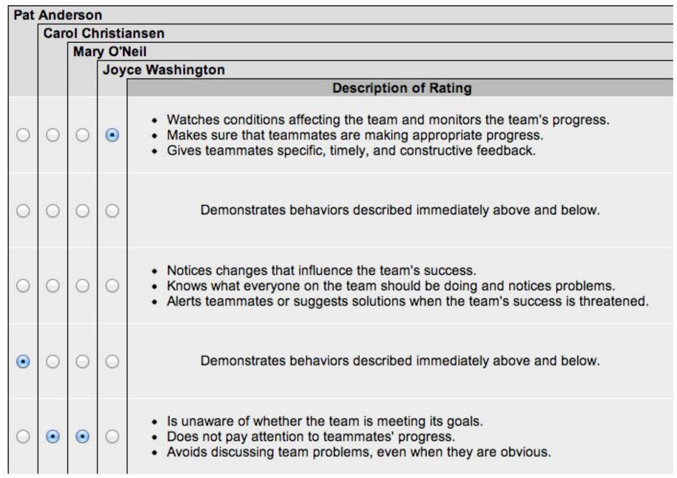

Figure 3. CATME Behavior Description Example

We administered two Peer Evaluation surveys during the semester. We assigned the first evaluation after the proposal (pre-survey) during week seven of the semester. The second evaluation was assigned after the progress report writing assignment (post-survey) during week 14 of the semester. Response rates were 91% (34/37) for each survey.

Three team satisfaction questions were included in the teaming assessment in addition to the behavioral questions described above: 1) I am satisfied with my present teammates, 2) I am pleased with the way my teammates and I work together, and 3) I am very satisfied with working in this team [13]. Responses were measured using a five-point Likert scale.

A. Behavioral Characteristics

Averages team ratings on a scale of 1-5 for the 5 behavioral categories for all students in a group were used to evaluate the differences between SRB and TVRC teams for the two peer evaluations. Error bars are reported with plus/minus two standard errors. Results for peer evaluations 1 and 2 are shown in Figure 4. and Figure 5.

The results indicate the TVRC group was more committed to teaming in both the pre- and post-tests. However, this difference only became significant in the post-test as students as a whole scored themselves slightly higher on average and as the variance decreased.

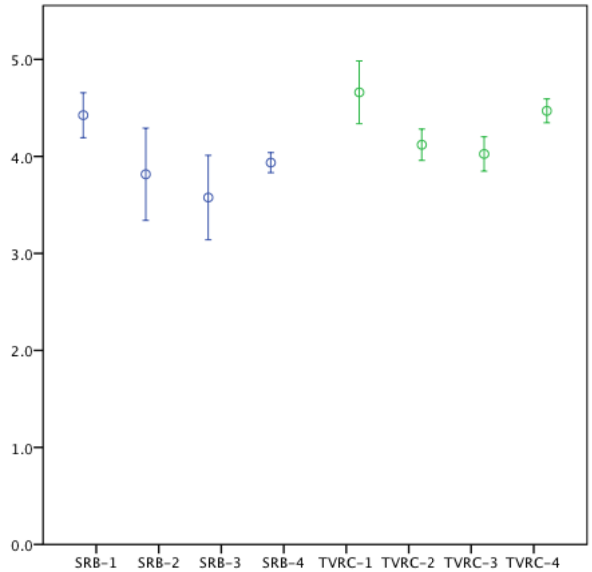

Figure 4. Average Behavioral Characteristics – Pre-Survey

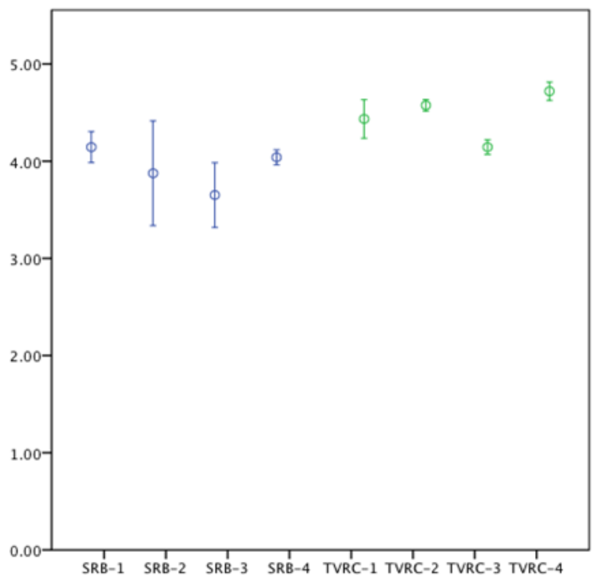

Figure 5. Average Behavioral Characteristics – Post-Survey

B. *Team Satisfaction*

The average scores for each of the three questions were added together for the team satisfaction evaluation, resulting in a maximum score of 15 (1-5 points for each question). Results for pre- and post-surveys are shown in Figure 6. and Figure 7.

TVRC group average scores were higher in the pre-test, but the difference was not statistically significant. TVRC group average scores were statistically higher in the post-test. The overall SRB group became less satisfied by the post-test, while the TVRC group became slightly more satisfied on average. The differences among groups at the post-test were significant.

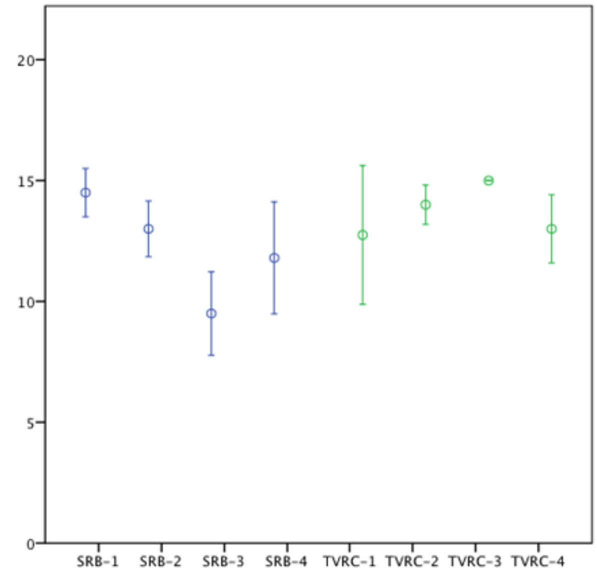

Figure 6. Average Team Satisfaction – Pre-Survey

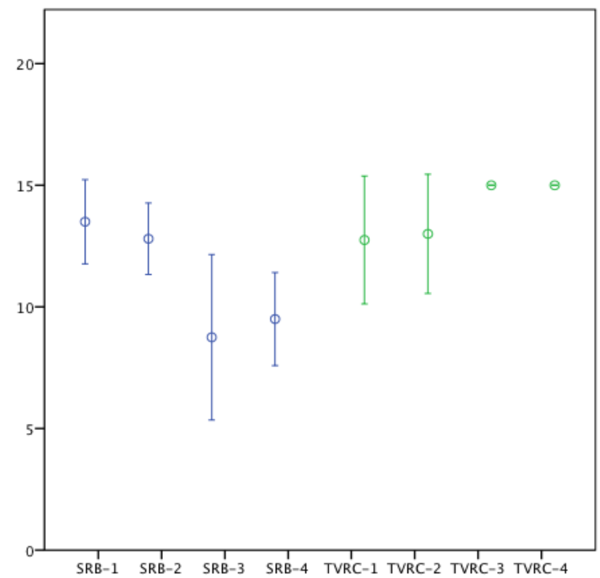

Figure 7. Average Team Satisfaction – Post-Survey

V. DISCUSSION

Engineering has been defined as the application of science for the benefit of humanity [14]. The results of the CATME behavioral and satisfaction surveys demonstrate that factors exist beyond the integration of learning activities in the construction of knowledge structures. Both the Thunder Valley Regenerative Community (TVRC) and the School of Mines Research Building (SRB) design projects contain constructivist elements. However, the TVRC project has an additional element of a clearly defined community that will benefit from the design. Students who worked on the TVRC project demonstrated responses consistent with altruistic behavior such as: increased satisfaction, a greater sense of accomplishment, and a more positive view of others. These behavioral and perceptual differences became more pronounced throughout the year-long project. The results may demonstrate the importance of providing students engaged in service learning with a clearly defined community that receives the service may be an important factor in student engagement in constructivist-based service projects.

These challenges required students to apply design principles on a larger scale and broader context than what they had experienced during their junior-level coursework. A small-group instructional diagnosis performed by a faculty member not associated with either Capstone Design Project revealed students were not comfortable extending this knowledge and suggested more technical feedback and focus would assist them in their learning. It is unclear how these challenges influenced the CATME Peer Evaluations.

Although both capstone design projects had similar design components and problem statements, it should be noted, different challenges for each project developed during the semester. Design tasks that fell outside of junior-level coursework for the Thunder Valley Regenerative Community included the use of a wetlands treatment option for wastewater and rammed earth and straw bale construction materials for the design of one of the residential structures. Additionally, laying out transportation and water infrastructure for a scalable community with up to 800 residents was challenging for students. Architectural drawings were available for the residential structure; however engineering coordination had not taken place and inconsistencies and incorrect information existed in the drawings. For the SDSMT Research Building, the largest challenge included laying out the building and research spaces that were only generally described in the University Master Plan. Architectural drawings were not available for the proposed building and information was only provided by a guest speaker with a career of industrial experience related to the subject. A second challenge was the land-space needed to meet parking requirements for the 600 person auditorium.

VI. SUMMARY

The OSSPEEC program is a collaborative effort between OLC, SDSU, and SDSMT to develop pre-engineering courses at OLC and to advise students in service-learning and research projects on the Pine Ridge Indian Reservation. One of the objectives of this program is to vertically integrate the design process beginning in the entry-level engineering courses, continuing through service-learning and research projects, and culminating in the Capstone Design course. A partnership established with the Thunder Valley Community Development Corporation has enabled the inclusion of an 800-person sustainable community development as one of two projects used for the Civil and Environmental Engineering Capstone Design course during the Fall 2012 semester. Results from two CATME Peer Evaluation Surveys indicate students working on the regenerative community project were more positive and consistent with their peer ratings and overall satisfaction.

ACKNOWLEDGMENT

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Student Beliefs about Learning Communication Skills

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***Abstract*—Communication remains an essential skill for engineering graduates in both academic and industry settings, and ABET considers it a key student learning outcome for accreditation. Despite numerous studies of effective approaches to integrating communication into disciplinary courses, few engineering courses apply those approaches. To address this gap, we have undertaken a multi-year mixed methods study to explore faculty and student beliefs about communication. Faculty beliefs have been reported elsewhere; this paper focuses on student beliefs. We analyzed five focus groups conducted with engineering students at partner schools. The focus groups sought to uncover students' beliefs about where and how they learned communication skills within their engineering education. Focus groups were recorded and transcribed verbatim, then coded using standard open-coding procedures. The findings indicate that while students do have opportunities to practice communication in engineering courses, they may not always have optimal opportunities to learn communication in those courses. Most notably, students desired more examples and direct instruction for communication skills, including not only samples of "good" documents but also explanations about why they were good. Identifying pedagogical gaps between faculty practice and student experiences can help us develop targeted strategies to help creatively integrate these critical skills into an already packed engineering curriculum.**

Keywords—communication; situated learning; student beliefs

I. INTRODUCTION

Communication remains an essential skill for engineering graduates in both academic and industry settings, and ABET considers it a key student learning outcomes for accreditation. Despite recognition of the importance of this skill, however, gaps in teaching persist. Despite numerous studies of effective teaching approaches, few engineering courses apply those approaches [1]. To close the critical gaps between belief and practice, we are engaged in a multi-year year mixed methods study that explores faculty and student beliefs about both communication and teamwork (another central professional skill). The overall project goals are to: 1) understand faculty and student beliefs about effective practice and learning outcomes related to communication and teamwork; 2) articulate how well student and faculty beliefs align and how well beliefs and practices align; and 3) identify and test interventions to enhance the teaching and learning of communication and teamwork skills in engineering courses.

This paper focuses on the first goal, and attends specifically to the student perspective to identify student beliefs about the teaching and learning of communication skills. Specifically, we analyzed five focus groups conducted with engineering students at partner schools. The purpose of the focus groups was to uncover student beliefs about where and how they learned teamwork and communication within their engineering education. The exploratory focus group protocol was developed to mirror the questions being asked separately of faculty about teaching and learning communication skills. Asking parallel questions of students and faculty, allows us to address the second goal of the study which is exploring the areas of alignment and divergence between the two groups. The results from the faculty perspective are reported elsewhere [2]. The purpose of this paper is to articulate the beliefs of a sample of engineering students to highlight their concerns and challenges with learning communication skills and to better aid in improving student learning of these objectives

II. THEORY AND METHODS

A. *Theoretical Framework*

Situated learning, which is vital to language development of engineering students, provides a basis to characterize how students learn to communicate [1, 3] and was used as a lens to examine the five focus groups. As articulated by Lave and Wenger, situated learning theory describes the relationship between the situation and the context of the concept being learned [4, 5]. Situated learning highlights the social and contextual nature of student development and, in Lave and Wenger's work, includes participation in a community of practice [5]. This participation, referred to as "legitimate peripheral participation" [4], occurs when students undertake tasks that are reflective of and aligned with the kind of work they will engage in after graduation. Legitimate peripheral participation is particularly salient in the current study in that it refers to the ways in which novices learn by taking on small tasks that begin "at the edges" of the authentic practice, under the guidance of experts, and gradually assume more responsibility as they move from the periphery to the center of the task. According to Lave and Wenger, *participation* is the process through which novices start on the edges of the community and work towards the inner circle of experienced members. Working towards the inner circle is indicated by an increase in responsibility and authority in the community activity (e.g. the writing activity) [4]. During a community sanctioned activity, such as oral or written presentation of technical information, the experienced members should model community behavior and explicitly provide examples for novices (learners) in the authentic environment. Because our focus was on advanced students (juniors and seniors), we argue that the classroom is an approximation of an authentic environment, particularly since many of the focus group discussions centered on design or project-oriented classes. Since classrooms and engineering practice have two entirely different functions (i.e., learning how to do engineering vs. doing engineering) the classroom may not be an exact match from what students will face in professional practice. In the case of communication, the engineering faculty mentors who are considered experts at communicating their technical knowledge can act as role models of effective professional behavior (e.g. gathering information about stakeholders or audience) and create sites for students to learn authentic engineering communication practices [3]. Therefore, the community behaviors around communication that students observe faculty mentors model in an authentic learning environment are an important component of this current study. Situated learning provides a means to consider how engineering students learn community sanctioned communication skills and how these skills relate to professional development [3]. The current study points to the ways in which faculty's ability to both exemplify and situate professional engineering communication may effectively support student learning.

A. Participants

As noted above, data for this paper is drawn from a larger multi-university study. The study includes five universities geographically distributed across the U.S.; the study sites include public and private institutions as well as technically focused and comprehensive institutions. The study focuses on mechanical, civil, and industrial/systems engineering programs to provide a large sample population with diverse perspectives on the role of communication in the discipline [2]. Sites were intentionally selected to provide broad representation of differing types of programs. In this analysis, we included one focus group from each of the five sites, for a total of 25 students. Focus group participants were identified through coordinators at each site, involving a combination of snowball and convenience sampling to provide a rich source of information designed to address the research question [6, 7]. In other words, the sampling combination (different sizes and types of schools in different geographic locations with different curricular focus and practices for teaching communication and students from three different majors) provided a broad representation of communication learning experiences and contexts to explore a range of student beliefs about where and how they learn to communicate as an engineer. Prospective participants (e.g. students in technical writing or senior design courses) were recruited via the site coordinators and through solicitation emails that indicated the time and location of the focus group. The students were offered pizza and soft drinks as a modest compensation for participation in the study. Students self-selected to participate, and their participation was not disclosed to either the coordinators or the engineering faculty at the site. All names used in this paper are pseudonyms.

B. Data Collection and Analysis

The central question for study, what are student beliefs about communication, is intentionally broad, exploratory in nature and requires a qualitative inquiry strategy to effectively answer.[7] With limited studies investigating student beliefs about how and where they learn to communicate, the intent of this paper is to begin developing thick, rich descriptions [8] of the complex set of factors relevant to students perceptions about communication. Since the factors were previously unidentified, a qualitative research methodology provided a means to gain a deeper, more sophisticated understanding [9] of student beliefs about the role communication plays in their engineering education. Therefore, this paper highlights a portion of qualitative data collected during the study and specifically synthesizes the student focus groups as one inquiry strategy in the context of the larger study.

The focus group protocol was developed to elicit student's beliefs about both effective communication and the process of learning to communicate; questions asked students to define "good communication" and to describe specific opportunities or experiences that helped them learn to communicate effectively. Prompts were drawn from the existing literature on learning to communicate (see [1] for an overview of this literature). The focus group discussions, typically lasting 30-70 minutes, were audio recorded and transcribed verbatim. Typically, two researchers conducted the focus groups, where one managed the focus group discussion and the other took notes and tracked speakers. After each focus group, field notes about the focus group were compiled and combined across researchers when appropriate.

To analyze the data, we used an open coding approach with MAXQDA software to code the focus group transcriptions. Multiple rounds of open coding were performed to identify emergent themes and a detailed codebook was developed to avoid code definitions drifting throughout the analysis process [10]. For example, modeling was defined as novices beginning to participate by taking on small portions of a project or a task of lower complexity under the supervision of an experienced member of the community such as a faculty mentor. The code was only applied to statements from focus group members about mimicking faculty behaviors on a writing project or sections of a paper distributed throughout the course of a semester. The code definitions were developed based on widely accepted literature on situated learning and pertinent literature review for this project. The primary code definitions can be found in Table 1.

Table 1: Code name and definitions

Code Name	*Code Definition*
Examples	Descriptions of sample texts or templates provided by faculty and is available to all students
Lack of examples	Statements explicitly noting a lack of examples
Example Source	Statements about the source of the example (e.g. Faculty mentor, project manager, or client who gives the students an example of a deliverable)

Code Name	*Code Definition*
Legitimate Participation	Statements in which students connect classroom work to engineering practices.
Lack of Legitimate Participation	Statements in which students explicitly note the lack of connection between classroom and workplace experiences or expectations.
Participation Source	Statements about who provided connections between classroom and workplace communication or modeled professional practices

III. RESULTS

Three primary themes emerged during data analysis that indicate that students desire more direct instruction for communication skills and greater articulation as to how these skills relate to professional engineering work –issues that are, in fact, critical in situated learning. The three themes are 1) a desire for explicit examples, 2) a clear distinction between engineering writing and other writing, and 3) a need faculty mentors to provide clear links between school assignments and workplace practices, and to model professional practice. Each theme is illustrated with corresponding quotes and a brief discussion on its relationship to situated learning. When applicable, counterexamples for each theme are included in the analysis to demonstrate the variety in students' beliefs about the emergent themes.

Note that although we asked about communication in general, focus group participants tended to focus on written communication. We recognize that there are many other forms of communication, including formal oral reports, informal conversations, etc. Our analysis is not intentionally excluding such formats of communication; rather, we represent the focus of the students which is heavily grounded in writing as communication.

Theme 1: Students desire "examples," where an example is a tangible product, such as a template, provided by faculty and available to all students

Students across sites believe that tangible examples or templates can enhance their ability to learn various communications skills. Several students stated they wished they had an example or template to follow to initially learn how to effectively construct a technical report. For example, a student at Site 3 is not confident in his or her ability to write an abstract due to the minimal exposure to technical writing in high school:

> "Or like, here's how to write an abstract or this is what an abstract is, because the work, you know, you look up papers and its like this is an abstract and I remember the first time coming out of high school I didn't really do anything with engineering coming here and it's like I'm looking for a paper and found the abstract, and was like, um, abstract, that's a weird concept like what is this (A: right) and no one had ever explained it to me (A: right, right) so I had to figure it out on my own."**_Site 3**

One interpretation of the quote is that the student not only desires an example of what engineering writing "is," but also wants to know how his previously learned skills prepare him to learn how to communicate as a professional engineer. The student has not learned the importance and function of an abstract from class experience, but clearly wants to understand. Another student at Site 3 expressed a similar lack of resources such as a class discussion about specific writing issues to explain how to communicate as an engineering professional:

> "There's never really been a class that's like, this, this is how you're supposed to sit down and write an introduction to a technical document." **_Site 3**

Both quotes suggest that students desire explicit examples and direct instruction on how to "write like an engineer," to borrow Dorothy Winsor's phrase [11]. While Site 3 did not have a required technical writing course at the time of the focus group, students at other partner sites with such courses expressed similar desires for explicit instructions about how to generate a technical report:

> "I always liked when teachers hand you an example that you can use as a blueprint initially, and just, for your first, like, two or three, almost copy it verbatim in terms of formatting, and then as your group develops you start to move in a different direction. 'Cause it's always really awkward, at least for me, when your teacher goes, 'Okay, I want a report on how you're doing' -what kind of report? A technical report, uh, informal report, an update, you know, a memo? What do you want?"**_Site 2**

Here, the student describes the value of explicit example and direct instruction. What is also notable here is that the student recognizes the example as a starting point that must then be adapted to the needs of a particular project.

In addition to multiple comments expressing students' desire for more explicit examples of engineering writing, some students described examples or resources they considered inadequate. Students at Site 3, for example, describe a resource not effectively articulating communication skills that applied to engineering:

> [Student 1; S1]: "You know, coming into [course] they tell you to get this thing called a guide to writing as an engineering." [Student 2] "It's largely worthless. [S1]: Well I've never read it because most of what I've seen when it's been references is ok, that's common sense, I haven't seen it actually have anything earth shattering or ground breaking or wow this is a way better way to write (Interviewer: hmmm) and there's never really been a class that's like, this, this is how you're supposed to sit down and write an introduction to a technical document." **_Site 3**

These students consider communication skills important, but do not see the relationship between the resource provided and its useful application to engineering writing. These students desire a clear connection between the resource and their own communication of engineering information. In this case, an explicit example that applies the information in the resource could demonstrate to this student the role of the communication resource within the field of engineering and how it pertains to professional development.

Examples and templates are a critical component of situated learning because they provide students with tangible examples of the practices associated with the professional. And while faculty may raise concerns about students "copying" examples, the comments from the student at Site 4, in particular, demonstrate that students have the capacity to learn from and then *adapt* effective examples. Fostering adaptation, however, requires some time on the part of faculty to provide not only exemplary texts (e.g. a "good" report), but also commentary to explain why the exemplars are "good" and how they might be adapted. This process is, in fact, one of the bases of the Calibrated Peer Review system that facilitates electronic peer review among students [12-14]. For faculty uncertain about how best to articulate the features students can or should emulate, dialogue with experts in writing can prove quite helpful [15]. Once the examples themselves are selected and documented, minimal class time can be used to introduce and situate those examples. Providing students with examples or templates helps communicate expectations regarding the style and quality of the written work.

Theme 2: Students believe that technical (engineering) writing is different from other (i.e. "English") writing.

The quotations noted above, as well as comments throughout the focus group discussions all illustrate the ways in which students draw clear distinctions between the kind of writing used to present and interpret the outcomes of engineering work and the "other" style of writing – a style students often link to English courses. For example students at Sites 5 and 3 had this to say;

> "Like, my English class, and what not. What I was taught is that engineering writing is real cut and dry… It's, 'These are the facts, these are the calculations I did to get these facts, uh, this is the outcome." Where if I went and took another writing intensive course, say with say, Greek mythology, [A: Right] or with other electives like that, they wanted to build up a characters…."**_Site 5**

> "…how to write an engineering document, you know it's, It's not what you wrote in IB English in high school that was you know spat out 2 pages about whatever. I'm writing my first paper for that and it was like a little sample paper and [professor] just scratched out the first paragraph and said like, extraneous" **_Site 3**

Both quotes show how students perceive engineering writing as different from past educational writing. More importantly, the students view engineering writing as highly direct and factual – a place where the kind of "extraneous" information they found helpful in reaching page limits on essays is dismissed out of hand by engineering faculty. One danger in students' perceptions, however, is that in treating engineering as "dry and factual," students may not understand their role as interpreters of data and the need to argue for engineering decisions [1], a possibility more fully explored in the work of Leydens [16] and Winsor [11]. Because they may perceive attempts to persuade an audience as "biased" or "made-up," they may not understand how to construct an argument within engineering communication. Thus students may not be aware of how to present or develop an argument within a technical report, for example, in order to demonstrate that the design they have completed is feasible, desirable, and meets the project requirements. The situated nature of writing and learning to write [1] implies that all writing has a function; in engineering, that function is often to persuade others of the value and significance of the data. Without sufficient context in which to communicate engineering knowledge, students may not learn to understand the more complex reasons for writing, or see the connection between arguments made in English courses and arguments made in laboratory or design courses.

The focus group findings also hint at the ways faculty may be complicit in promoting certain student beliefs. For example, a student at Site 5 described a faculty member telling the class that engineering writing was boring; the student had adopted that position and thus was limited in their ability to understand the "why" of technical reports.

Theme 3: *Peripheral Participation* is the process by which novices take on small portions of a project or tasks of lower complexity under the supervision of an experienced member of the community such as a faculty mentor.

The misconceptions about engineering writing noted above directly lead to the last theme – that of peripheral participation. Just as examples can provide students with clear statements of expectation, they can also help students understand how such documents are used in engineering practice. Example texts can provide faculty opportunities to discuss the connection between the information that engineers generate and how that information is communicated to a variety of audiences. In other words, the example or template can foster a discussion about why communication is important in engineering practice, and faculty can then share disciplinary expertise with students explicitly in ways that model effective skills.

What practices or behaviors are engineering faculty modeling to students in regards to communication styles/skills and its role within the engineering profession? Similar to tangible examples, students expressed a desire for more transparency and intentionality in understanding how faculty members connect communication skills to the curriculum and, perhaps more importantly, to engineering practice. Specifically, students want to understand the situated nature of communication as it fits into engineering work. Engineering faculty previously interviewed for this study expressed high levels of communication competence [2] but the students in the focus groups did not. Therefore, the confidence in communication skills expressed by engineering faculty is not being transferred to students. Based on the student focus group data, it seems the value of communication can be lost if students do not see the value in a class activity to develop communication skills purposefully linked to engineering practice. For example, students at Sites 2 and 4 had this to say:

> "Every single class has a presentation that you have to do once and it's five minutes long and, it's just a whole lot of anxiety and doesn't really serve any practical purpose. Nobody's gonna learn how to be a better presenter by doing one presen-, or five presentations at the very end of the semester when they're already crammed with everything else."**_Site 2**

> "I feel like there's not enough writing in Engineering. Well, I recently, well, last summer, got an internship-type

thing. And I could not believe how much writing there is in Engineering. Like, it's insane. I feel like I am not prepared for that at all. And like communicating with clients and being able to tell them, they have no Engineering background, and you have to tell them, like, you can't show them your calculations, and be like, "Doesn't that make sense to you?" [A: (laughs)] I just feel like just presenting, we don't have any presentation skills, I am horrible at presenting."_**Site 4**

In different ways, both students are identifying a gap between classroom experiences and expected practice. Both quotes speak to the low competence and confidence of students in regard to their communication skills, which contrast the highly competent faculty members teaching them. Implicit in the comments from the student at Site 2 is the sense that course presentations are a missed learning opportunity and that they lack any kind of workplace value – they are merely more course assignments to be done as quickly as possible. A class discussion about the purpose and goal of the presentations, along with expectations or guidelines for acceptable presentation skills for engineering professionals, and time for meaningful feedback could alleviate the student's concerns. The quote from the student at Site 4, in addition to pointing to the gap between classroom and workplace practice, highlights the misconception noted in the previous section regarding the "dry" nature of engineering writing. The student's workplace experience has demonstrated the ways in which engineering calculations do not speak for themselves but instead require skillful communicators to situate and interpret them appropriately. Such behaviors, the student notes, are not modeled in engineering curricula.

In other cases, students did find faculty who could help them make connections by modeling professional practice. For example, a student at Site 3 stated:

> "It's definitely individual like if you put the work in and try and learn how to effectively communicate there are tools here and there are professors here that will help you learn to communicate better but if you just come over here to get a degree and walk out of here with a piece of paper and hopefully a job 4 years later, (M2: you're not), you're not really gonna go anywhere with that." _**Site 3**

This participant describes an academic culture that clearly provides the resources, including faculty mentors/models, needed to develop the necessary communication skills. Notably, this participant is one of the few student comments who reflected on their own accountability regarding their learning of communication skills.

IV. Conclusions

Situated learning emphasizes the ways in which students learn by engaging in authentic activities situated in meaningful professional contexts. This study highlights students' desire for search learning when it comes to communication – a desire reflected in the need for more explicit instruction and more modeling around communication in engineering and its role in professional practice. The study used situated learning as a theoretical framework to make meaning of the student focus group comments. The three themes that emerged from the data analysis suggest a series of pedagogical adjustments that may help students understand the importance and value of good communication skills as they relate to professional engineering practice. Such adjustments can, in practice, be integrated seamlessly into technical courses with well designed examples and brief discussions, though engineering faculty may find discussions with technical writing experts helpful in the process. These pedagogical adjustments may result in the legitimate peripheral participation of students, as defined by situated learning theory, being applied in engineering courses. In other words, as faculty model behaviors and support the notion that communication skills are critical to engineering professional practice, the novices (students) can observe and adopt the community behavior and perspective.

V. Limitations and Future work

As with any research endeavor, our study has some limitations. One limitation is the small number of focus groups. Our results reflect the beliefs of an intentionally chosen (with regard to research site and major) sample of self-selected students. Our results may not reflect all beliefs within the major or schools we studied. Moreover, students with dissenting opinions may have chosen to not participate in the focus groups. Another limitation was the limited background available on each focus group participant. For example, we were unable to consider the academic level of participants and/or the academic performance of participants to contextualize responses. However, our findings are still meaningful with regard to representing the experiences and needs of some students. Future work could address these limitations such as a mixed methods study to relate student performance (e.g. GPA) to the places where students believe they learn the skills to communicate technical information. Also, future work could consider dimensions of academic culture that student believe impact the ability to learn communication skills.

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Professional communication skills for engineering professionals

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***Abstract*— Oral and written communication proficiency is an important professional skill for engineering graduates. However, developing these skills is often poorly integrated into the engineering curriculum. We present a three year integrated approach to developing professional competence in oral and written communication, which has been implemented in the IT engineering program at a Swedish research university. In the paper we describe the educational approach, the nature of assessment items and measures taken to ensure progressive skills development in order to ensure that graduates emerge with fully fledged communications skills. The goal of the paper is to describe a successful model for professional skills development, and to encourage a continuing dialogue on how to best equip students with communication skills for professional practice. (*Abstract*)**

Keywords—engineering education; communication skills; professional competencies; (key words)

I. INTRODUCTION

Professional engineers use communication for many different purposes, e.g., pitching ideas, describing solutions, reporting results, discussing work with collaborators, customers, etc. Graduating students need to acquire the necessary communication skills and become familiar with a broad selection of styles during their education. The American Computing and Accreditation Commission (ABET) acknowledges this, e.g., in their general criteria for accrediting engineering technology programs [1] where "*an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;*" is listed as a required student outcome.

Many teachers regard teaching the main course subject their only task and do neither teach nor comment on how well students communicate within the subject. IT faculty are hesitant to grade communication skills due to a perceived lack of language expertise or because they find the task tedious [2]. At Uppsala University, a Swedish research university, a student survey shows that isolated efforts, often in the form of writing assignments or oral presentations, have been made to improve the situation, but more often than not, students do not get the feedback they need to be able to develop their communication skills.

In this paper we present an approach to developing professional communication skills in engineering students. When this work was started, we focused primarily on written communication. The work has then gradually expanded towards including oral communication, but some of the work presented here has a focus on writing. Oral and written communication skills have a lot in common. For example, explaining a concept requires being able to adjust the amount of context that need to be presented in order for a specific audience to be able to understand, no matter whether it is done orally or in writing. Hence development in written communication will also be beneficial for oral communication and vice versa. The differences between the two forms of communication are, however, significant enough to motivate that they both need to be practiced in the education.

In the literature, there are two main approaches to teaching professional communication skills – those where communication is taught in dedicated courses [3] [4] and those based on writing across the curriculum (WAC) [5], where teaching is done in several courses throughout the education. Furthermore, communication can be taught in general language courses or in core subject courses, within the discipline, where it can serve both to enhance learning and to practice professional activities [6].

The approach presented here is an across the curriculum, within the discipline approach to developing both oral and written communication skills. The approach has been implemented in the first three years of the IT engineering program at Uppsala University. Our approach has been developed to address problems that were discovered through a student survey in 2012. We describe the ideas behind our approach, what has been done to achieve progressive development, how we work with assessment, and challenges that we have addressed in our design. The ideas presented constitute a framework that can be used to develop other competencies such as group working skills and information literacy and they are also valid for other branches of engineering education.

II. BACKGROUND

The IT engineering program at Uppsala University, in likeness with other engineering programs, aim at educating students to become competent professionals. This means that the students do not only have to learn their core subject, they

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also have to develop a number of competencies that are essential to professionals. We refer to OECD [7] for a definition of a competency:

"*A competency is more than just knowledge and skills. It involves the ability to meet complex demands, by drawing on and mobilising psychosocial resources (including skills and attitudes) in a particular context.*"

In this work, we focus on communication ability for IT engineers, which OECD describes by

"*the ability to communicate effectively is a competency that may draw on an individual's knowledge of language, practical IT skills and attitudes towards those with whom he or she is communicating*".

To graduate from engineering programs at Uppsala University, the students must

"*demonstrate ability in both national and international contexts, to, orally and in writing, in dialogue with different groups, clearly present and discuss their conclusions and the knowledge and arguments that form the basis for these.*"[1] [8]

This requires students to be skilled at communication within their subject, and to be able to adjust their communication to different situations and different audiences that they may encounter professionally.

Study programs at Uppsala University, typically consist of a collection of courses, most of which are in the program's core subject. In the IT engineering program, isolated efforts of including professional skills development have been done, but there has been no previous attempt to structure this development across the education.

In 2012, we explored the students' view on the current writing training situation in the IT engineering program at Uppsala University by conducting a survey. Although the survey focuses on writing, the results have been used as a basis for developing both oral and written communication education.

In the survey, we asked the students

- if they have had writing training previously during their education,
- if they think that writing training is relevant to their education, and
- how good writers they perceive themselves to be.

Free text answers and comments have been analyzed with the aim of finding a variation in how students experience the use of written communication in IT and in how useful they perceive the writing training they have had to be for their skills development.

Students from one course in year 2 and two parallel courses in year 3 were asked to participate. Out of the total 65 students that were asked, 27 participated which gives an answer ratio of 42%.

Slightly less than half of the students answered the survey. We cannot be sure of how representative this group is for the total student body. However, opinions expressed by a large number of students (>80%) in this sample would be strongly represented even if all other students were of a different opinion. It is also clear, both from statistics and from free text answers, that both students who are interested in and/or strong in writing and students who are not are represented.

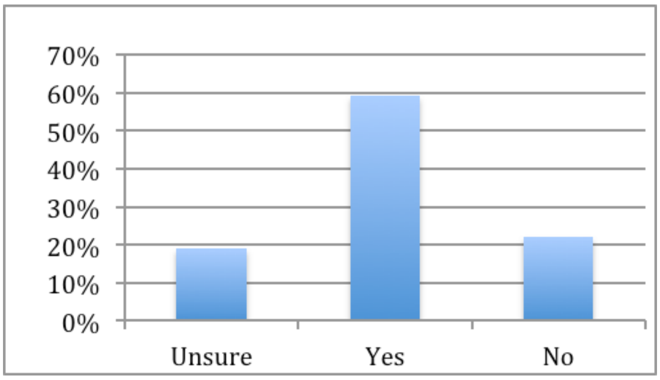

Figure 1: Previous writing training.

A. Writing training

As shown in Figure 1, the survey showed that 60% of the participating students say that they have had previous writing training in their education, 20% that they have not had writing training and 20% are not sure.

Students that reported having had writing training in their education were asked to explain in what courses and how that had affected their writing skills.

Half of those students (8 out of 16) reported having writing training in 1-2 courses, 2 wrote that writing training occurred only in project courses, and 6 reported that they had writing training in many courses. Of the 9 students who commented on how these courses has contributed to development of their writing skills, 5 reported that they could not see any development. 3 of these students also mentioned that they had not gotten any feedback on their writing. 2 students mentioned that they had learned the general framework for writing reports, and another 2 students claimed that they had learned to write reports by the practice they got from these courses.

We conclude that writing practice is useful and that we need to make sure that the students get more of it. We also see that not all students can learn from practice alone, and for that reason, feedback is very important. This result agrees with what is written about the need for feedback in [9]. In our survey, one student expressed that

[1] Translation from Swedish.

"Many of the courses within the IT program has given opportunity to practice writing, but never given specific feedback on the writing. It didn't develop much, but rather gave the opportunity to keep my previous standard up."[2]

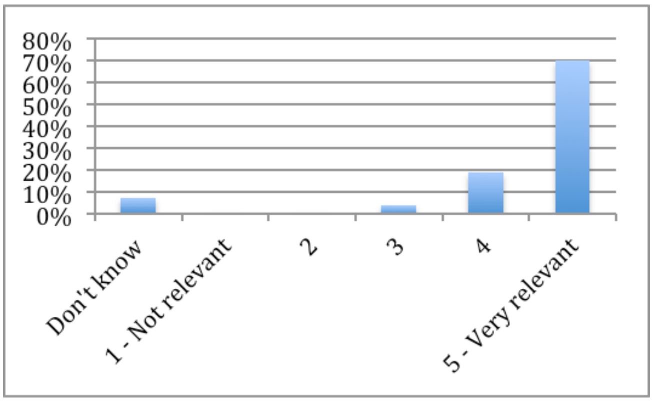

Figure 2: Relevance of writing training.

B. Relevance

On the question how relevant writing training is to their education (see Figure 2), 70% thinks that it is a 5 on a scale 1-5. Another 19% thinks it is a 4, 4% thinks it is a 3 and 7% do not know. Apparently, students think that writing is important for an IT engineer but this raises the question of why students think that it is relevant and how they expect to be using writing in their profession. In 11 free text comments to this question, we find that

- 5 students think that is it generally important to be able to express one self correctly but that it has no particular importance for their profession
- 5 students think that it is important to be able to present ones work by writing reports
- 2 students think that writing is important for making their work (products and solutions) and research available to others

It is also mentioned that writing will be used for work applications, communicating with coworkers and that good writing makes it easier to get through with opinions.

Our conclusion is that students have a general feeling that writing is important but their image of how it will be used in their future profession is not clear. In order to get through to students with the communication education that is provided, we need to provide examples of different kinds of professional communication.

C. Assessment of writing skills

The students were asked to assess their own writing skills on a scale 1-5, where 5 is "good enough for writing a thesis", 3 is "good enough for my current level of studies" and 1 is "I definitely need more training". 4% of the students chose not to rate themselves. 7% rated themselves 2, 85% rated themselves 3 or 4 and only one student was rated 5. The results are presented in Figure 3.

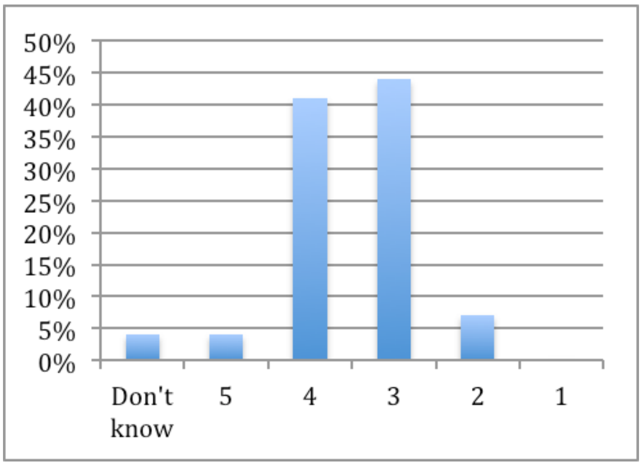

Figure 3: Self-assessed writing skills.

These figures suggest that 92% of these students need future writing training and at least 7% would have been better of with more writing training earlier in the program according to their own estimate. However, if we look at the 13 free text comments on this question, all but 3 students either express that they need more writing training or that they are unsure about the level of writing that is required. The other 3 students express that their general writing skills are good, but that they are unsure about their academic writing skills or about writing within their discipline.

We expect the students to learn good general writing skills in high school and to develop academic and discipline specific writing skills at the university. Our interpretation is therefore that the students lack of understanding of what writing in their subject is, leads them to rate their own writing higher than an IT teacher would and that improved communication education throughout the program is needed.

III. PROPOSED APPROACH

We will present the ideas and theory behind our approach before describing how it has been implemented at Uppsala University and explaining why this approach has been chosen.

A. Frequent practice.

Students need reoccurring opportunities to work on improving their communication skills. Students that are exposed to different writing assignments throughout their studies perceive improvement in writing skills [10]. Presentation skills are also improved by practice [11].

B. Practice within the subject.

Skills achieved in dedicated courses are not necessarily transferred to other contexts [12]. This means that general language courses may not have the desired impact on the students' development in professional communication, which is in their core subject. In addition to being ways of communicating, writing, explaining and discussing are also

[2] Translation from Swedish.

ways of learning [13] and help to form the professional identity [14]. If the practice is not performed within the discipline, these advantages will be lost.

C. Instructions, feedback and reflection.

Moore concludes that without proper instructions, guidance and feedback, the only effect of writing assignments is to reinforce bad writing [9]. He also argues that with proper guidance, students show significant improvements both in writing skills and in content knowledge. For oral presentations, [11] report getting good skill development when using a combination of practice, reflection and peer review. In [15], the authors report that letting students reflect on their own work, in addition to formal assessment, advances the development of professional competencies.

D. Progression.

We believe that it is not only important that students practice communication regularly and that they get feedback. In order for the students to continue progressing over time, it is important that the level of communication required in assignments increases as the students mature. The feedback should also meet students at their current level and promote further development.

IV. Teaching methods

To ensure that IT engineering students at Uppsala University are subject to reoccurring communication practice, communication proficiency is a prioritized learning outcome for at least two core subject courses each of the first three years of studies. This also makes it clear, for the students, when communication is practiced and assessed and stresses that development of communication skills is an important part of the education.

Factors like restricted time, limited access to information and the stressful situation makes assessing professional skills through traditional exams difficult [16]. In our approach, communication is therefore practiced and assessed in different kinds of assignments, where students can prepare for oral assessments and have time to work on written material.

From the survey presented in Section II, we learned that students agree that writing is important for IT professionals but when asked how it is used, they seem to lack an answer. This also means that the character of communication in IT, how it differs from general academic communication, is unclear. By providing students with a variety of different kinds of well-chosen communication assignments, we hope to acquaint the students with professional style communication and highlight the communication skills that are specific to IT.

In [2], Garvey presents a categorization of student writing with particular examples of assignments in each category. The communication assignments that our students encounter during the first three years are best described by Garvey's categories "Summarizing assignments", "Programs as writing", "Reviews/critiques of the writing of others" and "More creative kinds of writing" although, in our case, the work is sometimes presented orally. "Team-based writing" also occurs. Examples of assignments that our students encounter are paper reviews (summarizing), project proposals (creative), lab and project reports (programs), literature discussions (summarizing, reviews) and project presentations (programs). Sometimes our students present and critique each other's work resulting in assignments that span three of the categories, summarizing, programs and reviews.

Another important component in making students familiar with communication in their discipline is to provide examples. We are collaborating with the university's writing center to form a database of examples of student and professional writing. Reading and presenting research papers is also an activity that contributes.

In oral communication, students need to become skilled in presentation techniques, but it is equally important that they become skilled in discussing their subject. In addition to being able to present ideas and solutions, they need to be able to relate to and ask and answer questions about material that is being presented and they need to be able to communicate efficiently about their work when cooperating with others in teams.

Most approaches to oral communication education described in literature address presentation skills [4] [11]. We find that there is also a great need for practicing discussing the subject of studies. Students struggle with describing issues related to IT, concepts, solutions, etc. both orally and in writing. In discussions, this is even harder since a good description has to be provided without having as much time to think about how to explain what they want to say as when given a written assignment or preparing a presentation. This is obvious even when students are to describe and discuss what they have previously written about. The need for oral communication training that goes beyond presentation skills is supported by the work of Ruff and Carter [17], where professional communication goals were identified through focus groups and interviews with software engineers and managers.

To practice and assess discussion skills, we work with oral assessment of both theoretical content and practical work. With the help of follow up questions, the teacher can create a situation where the student can no longer rely on previously prepared answers but has to create explanations and solutions on the fly. Course evaluations show that students experience that they need to have a thorough understanding of course material to pass this kind of oral assessment. Teachers experience that oral assessments make students aware of what it means to understand contents and thus seem to encourage deep learning. In addition, they find that need for communication practice is exposed and that student performance is drastically improved with practice.

Teaching the main course content is the primary concern for many teachers and they do neither teach nor comment on how the students communicate in their work. Previous literature [2] [18] report that IT faculty hesitate to grade

Beginners, first course
Students should be able to
1. identify different types of text in the field and describe their structure.
2. write a text that reproduces information from other sources.
3. write a text that is suitable[1] for the intended reader.
4. write a text that has a clear theme and is appealing[1] to the intended reader.
5. write text that is linguistically correct for spelling, paragraphing, punctuation, etc.
6. use references and citations correctly.
7. discuss what information is necessary and what information is sufficient for a text.

First and second year
Students should be able to
1. provide constructive feedback on the work of others with the help of checklists.
2. write summaries of simple scientific articles.
3. describe and evaluate their own work in writing, e.g., lab report. The report should have a good structure.
4. apply principles of necessary and sufficient information in your own texts.

Second and third year
Students should be able to
1. give constructive feedback on the work of others.
2. describe and evaluate larger projects in writing. A special focus is on selection of appropriate levels of abstraction in different parts of the text.
3. use figures and diagrams in a proper manner.
4. produce "well-prepared" text in Swedish.
5. write original text in English.

Figure 4: Progression goals for writing.

writing since they do not have language expertise and since they consider evaluating writing to be a tedious task.

We collaborate with the university's writing center to offer support for teachers when it comes to making instructions for writing assignments and material on how to write. The writing center also supports the students by giving instruction lectures and writing aid, e.g., in the form of comments on student work before the final submission.

Providing feedback, especially to written work, is a time consuming task for teaching staff. We sometimes let senior students help with grading to reduce the teacher's workload and thus the teacher's task shifts from grading large numbers of assignments to supervising a group of students and making sure that their grading is at an appropriate level for the course. Peer reviewing, students giving feedback to each other, is also sometimes regarded as being a time saving alternative which has the additional advantage that students learn from reviewing as well as from doing the assignment. Investigations in [19] support our impression that students need training and education, both in giving and responding to feedback. Since peer reviewing is used frequently, students get to practice giving feedback. For written assignments, students must sometimes respond to feedback by improving their work.

For oral presentation, [11] report student development when using a combination of practice, reflection and peer review. When it comes to writing, our investigations support the results of [19], that students do not find feedback from peers as trustworthy and beneficial as feedback from teachers. In our approach, we use peer review both for oral and written work but for written work, we make sure that students also get feedback from teachers or teaching assistants. We also make it part of the assignment for students to reflect on their own performance. We share the experiences presented in [15], that students lack experience in reflecting on their work. Since reflection does not only advance development of skills, but is also an important tool for achieving lifelong learning if incorporated in professional practice, we make reflection a mandatory part of selected assignments spread throughout the education.

To encourage progressive development, we have defined learning outcomes for written communication, presented in Figure 4. The learning outcomes are linked to different course levels. The learning outcomes are designed for students that are native in Swedish, not in English. At Uppsala University, there are four course levels during the first three years of study. At each level, students should fulfill the outcomes from previous levels as well as the ones from their current level. The fourth level, which does not occur in Figure 4, is the level of Bachelor thesis work and does not contain any new learning outcomes. A more detailed description and an analysis of the learning outcomes in relation to competencies that are needed to fulfill them is presented in [20].

At the first level, for beginner students, the focus is on high school level writing skills and general academic writing skills such as proper academic style language and correct use of references. At later levels, other aspects, e.g., being able to explain and describe solutions at appropriate levels of abstraction, are added. A typical example from IT is that to explain an algorithm or a program, you need to provide a high level description, a figure or a natural language description. Just presenting excerpts from code is not sufficient at the second and third levels.

The learning outcomes serve as a structure, both for teachers and for students, for achieving progression in the level of assignments, the quality of student work and the grading criteria for assignments. Because of the many similarities between written and oral communication, it is easy to adjust the learning outcomes to suit both kinds of communication. To help students appreciate their own development, assignment solutions, feedback and reflections can be used to compile a student portfolio.

V. IMPLEMENTATION

The communication training starts at the beginners level, in the very first course in the IT program and is continued in five more courses spread over the first three years. By the end of the third year, the students show that they fulfill all communication goals discussed above in an independent project corresponding to a bachelor thesis.

In the first course, the writing education focuses on the difference between academic texts and general texts with a special emphasis on the style used in different types of IT related texts. For example, the students learn the structure of academic reports and they start to practice explaining IT concepts in a precise and unambiguous manner. Since the students do not yet have deep subject knowledge, typical assignments consist of presenting IT concepts and discussing them in relation to society and everyday life. The texts are directed towards audiences that are at the same level as the students themselves, audiences that do not have deep understanding of IT. An important goal at this level is that the students learn to use text sources in a proper manner.

To practice oral communication, the students are required to do most of the course work in groups. In addition to being an arena for practicing discussion skills, the groups can serve as a motivator for students to perform better and learn more and thus the group can have a positive influence on students' study habits [21].

The rest of the first year is dedicated to practicing describing and evaluating the students' own work. The students present their own solutions to programming assignments, both orally and in writing. They evaluate their solutions and draw conclusions e.g., about performance of algorithms. They start working on presentation skills by presenting small projects to the class. An important task for students during this period is to provide feedback on the work of other students. By doing this, the students get to see both good and bad examples and how they affect the general quality of texts and presentations. At this level, peer reviewing is guided by checklists that help students focus on relevant properties of texts and presentations rather than getting stuck in commenting on details, such as spelling errors.

In the second and third years, this work continues but as student projects get larger, the demand for descriptions at different levels of abstraction increases. Although the students have used illustrations earlier, the emphasis on proper selection and use of illustrations is increased. At this level, we also require that students relate their work to other work in the field properly.

Peer reviewing is still used, but with less aid from checklists as we expect students at this level to have a general knowledge of what to look for. Group work and oral examination is also used, but as the students' subject knowledge increases, so does the required level of correctness in descriptions and of how students can draw conclusions from course contents.

In the later years, students are required to present their work to different audiences ranging from novice students to professionals depending on the purpose of the different assignments. An example from the third year is a writing assignment where students are required to explain database concepts and give illustrative examples directed towards audiences not knowing anything about databases. Another example, from a concurrent programming course in the second year, is a project proposal where the students have to sell an idea while giving enough technical background to convince a professional that their idea is realistic and should be accepted.

VI. DISCUSSION

We have described a model for professional skills development and how it has been implemented to develop communication skills in IT engineering students at Uppsala University. Through a student survey, we have found that the isolated efforts that have previously been implemented in the program, students have encountered communication practice, but that feedback and progression have been sparse. It is also clear that students have a vague and incomplete picture of how communication will be used in their future profession. We argue that an across the curriculum approach is needed to ensure that students encounter a broad variety of professional communication activities and thus develops a knowledge of what communication in their discipline is and how it is used. Such an approach also makes it possible to progress the level of communication activities the students are to engage in and how they are graded.

Our approach has been successful in that it has engaged faculty in participating in developing students' communication skills to a much larger extent than previously. The model have not been used to a full extent long enough to present definitive results on how student performance is improved, but the preliminary impression is that students are adopting study habits more directed towards deep learning and that students' oral communication skills are developing.

Groups are natural training grounds for communication. Hence, an interesting future extension of this work is to include group and project working skills. A well functioning group can have a positive impact on learning that would be interesting to take advantage of in professional skills development.

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Correlation of Learning Styles with Team Performance and Perception in a Chemical Engineering Unit Operations Course

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Abstract—**Teamwork is emphasized in high-level engineering courses to help prepare students for their chosen career. When left to self-select, students often form homogenous groups with respect to several indicators, including learning style. While homogeneous groups may occasionally be preferred for specific tasks, heterogeneous groups have shown better performance over a wider range of tasks. Qualitative data (interviews) suggest that students grasp the value of heterogeneous groups and are able to recognize the gains of such diversity. We are interested in the relationship between learning styles and team dynamics in advanced chemical engineering students taking the team-based unit operations course. We are looking to correlate team composition with respect to learning styles preferences with team performance and student perceptions of team efficacy. Students are given a learning styles questionnaire to determine preferences in the course's lecture portion. These are used to identify potential correlations between team make-up, team performance and student perceptions during the subsequent laboratory portion. Understanding variability in performance based on team composition can help elucidate the complex nature of team dynamics. Armed with such information, instructors can create the most educationally efficient teams, and students will have a better understanding of teams as they enter the workforce.**

Keywords—team dynamics, learning styles, student performance, student perception

I. INTRODUCTION

Engineering is a highly team-oriented discipline. Undergraduate engineering curriculum emphasizes teamwork in upper-level courses in an effort to prepare students for the demands of their future careers. There is a general understanding that diversity in team members is of high value, but when left to decide for themselves students will self-aggregate into teams that are homogenous based on several indicators. We are interested in exploring the correlation between team make-up with respect to student learning styles and the perceived team dynamics and team performance in the context of a senior-level chemical engineering unit operations course.

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II. LEARNING STYLES PREFERENCES

While the validity of learning styles has been disputed since their establishment, many models exist to describe how individual's best receive new information. We are specifically interested in learning styles in the context of engineering.

A. Felder-Silverman Learning Styles Dimensions

Published in 1988, the Felder-Silverman model of learning styles for engineering identifies five dimensions: active/reflective, sensing/intuitive, visual/auditory (verbal), sequential/global, and inductive/deductive [1]. While the names of several dimensions give an intuitive understanding to the dimensions, they are also previously described in detail [1]. The inductive/deductive dimension was later removed from the Felder-Silverman model, as described by Felder in a 2012 preface to the work. Because of its specificity to engineering, we will be using the updated Felder-Silverman model of learning styles dimensions.

B. Felder-Soloman Index of Learning Styles

The Felder-Soloman index of Learning Styles (ILS) is a 44 item questionnaire designed to identify student learning preferences in the four dimensions of the Felder-Silverman model [2]. There are 11 questions for each dimension, each of which has two possible answers representing the opposing preferences within the dimension [2]. Each dimension is scored on a scale from -11 to +11, with individual answers being either a +1 or -1 [2]. For example, when considering the active/reflective dimension, answers showing an active preference are +1 and answers showing a reflective preference are -1. The absolute value of the final score reveals the "strength" of a preference, ranging from "balanced" (score of 1 or 3) to "strong" (score of 9 or 11) [2]. Reliability and validity studies of the ILS have shown student agreement with results [2][3]. While the Felder-Silverman model is considered specific to engineering, the ILS instrument has been used in not only engineering, but also other fields such as computer sciences and internal medicine [2][4][5].

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III. TEAM DYNAMICS

Teamwork is emphasized in high-level engineering courses to help prepare students for the highly team-oriented career their degree entails. When left to themselves, students will form groups that are homogenous with respect to several indicators, including personality and learning style [4][6]. While homogeneous groups may occasionally be preferred for specific tasks, heterogeneous groups have been shown to have better performance over a more broad range of tasks [4]. Qualitative data from interviews suggests that students also grasp the value of heterogeneous groups, and that despite some difficulties because of clashing styles are able to recognize the gains of such diversity [7]. Quantitative data on the matter regarding teamwork and learning styles consists of student surveys conducted on a numerical scale corresponding to agreement (*e.g.* Likert scale) [7]. This does not provide concrete data regarding group success at tasks, but rather gauges the student perceptions of team efficacy.

IV. UNIT OPERATIONS IN CHEMICAL ENGINEERING

Unit operations is a team-based laboratory course in chemical engineering. At most institutions it is taken as part of the senior year curriculum. At The Ohio State University (OSU) the course is divided into a spring semester lecture, taken by most students at the end of their third year, and a one-month laboratory course taken immediately following.

A. *Chemical and Biomolecular Engineering 3630*

Chemical and Biomolecular Engineering (ChBE) 3630 is the semester-long lecture based prerequisite for the unit operations laboratory course. This course offers the foundation material for completing the month long laboratory. Topics covered range from teamwork and six sigma leadership to how to read a temperature indicator or review of heat exchanger systems.

B. *Chemical and Biomolecular Engineering 4630*

ChBE 4630 is a four-week, team-based laboratory course. Students complete week long laboratory assignments in teams of four in one of three tracks: classical, biological, and environmental. Team members take on specific roles (team leader, design engineer, operating engineer, development engineer) that reflect the common components of industrial process teams. Roles rotate among the students so that each student may serve in each role once during the course. Students report to Teaching Assistants (TAs), who serve as supervisors, during their experiments. Requirements of each laboratory exercise include a daily summary report, data submission, design extension problem, and formal written laboratory report. Students are evaluated on the group laboratory reports and individual quizzes throughout the term, as well as a final examination at the end. A peer evaluation is also submitted by each group member for every laboratory.

V. STUDY DESIGN

We are interested in the correlation between team composition with respect to learning styles, perceived team dynamics, and team performance in the context of ChBE 4630. Approximately 150-200 students are enrolled in the course annually, providing a large potential sample size.

The study will be correlational, using surveys as a means of data acquisition. It will have qualitative and quantitative components, as we will be examining student performance as reflected by assignment grades and student feedback on both a Likert scale and as open response. The primary variable of interest is team composition with respect to student learning styles. We are interested in determining whether team composition has a significant effect on performance and perception, as measured by team performance on each assignment as well as post-assignment attitude surveys.

We aim to investigate the team dynamics of the students in ChBE 4630 without otherwise influencing the course content or design. The study will consist of the following:

1) Administration of ILS early in the spring 2013 ChBE 3630 course, as well as collection of informed consent responses.
2) Compilation of ILS data to determine make-up of student population enrolled in course with respect to learning styles dimensions.
3) Assignment of students into groups, done as usual by the faculty member teaching the course. Group assignments do not consider learning styles, offering a variety of team compositions with respect to learning styles.
4) Progression of course in month long “Maymester” term, as usual, with administration of additional survey for all students (disseminated by TAs to each team they are supervising) at the end of each laboratory to evaluate students’ perspective on their work as a team. Also, collection of informed consent and ILS from any students who may not have taken ChBE 3630 the preceding spring semester.
5) Collection and compilation of team grades, and analysis (of data from students who have consented to participate) to determine whether a correlation with team composition exists.
6) Comparison of performance of teams in the course as suggested by grades and students’ survey results.

VI. SURVEY DESIGN

The survey consists of a combination of statements evaluated on a one to five Likert scale and short answer questions. Statements are designed to evaluate student perceptions of their group dynamics. We are interested in whether the group communicated well, considered each other’s input, and whether the student believes that both the laboratory protocol and report benefitted from working in a team. Furthermore, we are interested in whether the student believes the final report is of high quality and if they would have preferred to work alone. The short answer questions are directed toward identifying the student’s personal contributions to the group, as well as understanding what specific benefits they received from the group. There is also room for further comments.

VII. Inherent Challenges

Successful implementation of this study requires clear communication between the investigators, the faculty instructor, and TAs (of which there were nine during 2013). Throughout the term, teams meet among themselves and with their respective TAs, but the entire class does not often gather in an organized manner. Students and teams come and go as needed in order to get their laboratory exercises completed. Thus, we are relying on the TAs to consistently provide the students with the perception surveys and accompanying instructions for completion and submission.

As with any study that relies upon survey results for data, another inherent challenge is obtaining responses and ensuring those responses are valid. Survey completion is incentivized by awarding ½ point to the student's final grade for each survey completed (regardless of consent or declination of participation in the study). To ensure the validity of all survey responses analyzed, the survey includes repeated questions restated for both affirmative and negative responses. Thus, a student who answers affirmative or negative to both conflicting questions (*i.e.*, "group members communicated clearly" and "group members did not listen to each other's contributions") is likely guilty of completing the survey without paying proper attention to the questions. These responses will be omitted from the data used in analysis.

VIII. First Trial Improvements

After conducting the study in 2013 (results not yet available at the time of this submission), several areas of improvement have been identified for a more robust study. First, logistically, we need to ensure that all TAs understand the study intent, consent process, and the intended administration dates for the four surveys (one with each laboratory assignment). In Maymester 2013 there were three graduate and six undergraduate TAs. Communication of the study details to these TAs is crucial, and may require greater involvement from the investigators.

There are several potential improvements in regards to survey design. While we opted for a five point Likert scale to simplify responses for the students, the commonly used ten point scale appears preferable to further differentiate perceptions. The administered survey only had two short answer questions asking students for their perceived specific contribution to the group and the aspect of working with their team that they found most beneficial. This offers room for expansion to additional short answer questions. While we strive to keep the survey short and manageable, it would be worthwhile to ask students to expand upon any responses that indicate a negative perception of their team/teamwork.

These improvements will be outlined in a revised IRB application for exemption and implemented with the next trial in Maymester 2014.

IX. Desired Outcomes

Understanding the relationship between team learning style make-up and team dynamics and performance will establish a foundation for improved curriculum with respect to teaching teamwork. A greater emphasis on incorporating an understanding of learning styles and their role in team dynamics may prove to be a valuable component to undergraduate engineering education as we prepare students to enter the ever-shrinking and changing global workforce.

Acknowledgment

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PBL in Teaching Computing:
An overview of the Last 15 Years

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Abstract— **In computing courses, the teaching and learning approach normally emphasizes theoretical knowledge at the expense of practical knowledge. The major disadvantages of this approach are learners´ lack of motivation during class and their quickly forgetting the knowledge they have acquired. With a view to overcoming these difficulties, Problem Based Learning (PBL), an institutional method of teaching, has been applied to teaching computing disciplines. Despite the growth of the practice of PBL in various disciplines of Computing, there is little evidence of its specific characteristics in this area, the effectiveness of different PBL methodological approaches, or of benefits and challenges encountered. In this context, this paper presents a systematic mapping study in order to identify studies which involve best practices when using the PBL method in Computing between 1997 and 2011, answering five research questions: "What are the main characteristics of PBL that support teaching in Computing?"; "What are the criteria for applying PBL effectively in this area?"; "How is the PBL methodology applied?", "What are the advantages and benefits of applying PBL in Computing? "and, finally, " What are the main challenges about learning in PBL in Computing?".**

Keywords-component; Problem Based Learning; Education; Computing.

I. INTRODUCTION

In the evolution of the Information Technology and Communication (ICT) industry, professionals in the field of Computer face constant changes which leads to there being a need to adapt concepts, methods and techniques for specific situations that may arise in the labor market. These issues affect not only businesses, but also software engineers, who besides having as a prerequisite vast knowledge of software development tools, should also have a broad view of the problem to be solved, ie, an understanding of business, entrepreneurialism and interpersonal skills [1].

To succeed in the field of Computer Science, one needs to have knowledge of and to master a variety of skills such as: being at ease with mathematics, logic, problem solving, algorithmic thinking and programming. Unfortunately, many students struggle to develop these skills, especially when the subject is related to object-oriented programming, discrete mathematics, data structures and analysis of algorithms [2]. This happens because of the way in which teaching is approached in undergraduate courses, since what can be seen is a lack of practice after being given the theory [3]. Practice along with theory enables students to make connections, and thus to link prior knowledge to new knowledge learned during the new learning process [4, 5].

As a consequence of this factor, what also needs to be mentioned is that teachers get greatly frustrated and students abandon their courses, as many give up working in the area due to such difficulties [2]. When students do not give up, there is poor professional training, as they do not have enough practice for the labor market. [6]

With a view to finding solutions for these problems, the instructional method of teaching, Problem Based Learning (PBL), has been applied to the teaching of computing, aiming to promote collaborative and motivating learning, based on problem solving. According to Peterson [7], PBL meets three important criteria that promote ideal learning: first, it provides an environment where students are immersed in a practical activity, secondly, they can receive guidance and support both from other students and a responsible teacher/ tutor; and, finally, learning is based on solving a real problem.

Despite the growth of the practice of PBL in various disciplines of Computing, there is little evidence of its specific characteristics in this area, of the effectiveness of different methodological PBL approaches, or of the benefits and challenges encountered. It was out of this context, the problem tackled by this research arose which sought to understand the studies that highlight best practices for using the PBL method in disciplines related to the field of computing. To this end, the method of systematic mapping was used and focused on constructing a broad overview of how the PBL method was applied in the everyday routines of these courses from 1997 to 2011.

II. PROBLEM BASED LEARNING IN TEACHING COMPUTING SCIENCE

Problem Based Learning (PBL) is an instructional method of teaching that differs from the traditional model by virtue of its using real-life practical problems to start the learning process in order to encourage the development of problem-solving skills. These problems based on reality are worked on in groups, in order to initiate, direct, motivate and focus learning, unlike traditional methods that put the problem at the end of the presentation of content [8, 9].

This approach began in the medical field, in the 1970s, at McMaster University's Medical School [10], the precursor

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being the physician and educator Howard Barrows who developed methods to instruct doctors to develop their own capacities for reflection when not in medical school [11]. The goal of this method is not only the solution of the problem, but rather learning from the problem presented, ie reporting solutions based on the problem and the process used to obtain them. Barrows [12] describes six key characteristics of PBL:

- Learning is student centered;
- Learning takes place in small groups of students;
- There is the presence of a tutor who is seen as a facilitator or guide;
- The problems are presented at the start of the process.
- The problems encountered are used as instruments to attain the knowledge and skills to solve problems;
- New information is acquired through self-directed learning.

In the process of teaching, teachers must understand correctly the problem as being the basis in the learning method, which differs from the traditional model of education, which is teacher-centered. PBL directs the role of learning to the students and the teacher's role changes to a single form of teaching: that of guiding, as well as that of teaching. [6]

In Computing Science, the difficulty lies in having good professionals in the area of information technology, viz., software engineers. PBL tries to overcome this difficulty by offering students a way to acquire knowledge and develop the skills and attitudes expected of a professional.

Software engineers face many problems of adapting concepts, methods and techniques to the specific situations of problems in the market, in general influenced by the variation in scope, cost and deadlines of software projects. For the professional training of software engineers, PBL approaches can help by fostering the ability to work in teams, to solve problems and also to encourage the development of one’s skills and attitudes, such as self-directed learning skills, cooperation, ethics and respect for people’s other points of view. [3]

Authors like Peng [6] discuss problems with reference to textbooks on programming, and state that part of the books are written with the main focus on the logical structure of knowledge, starting with the introduction of an abstract and unclear concept, for example, the concepts of "object", "property", "event" or "method", and thus do not respect the students’ cognitive rules.

Bearing in mind the benefits of the PBL method, in different areas of knowledge, it is appropriate to make a more in-depth study with the aim of supplying a broad overview of research studies that that have been undertaken in the area of Computing Science and of analyzing gaps that may yet need to be explored in research on PBL

III. SYSTEMATIC MAPPING

The study of Systematic Mapping (SM) is a method designed to provide a broad overview of a particular area of research that enables the results to be identified, quantified and analyzed, thereby establishing evidence on a particular topic [13, 14].

The Systematic Mapping conducted in this study was divided into three stages, based on the guide by Kitchenham [13], namely:

1. *Planning Systematic Mapping*: drawing up a protocol containing all the information of the study;

2. *Driving the Systematic Mapping*: carrying out searches and collecting data;

3. *Presenting Systematic Mapping:* analysis of results and writing a report from the information stored.

The initial research studies were conducted using digital libraries: IEEExplore Digital Library, ACM Digital Library, Elsevier Scopus, Elsevier ScienceDirect. The selection of these sources was based on the relevance and credibility of articles indexed in the area of Computer Science.

Starting out from the objective of answering the central question of the study: "How is learning based on PBL characterized and what is its contribution and challenges for teaching Computing Science?", five secondary issues were put forward for answer:

1.What are the main characteristics of PBL that were found and supporting education in Computer Science?

2. What are the criteria for the *effective application* of PBL in Computer Science?

3. How is the PBL methodology applied in the teaching of Computer Science?

4. What are the *advantages and benefits* of applying PBL in Computer Science?

5. What are the main *challenges* about learning in PBL in Computer Science?

For the construction of the key terms of the research, the key-words of the central question were used. In addition to the key-words, their synonyms were identified based on the area of research, which facilitated the search: Learning (learner, education, educational program, constructivism, constructivist, instruction); Problem Based Learning (PBL, problem-based learned); Contribution (advantages); Challenges (outcome, results); Computer (software, computer engineering, information technology, computer science).

The search string was constructed by combining key-words and synonyms. Two operators were, OR (or) between the synonyms and AND (e) between the key-words, as shown in Table I

TABLE I. SEARCH STRING.

Search String
(learning OR learner OR education OR methodology OR approaches OR "educational program" OR constructivism OR constructivist OR instruction) AND "problem based learning" OR PBL OR "problem based learned") AND (contribution OR advantages) AND (challenges OR outcome OR results) AND (computer OR software OR "computer engineering" OR "information technology" OR "computer science")

Initially, using the search string resulted in 2,464 studies being located. From that number, the process of selecting primary studiesbbeagan and was conducted first of all on the title and abstract. As a result, 2,412 studies wwere discarded from this total.

For the classification of the studies, inclusion and exclusion criteria wer designed, which are:

- Inclusion: the relevance that the study has in relation to the proposed research question: Studies that describe research related to the topic of the PBL teaching methodology and Computer Science; studies that relate experiences of the teaching methodology being favourable for teaching on Computer Science courses.
- Exclusion: Studies published in editorials, prefaces, summary articles, interviews, news and reviews; Studies with experimental results that are inconsistent or with incomplete content; Studies that are not part of the research area.

Based on reading the introduction and conclusion of the Relevant Studies and the criteria for inclusion and exclusion, a total of 52 Primary Studies was obtained. Of the 133 ostensibly Relevant Studies, 80 of them were considered "Not Relevant" and 12 were unavailable for download, as shown in Table II.

TABLE II. RESULTS OF THE SEARCH.

Primary Studies					
		1st Phase: Title and Abstract	2nd Phase: Introduction and Conclusion – Excluded		2nd Phase: Introduction and Conclusion – Included
Sources	Returned Studies	Relevant studies	Irrelevant	Unavailable	Primary Studies
IEEE	1,242	69	33	0	36
SCOPUS	681	38	30	12	8
SCIENCE DIRECT	327	3	3	0	0
ACM	214	23	15	0	8
TOTAL	2,464	133	80	12	52

During the process of analyzing the studies, they were classified according to their year of ublication year. Thus a count could be made of studies on PBL over the last 15 years. Figure 1 shows a graph of the the evolution of the PBL approach over the years.

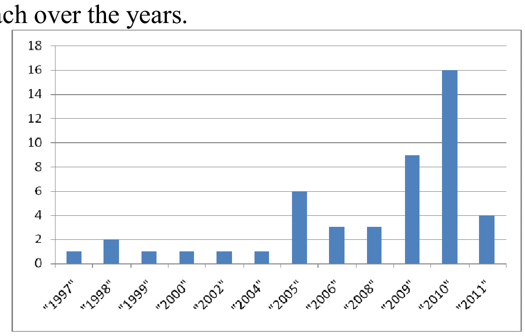

Figure 1. Distribution of results published over the years shown above.

As can be seen, it is clear that PBL approaches in the area of Computer Science have been growing since 2009, with a high incidence in 2010.

IV. MAIN RESULTS

The studies found were associated with categories corresponding to the secondary research questions outlined in Section III. To prove each association, evidence was collected from each "Primary Study", represented in the following subsections by the notation "EP". The following subsections present and comment the results for each category. Due to size limitations of this article, only some evidence of the complete work will be mentioned.

A. *Characteristics of PBL*

The purpose of this question was to map the characteristics of the PBL method in the teaching of Computing Science. The topics were defined as per the characteristics of PBL defined by Woods [15] and Barrows [16]. Figure 2 shows the primary studies qualified for each of these topics.

Topic	Primary Study	Qty -%
Change in the role of student	EP_08	1 – 5%
Change in the role of teacher	EP_01, EP_16, EP_18, EP_37, EP_43	5 – 25%
Problem starts the process	EP_35, EP_46	2 – 10%
Focus on solving problems	EP_09, EP_11, EP_14, EP_27, EP_31, EP_39	6 – 30%
Self-directed learning	EP_22, EP_23	2 – 10%
Collaboration among participants	EP_03, EP_07	2 – 10%
Learning in a group	EP_21, EP_24	2 – 10%

Figure 2. Results on Characterístics of PBL

In general, the authors are clear when they affirm the need for a problem that starts the process, and that all knowledge should be acquired through solving problems, thus enabling the student to have greater contact with real-world problems, as the evidence makes clear:

EP_11: "The problem-based learning method dictates that the students' projects must aim at solving a problem.

EP_03: "In PBL students learn by addressing ill-defined and open-ended problems and reflecting on their experiences, thus developing problem-solving strategies and building domain knowledge in a self-directed manner."

Another important feature is the need for a change in attitude and role of teachers and students, in the latter, thereby stimulating the capacity for self-initiative:

EP_08: "...teaching based on problem solving (in which students have an active role in their learning) allow students to understand difficult concepts better and retain the knowledge acquired for a long period of time."

EP_14: "The educator should use a problem to prompt students' experiences and interests, and then help them to be actively involved with further learning."

EP_27: "the author takes the method of problem-based learning and suitably arranges the course design, which with a good result not only improves the quality of teaching, but also trains students' capacity for self-learning, active exploration and mutual cooperation."

Finally, the studies highlight the characteristic of collaborative learning activities with emphasis on group learning as a key point of PBL:

EP_08: "The design project is structured around a formalized base group which exists for the duration of the subject. The base groups are selected at random from the different degree programs and, in general, consist of three members with no two members from the same degree program."

EP_11: "It is clearly an advantage of the PBL curriculum that students have ample opportunities to practice teamwork skills."

B. *Effectiveness*

The purpose of this question was to research in primary studies which of them showed their effectiveness, ie good results as to applying the PBL method. The studies were divided into eleven (11) topics that diversify the effectiveness of the PBL process, as given in Figure 3.

Topic	Primary Study	Qty -%
Interactions	EP_36	1 – 3,57%
E-Learning support tools	EP_08, EP_17, EP_48	3 – 7,14%
Critical vision	EP_18	1 – 3,57%
Better environment for the lessons	EP_13	1 – 3,57%
Homework	EP_28	1 – 3,57%
Developing games	EP_29, EP_46	2 – 7,14%
Use of real problems	EP_01, EP_43, EP_44, EP_45	4 – 14,29%
Group work	EP_01, EP_34, EP_43	3 – 10, 71%
Use of other approaches	EP_01, EP_03, EP_24, EP_26, EP_29, EP_31, EP_38, EP_40, EP_46, EP_47, EP_48	10 – 35,7%
Construction of applications	EP_13, EP_36, EP_37, EP_44	4 – 14, 29%
Competitions	EP_42	1 – 3,57%

Figure 3. Results on the Effectiveness in PBL.

Most studies (35.7%) are summarized into one topic, where the authors state that PBL is more effective when combined with collaboration strategies, such as collaborative learning, and constructing motivating applications, such as developing games, competitions or applications related to market problems, as highlighted in the evidence:

EP_01: *"This article described o PBL mode under the guidance of instruction system design, constructivism learning theory, Brunner's discovery method and PBL pedagogy."*

EP_03: "Combining PBL with cooperative learning provides a mechanism for students to maximize their own and other group members' learning by working in teams to accomplish a common task or goal."

EP_29: *"In a game development project, students can develop their own requirements for a domain in which they are experts."*

EP_42: *"... develop a National RoboCode Competition both authors saw potential benefits to enhance their PBL initiative and to add an interesting challenge for their students.*

EP_43: *"The cases are written in close consultation with industry practitioners to ensure that they resemble, as realistically as possible, real-world business problems."*

EP_44: *"I examined how student self-efficacy, as it relates to being software development professionals, changed while involved in PBL environment."*

Other criteria were also mentioned, such as the formation of teams of group work, e-learning support tools, development of critical vision by the students and activities outside the classroom:

EP_34: *"The team includes a group of people (about 5-6 people) that work together to learn or work on a subject or project. They have different backgrounds, such as academic disciplines, skills and expertise, and working experiences."*

EP_n:"... in an internet-based learning environment, it is considerably more efficient for students to exchange information and opinions in comparison to the traditional classroom-oriented learning environment, which indirectly encourages communication among students."

EP_18: *"MALESAbrain encourages learners to judge or critically evaluate the solutions posted by others before exploring further knowledge-content."*

EP_28: *"it is also necessary to leave homework, especially experimental projects to students so as to consolidate their knowledge learned in the classroom."*

C. *PBL Methodology*

The purpose of this question was to point how the PBL methodology is applied in the teaching of Computer Science. To answer this question, five elements considered essential in a PBL methodology applied to the teaching of computing were used, which, according to the authors Santos et al. [3] and [17], are problem, environment, content, people and processes. Figure 4 shows the topics and the number of primary studies associated with these elements

Topic	Primary Study	Qty-%
Problem	EP_04, EP_06, EP_45, EP_46	4 – 8,5%
Environment	EP_05, EP_08, EP_09, EP_10, EP_14, EP_18, EP_31, EP_32, EP_36, EP_39	10 – 21,3%
Role of the student/teacher	EP_24	1 – 2,13%
Content	EP_01, EP_02, EP_03, EP_04, EP_06, EP_07, EP_08, EP_10, EP_13, EP_14, EP_15, EP_16, EP_25, EP_28, EP_40, EP_45	16 – 34, 4%
Process	EP_03, EP_09, EP_10, EP_11, EP_14, EP_25, EP_28, EP_29, EP_38, EP_39, EP_40, EP_42, EP_43	13 – 27,66%

Figure 4. Results on the PBL Methodology.

Among the criteria cited, the part of content was the most discussed, 34.4% of the primary studies doing so, in which the disciplines that adopted PBL methodology were cited: software engineering, robotics, embedded systems, information systems management, operating systems, digital systems, and the development and quality of software. Some pieces of evidence comment on the proposals of these disciplines:

EP_01:"The Software engineering course was taken as the example to illustrate the implementation of the PBL model."

EP_02:"Topics are introduced in a way such that students are confident with what computer studies imply despite the use of the robot. Robotics is only the "toy" for motivating beginner students on the subject."

EP_16: "In order to verify the effect of PBL in online teaching, we have made an experiment on the course of "Object-Oriented Programming With Java" over the last 3 years: we recorded students' performance, their feelings and the outcome of study; by making comparison, we analyzed and summarized the strategy for guidance, improved the strategies and teachers' ability in guiding students."

The criteria associated with the processes of the PBL method, for example, the steps of teaching and assessment methods used were also highlighted in 27.66% of the primary studies:

EP_03: *"Student feedback is used extensively to evaluate the performance of both the teaching staff and the subject. These student evaluations consist of both formalized university-wide evaluations (JCET) and informal evaluations conducted solely for this subject by teaching staff associated with the subject.*

Another important element was the environment, mentioned in 21.3% of the studies, in which the most diverse environments that support teaching based on PBL were discussed:

EP_08: *providing a richer learning environment, offering students alternative ways of gaining knowledge and information, enabling more accurate assessment, and individualizing practice, feedback and reflection."*

D. *Advantages and benefits of PBL*

This question aimed to investigate the advantages and benefits of using PBL methodology in Computer Science. Various benefits were listed, divided into eight (8) different topics. The most discussed topic, with 38.24%, was that of the students' improvement in developing their skills. Also from the perspective of the students, other topics were highlighted such as the ease in solving problems, a better critical view on various subjects, motivated students mmotivated by the lesson and more participatory, self-directed learning, planning study time, being better prepared for the work environment work. From the perspective of the teacher, what stands out is the improvement in the practice of teaching. Fig.5 summarizes all the topics, as well as primary studies associated with them.

Topic	Primary Study	Qty-%
Improvement in the development of the the practice of teaching	EP_28, EP_29, EP_37, EP_40, EP_42, EP_45	6 – 17,65%
Improvement in the development of skills	EP_02, EP_03, EP_04, EP_06, EP_07, EP_09, EP_10, EP_18, EP_24, EP_25, EP_39, EP_42, EP_44	13 – 38,24%
Facilty in identifying and solving problems	EP_01, EP_22, EP_33, EP_38, EP_41	5 – 14,71%
Better preparation for the jobs market	EP_43, EP_44	2 – 5,88%
Application in other courses	EP_08, EP_12	2 – 5,88%
Positive feedback from the students	EP_19, EP_24, EP_35, EP_37	4 – 11, 75%
Better management of study time	EP_31	1 – 2,94%
Better/ greater particicipation in class	EP_16	1 – 2,94%

Figure 5. Results on the Advantages and Benefits of PBL.

Among the pieces of evidence found, are those that stand out which reinforce these advantages and benefits:

EP_40: *"... the application of this methodology have enabled students to receive all the theoretical concepts and, also, the students have developed transversal skills such as writing, learning and oral expressions in the same course, thereby developing a project consisting of a semi-complex digital system."*

EP_07: *"PBL skill is very important in learning. Students are encouraged to use their present knowledge and skills to find the answer in PBL. Assessment is ongoing and regular so as to provide feedback that assists, extends and improves learning. The tutor is an essential part of providing appropriate and constructive feedback that is meaningful to students, supports and empowers their learning, and contributes to their development."*

EP_44: *"Twenty-seven students indicated that because of the course they were ready to deal with the demands of actual software development projects, even though some seemed surprised about their new-found confidence."*

EP_24: *"Student feedback indicated that the project was preferred as a learning experience over traditional, lecture-based methods. The product-based method maintained student engagement and encouraged intentional learning tendencies."*

EP_16*:"Class participation rate has increased by 73%, and the rate of on-time handing in assignment by 36%, and the percentage of significant questions increased prominently too."*

E. *Challenges Identified*

This question aimed to list the main challenges and problems encountered during the process of teaching / learning with PBL in Computer Science. Twelve (12) different topics that address challenges and problems were identified. Figure 6 shows the 12 topics and the number of primary studies associated with them.

Topic	Primary Study	Qty-%
Application of the methodology	EP_09, EP_10, EP_28	3 – 13,04%
Difficulties in disciplines	EP_28, EP_37, EP_39	3 – 13,04%
Knowledge of methodology	EP_09, EP_35, EP_39	3 – 13,04%
Time	EP_25, EP_28, EP_40	3 – 13,04%
Few goood problems	EP_42, EP_43	2 – 8,70%
Resrictions on the methodology	EP_29	1 – 4,35%
Variety of knowledge of the students	EP_14	1 – 4,35%
Dissemination of knowledge	EP_12, EP_28	2 – 8,70%
Use of other technologies	EP_36	1 – 4,35%
Interest of the students in Computer Science	EP_46	1 – 4,35%
Difficulty in the objectives reached and good results	EP_03, EP_07, EP_11	3 – 13,04%

Figure 6. Results on Challenges found in PBL.

According to the studies, the main challenges of using the methodology are the lack of belief in and knowledge of the methodology, deficiencies in the formation of basic foundations of Computer Science and difficulty in applying the methodology as highlighted by some of the evidence found:

EP_28: *"It is difficult for a teacher to organize and control the learning process when the number of students is large."*

EP_28: *"Before taking this course, students generally have learned object-oriented programming language(s) such as C, Java, unfortunately they usually only know the language syntax but don't have practical project experiences."*

EP_35: *"... in o PBL environment, these students have to climb a stiff learning curve and overcome much resistance that might pose challenges to students in the initial stage, and limit the potential effects of PBL."*

EP_25: *"... the traditional teaching method is more efficient in knowledge of teaching and learning; in contrast, PBL may require teachers and students to expend more time and effort. Under the limited class hours, the teaching timetable may not be completed in*

PBL. In this regard, we believe that some appropriate additions and adjustments be made according to the actualnumber of class hours."

EP_43: *"Unfortunately, the adoption of a real-world project is not always a feasible option. This is mostly due to difficulty in gaining access to suitable real-world organizations and resource constraints in managing the projects."*

EP_29: *"What challenges educators the most is often not the lack of teaching materials, but the constraints imposed upon a course. These include (1) type of audience, (2) the limited amount of time available for a prearranged set of course objectives, (3) a rigid curriculum, and (4) the choice of teaching methods."*

EP_14: *"The variety of student backgrounds had the potential to cause problems when teaching the module."*

Another important point refers to the learning process, since not all students learn equally. Also, some students take on different responsibilities, thus making teachers' evaluation of this difficult. As a result, teachers very often do not know how to assess students and hence the effectiveness of the methodology, by ensuring that students have achieved the desired goals, as the evidence stresses:

EP_28: *"When students are organized as groups, their capabilities may not be developed equally. Some play a dominant role in the group, while others are there just to make up the number."*

EP_11: *"Besides the fundamental challenge of creating a good problem, educators are faced with the task of deciding how to evaluate the technique's effectiveness and how to assess whether students have met the overall learning objectives for the course.*

V. FINAL REMARKS

This paper has presented and discussed the results of a systematic mapping, and has identified the main characteristics of having used PBL in the field of Computer Science from 1997 to 2011. After the initial assessment of 2,464 articles, 52 primary studies were selected tthat were relevant for the research. From five research questions, it was possible to find evidence in a satisfactory way which showed that most applications of the PBL methodology are geared towards its applicability in the disciplines of Software Engineering and Programming.

From all the evidence reviewed, it was moreover possible to conclude that the PBL methodology has been applied in Computer Science, and been widely accepted by teachers and students and facilitated improving the education and training of professionals by providing a broader view of the real problems in the area. However, there is still a need to overcome several challenges and, above all, to provide good results from the application of the methodology with a view to disseminating positive points of this method and to increase belief in it by both educators as well as the students who have no knowledge or understanding about PBL.

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Women's Ways of Knowing in Information Technology Specialties at a Community College

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Historically, very limited studies have focused on information technology (IT) programs in community colleges, let alone of women's participation in them. In light of the growing national debate on the need to increase female participation in Science, Technology, Engineering, and Mathematics (STEM), this study closely examines women's involvement in IT in higher education. This study builds on Belenky et al's study of women's five ways of knowing (silent knowing, subjective knowing, received knowing, procedural knowing, and constructed knowing) in the social sciences and humanities. Through analysis of women's IT pursuits at a community college, this study provides evidence not only for the five existing ways of knowing found in Belenky et al's study but also for a new way of knowing exclusive to IT: logistical knowing.

Keywords—Gender, STEM, Women's ways of knowing

I. INTRODUCTION

Over the last three decades, numerous studies have focused on addressing the concerns of women's representation in science, technology, engineering, and mathematics (STEM) programs in higher education [1]-[10]. In particular, since the birth of the computer, the field of information technology (IT) has seemed male dominated. Joint efforts of more than 1,200 American colleges and universities and STEM programs to promote, attract, and retain women, as well as seek female representation, have increased in the last few years [10][11]. This trend is reflected in a study done by Snyder, Tan, and Hoffman [12], in which women made significant progress in STEM programs, particularly in engineering, physics, and chemistry. However, the number of IT-related bachelor's degrees awarded to women dropped nearly a third during the same period, while degrees in other sciences increased progressively [9][13][14] (see Fig. 1).

According to statistics from U.S. Department of Education [15], from 1991 to 1997, there was nearly no significant difference between the numbers of associate degrees awarded in IT-related subjects to men and those to women. However, between 1997-1998 and 2002-2003, the number of degrees awarded peaked, and the growth rate of male students receiving associate degrees in IT-related subjects almost doubled, growing faster than the rate for female students [15] (see Fig. 2). Although the growth rate began to decline, the total number of men receiving associate degrees in IT-related subjects was still three times higher than the total number of women doing so.

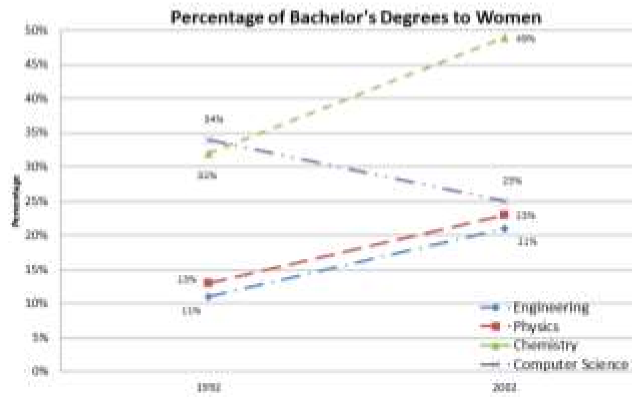

Fig. 1. Bachelor's degrees awarded to women in STEM 1992-2002

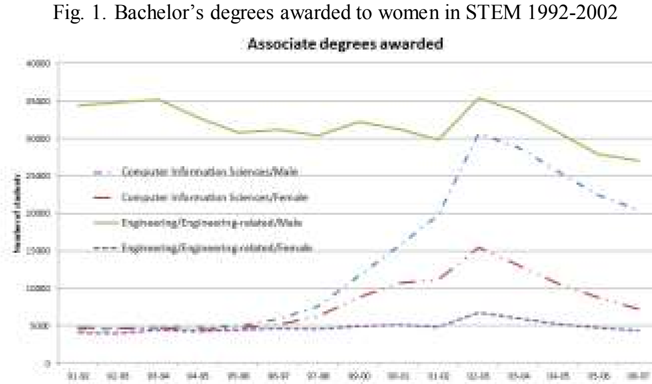

Fig. 2. Associate degrees awarded to men and women in STEM 1991-2007

Community colleges offer vocational education to both students who need technical training for employment and students preparing to transfer to four-year colleges and

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universities. As Tsapogas [16] stated, the National Science Foundation (NSF) documented the positive impact of community colleges on undergraduates' and graduates' career and educational paths in science and engineering. Based on data from NSF's 2001 National Survey of Recent College Graduates, Tsapogas finds that 42% of computer and mathematical science bachelor's and master's degree graduates attended community colleges some time during their study. Of these, about 38% earned associate degrees in computer and mathematical science.

In Tsapogas' [17] second report, as of April 2003, there were more than four million individuals (less than 25% of whom were female) with at least a high school education working in science and engineering professions in the United States. Within that group, about 17% of responses indicated that their highest levels of educational achievement was an associate degree. However, in the computer and math occupations, less than 7% of four million individuals were females.

A variety of reasons has been suggested to explain this phenomenon, including a lack of female mentors and instructors [9][18][19], and parental support [18][19]. As technology plays an increasing role in people's lives and usage of computer applications, women's low representation and decreasing participation are receiving more attention [9]. There is no simple explanation for the imbalanced gender representation in IT-related subjects. This study approaches this gender imbalance by investigating women's ways of knowing in six specialties of IT-related subjects rather than in a traditional approach of treating computer science subject as a whole. The six specialties used in this study are: (1) computer programming, (2) Office application development, (3) Web application development, (4) database application development, (5) networking, communication, and security, and (6) non-IT.

II. METHOLODOLOGY

The focus in this study is women. Mertens argues that the qualitative methods, from feminists' perspectives, are the only truly "feminist" choice because they include the use of open-ended interviewing and ethnographic data collection to focus on interpretation, allow the immersion of the researcher in the social setting, and facilitate intersubjective understanding between the researcher and the participants [20].

Thus, the rationale for choosing the qualitative method, as Fine [21] argues, is to avoid a separation between the investigators and the persons under study. Such separation is considered a result of quantitative methods, which some feminists believe is a representation of patriarchal thinking.

A. Participants

Three departments of a local community college from one of the Midwest metropolitan areas in the United States participated in this study. This community college serves an average of 31,000 students a year. It offers more than 90 certificate programs, 59 occupation degrees, and 45 transfer prebaccalaureate programs. It is the largest single-campus community college in the nation outside of California. The departments involved in the study belong to the technology subdivision which offers computer-related courses to the community college district. On average, over 100 sessions of classes are offered and over 3,000 students are served every term by this technology subdivision.

Participants were students who took IT-related subjects at this college. In order to recruit these participants, the researcher contacted faculty members in three departments via e-mail to explain the nature of this study and request a list of women student's e-mail information. From the list, over 60 potential candidates were contacted by e-mail. Only 51 of them confirmed participation in the study. Ultimately, 41 participants successfully completed the questionnaires: two women preferred not to participate after reviewing the questions; six women did not return the questionnaires; and two returned questionnaires which were not included in the analysis due to insufficient data. For the five participants who were students taking courses with the researcher during the study, they were notified that their final course grade regardless would not be impacted in any way regardless of their participation or results in the study. Students who took basic classes such as introduction to computers were not chosen due to insufficient IT knowledge or skills to identify themselves as students in one of the IT specialties.

Demographic information of participants is grouped by the specialty rather than by IT as a whole, which is a typical and traditional way to analyze data. The racial composition of the sample included: 31 Caucasians; 1 Hispanic, 6 Asians, 2 African-Americans, and 1 American Indian. The ages of the participants ranged from 22 to 60 years.

B. Data Collection

Students' contact information was removed if they declined to participate in the study or if they did not respond to the questionnaires via e-mail. After receiving questionnaires via e-mail from 41 participants, each of the participants was assigned to a unique ID code. In the final analysis, an alias was assigned to each participant to further maintain anonymity. They were informed of how the study would be conducted under the guidelines established by the Office of Research Compliance and approved by the Institutional Review Board (IRB).

C. Instrumentation

A set of questionnaires (see Appendix) was incorporated with open-ended questions retrieved from the study conducted by Belenky et al. [22]. Permission to use the questions from Gilligan and Belenky et al.'s study was received via e-mail. These questionnaires were designed using the following eight categories:

Section I Profile: This category contains 10 multiple-choice questions to gather participants' demographic information, such as race (African American, Asian American, American Indian, Caucasian/White, or Hispanic American), highest level of education before taking courses at the college, IT specialty pursued, full- or part-time student, employment status, age (filled in), computer ownership, Internet accessibility, and parents' highest education level (none, high school, college degree, graduate degree, or professional degree).

Section II Background [22]: This category contains two open-ended questions to solicit participants' reflections on their lives over the years, what is important to them, and their present life.

Section III Self-descriptions [23]: Three open-ended questions are in this category to determine how participants see themselves, how they present themselves in their own words, what has changed in their lives from the past, and how they see themselves in the future.

Section IV Gender [22]: One open-ended question is in this category to ask participants how it feels to be a woman, and prompt self-examination of gender issues at work and home.

Section V Education: There are 14 open-ended questions (5 questions from Belenky et al.'s study) in this category to ask participants how they feel about the learning environment in terms of meeting learning needs for job or personal enrichment, why they chose this specific field/specialty, what influences they received to encourage or discourage to work/study in this specific IT specialty, the faculty/student relationship, a description of their learning style, their confidence level before and after entering the study, and what was the powerful learning experience they had.

Section VI Ways of knowing [22]: There are 10 open-ended questions in this category. It is designed to provide insight into their intuitions on how they judge an expert, how they determine the truth, how they deal with contradictions between answers between authorities (that is professors), how they assess some books, movies, or ideas to be better than others, and how they view opinion.

Section VII Comments [22]: It contains three scenarios to ask them for comments, such as, "Sometimes when someone has written something that really impresses me, I say to myself that I'll never have an idea as good as that," "People from different countries believe something is different in terms of right and wrong," and "Sometimes I really get bored with school because it is sitting around listening to people talk about unimportant things." There are no standard comments here. The purpose was to see how participants approached the scenarios and how they analyzed, expressed, and built their responses by identifying the words participants used in the responses to support what way of knowing they possess.

Section VIII Conclusion [22]: Two open-ended questions are in this category to ask them how they view themselves 15 years from now, and give an opportunity for a free response to any concerns not covered by the above questions.

This interview was designed to allow participants to review their responses on each question before sending in. Authentic answers for each question would be anticipated from these participants since they sat in their own comfort zone at home or in an office with ample time to think their responses.

D. Data Analysis Strategies

A paper copy of each answered questionnaire was prepared and grouped into a folder according to the IT specialty claimed. Making sense out of text, as Creswell [24] notes, is involved in the process of data analysis. Ryan and Bernard [25] say that the qualitative data is text. Therefore, the method to analyze texts found in questionnaires is called key-words-in-context (KWIC) [25]. KWIC uses particular words or phrases as units of analysis.

After questionnaires were checked for completion, analysis proceeded from one specialty to the next. This means that participants within the same specialty would have all of their responses reviewed and marked using the KWIC method before the researcher analyzed the responses of participants in another specialty. The particular words, phrases, or implications used in the KWIC analysis method were cited from the study conducted by Belenky et al. [22] except the logistical knowing, which was found by this study. They are grouped by each way of knowing as follows:

- Silence: follow, take order, just do it, whatever, feel deaf, feel helpless, do not care, etc.
- Received knowing: professor says, I believe my instructor, either yes or no, assume there is only one right answer, believing that truth comes from others, they still their own voices to hear the voices of others, I have to rely on the experts, no way to determine "truth" without the aid of authority, etc.
- Subjective knowing: I want, I think, my experience, stubborn, generous, opinionated, no longer agree with what some people thought was a simple matter of right and wrong, intuition, instinct, just knowing, I have a right to my opinion, it's just my opinion, women become their own authorities, I think and feel all at the same time and I know what is right, my gut is my best friend etc.
- Procedural knowing (separate knowing): step by step; follow the instruction; objective; feel; reasons; "ways of looking" is central to this position; you have to see things for what they are, not for what you want to see them; applying procedure for obtaining and communicating knowledge.; world becomes more manageable; knowing requires careful observation and analysis; engaging in conscious, deliberate, systematic analysis; truth lies hidden beneath the surface, not immediately accessible; think before they speak, they speak in measurable tones. Often, they do not speak at all. But, this is not a passive silence, it is on the other side of silence; reason is stirring; law, not men, govern the world; authority is nonarbitrary; it rests on reason rather than power or status; experts are only as good as their arguments, etc.
- Procedural knowing (connected knowing): trustworthy knowledge comes from personal experience, rather than the pronouncements of authorities (builds on the subjective conviction);

develop procedure for gaining access to other people's knowledge; share experience; believing game; not engage in metaphysical debate; no one tried to prove anything or to convert anyone; do not judge but to understand people's words by some impersonal standard, etc.

- Constructed knowing: reclaim the self by attempting to integrate knowledge learned from others, all knowledge is constructed, circumstances change our ways of looking at thing change, good expert whose answers reflect the complexity, passionate knowers, true expert must reveal an appreciation for complexity and a sense of humility about their knowledge, aspire to work that contributes to the empowerment and improvement in the quality of life of others; using my mind to help people, caring for others, a room of their own, commitment and action, cradling the environment, humanizing cities, etc.

- Logistical knowing: needs a degree to prove to employer, needs a degree/education in order to find employment, update skills, strengthen ability, working experience related to education, try to connect what they now have to what they want to have, having a career, to be independent, to be self-supportive. This logistical knowing was identified by this study and was not found in Belenky et al.'s study [22].

Following the analysis, a table of all participants' ways of knowing was created by listing their responses that were most representative of the characteristics found in Belenky et al.'s model [22]. The purpose of this table of knowing is to highlight the ways of knowing each participant possesses.

III. FINDINGS

This section shows the most common ways of knowing among women from each IT specialty. The most common ways of knowing are shaded in colors according to the table of knowing found in each specialty.

Figure 3 shows three common ways of knowing (constructed knowing, procedural knowing, and logistical knowing) exhibited among participants in the programming specialty.

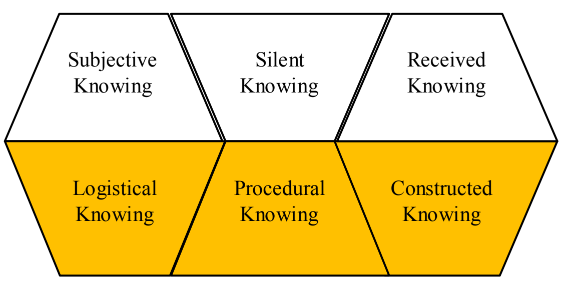

Fig. 3 Ways of Knowing for Programming Specialty

Figure 4 shows two common ways of knowing (subjective knowing and procedural knowing) found among participants in the Web application development specialty.

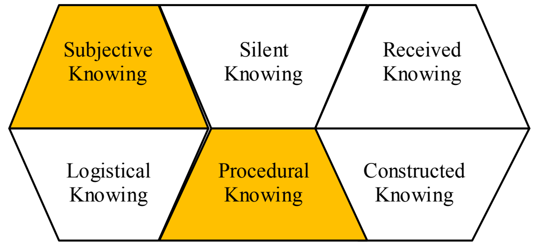

Fig. 4 Ways of Knowing for Web Application Development Specialty

Figure 5 shows three common ways of knowing (constructed knowing, procedural knowing, and logistical knowing), identical to that of the programming specialty, found among participants in the Office application development specialty.

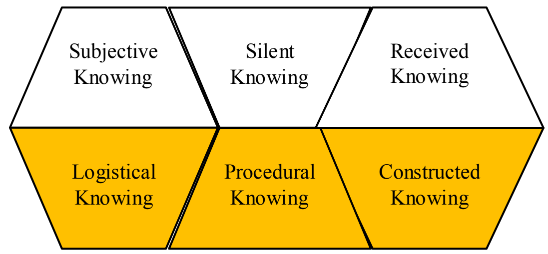

Fig. 5 Ways of Knowing for Office Application Development Specialty

Figure 6 shows two common ways of knowing (constructed knowing, and logistical knowing) found among participants in the networking, communication and security specialty.

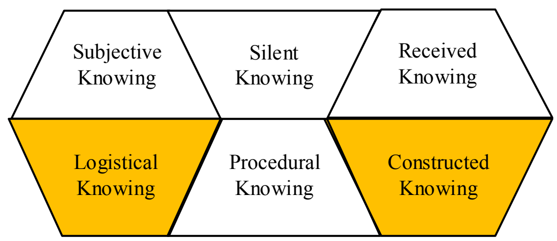

Fig. 6 Ways of Knowing for Networking, Communication and Security Specialty

Figure 7 shows only one common way of knowing, which was found in participants from the database application development specialty.

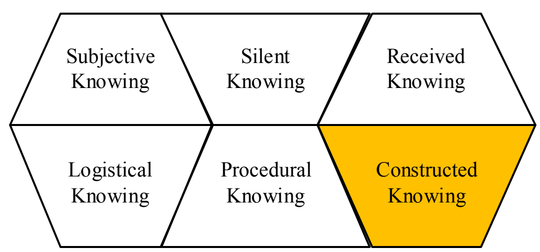

Fig. 7 Ways of Knowing for Database Application Development Specialty

Figure 8 shows two common ways of knowing constructed knowing and logistical knowing) found among participants in the non-IT specialty.

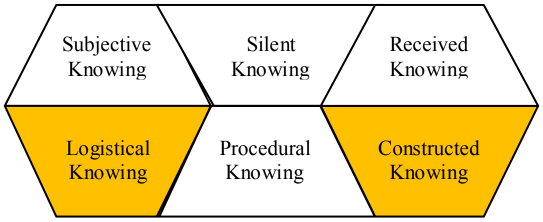

Fig. 8 Ways of Knowing for the NonIT Specialty

IV CONCLUSION

The ways of knowing, Belenky et al. found [22], do not always exist or stay the same; they are a snapshot which should not be used to represent the whole picture of women's thoughts and lives due to their complexities and uniqueness. Similar ways of knowing can be identified in men's thoughts and lives as well, and different researchers might approach this subject differently. This study did not intend to replicate Belenky et al.'s study [22]. Instead, it used their findings as a foundation to interpret the ways of knowing among women studying in six IT specialties.

The findings for women from the same IT specialty showed that they did not possess all six ways of knowing. During different stages in life, these women exhibited different ways of knowing. In different IT specialties, these women might not possess the same ways of knowing either. Thus, this study echoes Belenky et al.'s findings that women do not keep the same way of knowing all the time and it is only a snapshot of the whole picture in these women's thoughts and lives which are not only complex and unique, but also inspiring. The sequence of the ways of knowing (silent knowing, receiving knowing, subjective knowing, etc.) in this study does not imply that one way of knowing is superior to another. Further research is necessary to determine the causes of such different ways of knowing, such as childhood, socioeconomic background, heritage, and life experiences.

This study has two implications for practices and two implications for research. For practices, the first is to show female students what ways of knowing they possess and how each fits into the IT specialty they want to pursue. Doing so allows them to take advantage of their ways of knowing and to reach their potential. The second is to show IT instructors that women possess many ways of knowing that are shared among men as well. Harding [26] points out that "women can do good science just as well as men; [therefore] they should be given the same opportunities to demonstrate their abilities" (p. 61). However, equal opportunity does not mean teaching everyone in the same way. Instead, based on individual ways of knowing, instructors should consider applying different pedagogy to different women, but uphold the same requirements. In terms of implications for research, the first is that women using certain ways of knowing are suited for one or more of the IT specialties. Web application development, for instance, is well-suited for women possessing a subjective way of knowing with a talent in design. Identifying ways of knowing aids selection of an IT specialty to study. The second implication for research is that women's ways of knowing exist not only in the field of social science and liberal arts [22], but also in the field of IT in higher education. Due to the growing reliance on IT in business and everyday life, women in this study also show use of the logistical way of knowing, which did not exist in Belenky et al.'s study.

Furthermore, there is no need to overemphasize how valuable women's participation in technology was in the past, such as in the creation of typewriters [27][28][29], the microwave oven [30][31], automotive design, and the computer keyboard [31]. The value of women's participation should not be discounted and absent from present and future IT development. Thus, the significance of this study is identification of not only a new way of knowing - logistical knowing - but also provision of direction for educators to assist women in selecting IT specialties in higher education. Continued research can harness this knowledge to establish an inventory of ways to best support women in their exploration of IT.

Appendix

I. <u>Profile</u>

A. Which one can best describe your race/ethnic group?

(1)African American (2) Asian American (3) American Indian (4) Caucasian/White (5) Hispanic American

B. Your highest level of education before taking courses at this institution.

(1)High school or less (2) Some university or college (3) University or college degree (4) Graduate degree (master, doctoral or equivalent) (5) Professional degree

C. What is your major/concentration/emphasis? (select **<u>one</u>** that most closely matches your study/learning/job):

1) Programming (all programming languages, C++, Java, VB, C#, .Net etc.)
2) Web application development (HTML, CSS, ASP, Perl, XML, Dreamweaver etc.)
3) Office application development (Word, Excel, Access, PowerPoint, Publisher, Keyboarding, etc.)
4) Networking, communication & security (CISCO, Unix, security, Windows etc.)
5) Database application development (Oracle, SQL Server, DB2, MySQL etc.)
6) Game application development
7) Management of information systems
8) Other (please specify)_______

D. Are you a? 1. full-time student 2. part-time student

E. Current employment status 1. full-time 2. part-time 3. N/A

F. Your age____.

G. Do you own a computer at home? 1. Yes. 2. No.

H. Do you have Internet access at home? 1. Yes. 2. No.

I. What is your mother's highest level of education?

(1)None (2) High School Diploma (3) College Degree (4) Graduate Degree (5) Professional Degree

J. What is your father's highest level of education?

(1)None (2) High School Diploma (3) College Degree (4) Graduate Degree (5) Professional Degree

II. Background

A. What stands out for you in your life over the past few years? What kinds of things have been important? What stays with you?

B. Tell me something about what your life is like right now. What do you care about, think about?

III. Self-Descriptions

A. How would you describe yourself to yourself? If you were to tell yourself who you really are, how would you do that?

B. Is the way you see yourself now different from the way you saw yourself in the past? What led to the changes? Have there been any other turning points?

C. How do you see yourself changing in the future?

IV. Gender What does being a woman mean to you? Do you think there are any important differences between women and men? How has your sense of yourself as a woman been changing?

V. Education

A. What do you think will stay with you about your experiences here in this school, in this program?

B. Did you meet anyone during the study who had the same experience as yours?

C. Has being here [being in this program] changed the way you think about yourself or the world?

D. In your learning here, have you come across an idea that made you see things differently or think about things differently?

E. What has been most helpful to you about this place?

F. Are there things this [school, program, environment] doesn't provide that are important to you? Are there things you would like to learn that you don't think you can learn here?

G. Looking back over your whole life, can you tell me about a really powerful learning experience that you've had, in or out of school?

H. Why did you choose this specialty/concentration/profession you are studying?

I. How did your family members influence the above choice?

J. How did your professors and peers influence your choice of specialty?

K. How confident did you feel before and after entering to your program of study?

L. Describe your learning style (visual, group, individual etc.)? Give some examples.

M. If you could change three things about your program, what would they be?

N. What are student/faculty relationships like in your program? Are you happy with the student/faculty relationships as they are? In your opinion, what would the ideal student/faculty relationships be like (i.e. role model, mentor, facilitator etc)?

VI. Ways of knowing

A. Please comment on: "In areas where the right answers are known, I think the experts should tell us what is right. But in areas where there is no right answer, I think anybody's opinion is as good as another."

B. In learning about something you really want to know, can you rely on experts, why or why not?

C. How do you know someone is an expert?

D. What will you do if the answer from two professors contradicted each other?

E. If experts disagree on something today, do you think that someday they will come to some agreement? Why or why not?

F. How do you know what is right/true?

G. Do you agree with this person who says that where there are no right answers anybody's opinion is as good as another's?

H. Can you think of an opinion that you think is wrong?

I. Are some movies (books, ideas) better than others? (If yes) What makes them better?

J. Sometimes people talk about "searching for truth." What do you think people mean when they say that? Is that what scientist are doing, do you think? Searching for truth? Will they find it? How about artists (painters, writers, and so on)? Are they searching for truth?

VII. Comment on followings:

A. "Sometimes I read something that someone has written or I hear somebody say something, and it really impresses me. I say to myself, 'I'll never have an idea as good as that.' I just don't know how people ever get to the point where they have something so important to say."

B. "If the people in one country say,' We believe such and such is the right way to think about something,' and people in another country say just the opposite, and the opposite is so or the right way to think, then time will usually tell which country is right."

C. "Sometimes I really get bored with school, because it is just so much sitting around listening to other people or the teacher talk about things that aren't important."

VIII. Conclusion

A. What will you and your life be like fifteen years from now?

B. Are there any other questions that I should have asked you, that would have thrown some light on these issues we are interested in: women's lives and women's learning?

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The Good, the Bad and the Ugly: Using Videos to Reverse Systems Analysis and Design Instruction

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***Abstract*—Systems Analysis and Design (SAD) is a second-year subject offered within the Information Technology (IT) course at the Vaal Triangle Campus of the North-West University in South Africa. The diverse environment of this campus includes students representing most ethnic groups in South Africa, adding to the complexity of classroom interaction. This is further complicated by the fact that students find the subject difficult, mostly because it includes many new concepts used in different contexts. SAD students also grapple with fuzzy issues such as fact-finding from system users and representing information obtained from models that are designed for feedback. SAD is therefore far removed from the more exact subjects like programming and mathematics that many IT students excel in.**

Videos explaining difficult SAD concepts were produced and made available to students on a Learning Management System (LMS). The students were motivated to come to classes prepared. During the first semester concepts were explained during formal class times. Formal explanations were not given during the second semester because students were expected to build on the knowledge that they had gained during the first semester. The students were also required to make use of all the resources available to them to come to class prepared. Group work was done in class during both semesters.

The success of implementing reverse instruction in the second semester is evaluated through an interpretive lens. The fifteen modal aspects developed by the philosopher Herman Dooyeweerd were used to ensure a clearer picture of the researched situation was painted with a view on diversity and unexpected usage.

Keywords—reverse instruction; Dooyeweerdian modal aspects; Systems Analysis and Design; video usage

I. Introduction

In an environment where resources are limited and where students come from diverse and predominantly deprived backgrounds, instructors are expected to find ways to enable students to enhance their learning. In the information technology (IT), the situation is even worse, especially when some students have access to their own computers while others do not. In a subject like Systems Analysis and Design (SAD), certain module outcomes overwhelm the students. Some of these outcomes include addressing an overload of new material in combination with a practical group system implementation, acquiring new skills and building solid relationships with both business users and technical staff. This is due mostly to the fact that many students prefer the rigor of writing a program to the fuzziness of determining the needs of business people.

In this context, it was decided to produce videos that explain the difficult concepts students come across when studying SAD. Videos were uploaded onto eFundi, the university Learning Management System (LMS). All registered students have access to eFundi and computer laboratories are available to students on a 24/7 time-table. Students who have access to their own computers and the Internet can access eFundi from home. It is also possible to download the videos to watch offline.

Several reasons motivated the decision to use videos: they are easy to make; they can be used in subsequent offerings of SAD; they can be used in other subjects to do revision on concepts previously discussed; they do not take up any class time (a limited commodity at university level) and; students can watch videos an endless number of times.

As a starting point it was decided to focus on difficult concepts and to keep the video lengths as close as possible to ten minutes.

This paper aims to investigate the use of the modal aspects as developed by Dooyeweerd to achieve a greater understanding of this intervention, while providing the grounding necessary for further research.

II. Literature Review

A. *Utilizing Videos*

Videos are a very good way to encourage learning. YouTube, for example, allows one to learn about a topic of your choice. A more sophisticated example of this is the Khan Academy (www.khanacademy.org) developed by Salman Khan, which uses videos to tackle more than 4000 topics and concepts which are covered in school as well as at tertiary level. Students of today, the millennials, are accustomed to using videos as learning tools. According to Thompson (2011), Khan-videos are seven to fourteen minutes in duration and are used in structured and unstructured ways by teachers and pupils all over the world. Prensky (2011) states that the most valuable feature of these videos is that they, or parts of them, can be replayed numerous times. This happens in an environment where a student does not have to reveal his or her ignorance or slow down the class.

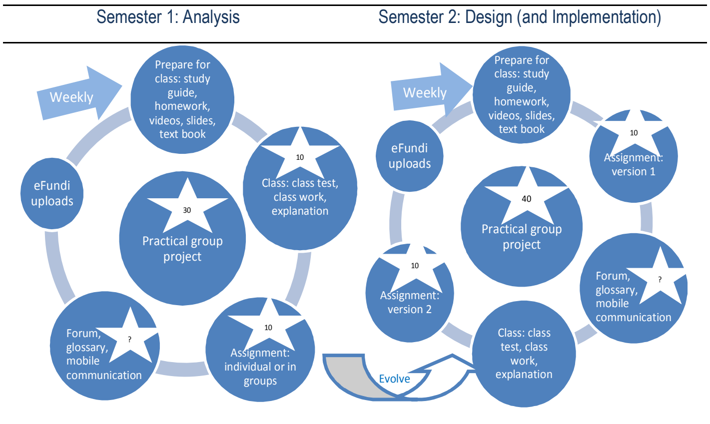
A study conducted by Laine, Myllymäki and Hakala (2010) found that in the context of technology subjects, video-teaching offers a different learning environment to that of face-to-face teaching. They also found that one of the advantages of using videos is that a student can control the progress of his or her own learning. Keenan (2008) found videos to be a cost effective way to train people. This finding is significant in an environment where budgets are tight – something that is true in many educational settings.

B. Reversed Classes

One of the purposes of Khan-videos is the flipping of classes, or reversing instruction. This happens when lectures are made available to students in the form of videos. The videos are assigned to students as homework. In this context class time is viewed as too valuable to be used for formal lectures and is reserved for guided homework, one-to-one tutoring and hands-on project work (Khan & Noschese, 2011). According to Crouch and Mazur (2001), Eric Mazure, who does not make use of videos but who does make use of reverse instruction, reported that students learn very little through traditional lectures. According to him, students need to be actively engaged with study material and this can only happen when they come to class prepared.

C. Context of the Research

The course offering relied on conventional classes, supported by an LMS – an open source Sakai development used by the university. Students were expected to come to classes prepared. Classes commenced with baseline assessment, followed by class discussions and the completion of assignments which were facilitated by the instructor. A practical project spanned the full year and students applied the concepts covered each week in order to develop a practical system. Individual as well as group assignments formed part of the course structure. The focus of assignments was to encourage students to participate actively in the learning process. The group project and some of the assignments (towards the end of the semester) allowed students to learn collaboratively. This is similar to peer instruction which is advocated by Crouch and Mazur (2001). During class various strategies and forms of media were used to accommodate different learning styles. A bonus mark scheme was implemented to encourage students to read beyond the prescribed course material.



Notes:

- Bubbles with stars indicate assessments contributing to the participation mark.
- Semester Tests (not shown in the depiction) are written every few weeks (3 per semester) and make up the remaining marks (50% in semester 1 and 40% in semester 2).
- Strict guidelines were established regarding the allocation of questions according to Bloom's taxonomy.
- During semester 1 forum and glossary contributions were evaluated to improve low scores for assignments/class tests.
- Examinations take the format of a first opportunity followed by a second opportunity if the first is failed. Both the participation mark and the examination mark have a weight of 50% in the calculation of the final mark.
- Examination questions are drawn from semester tests, class tests, assignments/class work, homework and videos.

Fig. 1. Instructional design of systems analysis and design modules.

The following learning outcomes on National Qualifications Framework (NQF) level 5 were covered in the modules and the students should have mastered these upon completion of these modules:

- Knowledge: Upon completion, students will demonstrate that they possess the necessary knowledge of and insight into the phases and techniques of the Systems Development Life Cycle to apply this to the planning, analysis and design of a system.
- Skills: Students will be able to apply the phases and techniques of systems analysis, design and techniques of systems development in a project. They will be able to manage a project. Students will be able to apply creative skills when they develop a computerized system. Teamwork forms an integral part of their skills. The student will be able to solve problems creatively and develop a computerized system. Group work will be completed successfully.
- Attitude: Awareness of the following is important:
  - Systems are developed for consumers and their preferences and requirements have to be addressed during the analysis, design and development process;
  - Systems must be completed accurately and according to the agreed upon manner;
  - Client information must be treated with the necessary confidentiality; and
  - Computer resources must be used ethically and responsibly.

The framework for the application of system thinking forms the backbone of the course. This is the hypothetical methodology used throughout the course to demonstrate a representative systems development process. Students were also introduced to alternative routes and strategies, like the waterfall development approach, the iterative development approach, model-driven development and the rapid development strategy. These are all covered in the prescribed textbook *Systems Analysis and Design for the Global Enterprise, 7th Ed* by Bentley and Whitten.

The second semester focused on self-directed learning and reversed instruction (or flipped instruction). A depiction of the instructional strategy is shown in Figure 1.

D. Issues to be Addressed

From the discussion on background general issues influencing the research were identified. These two issues are: (1) problems resulting from the diversity of students and within the learning environment, and (2) the unexpected uses of the technology.

1) Diversity

Several issues related to diversity played a role in this research. As stated earlier, the students in this course came from several diverse backgrounds. This impacted on the interaction in class. A further issue related to the fact that not all students had access to their own computers. This resulted in them using a diverse number of computers from the university, family members and friends to gain access to the material – which was in this case a minor challenge. In addition, a diverse group of people was involved in this study, each of whom played an important role and offered up different perspectives. The lecturer guided the students, the students made use of technology to learn about technology, and their peers supported and interacted with them. Each of these role-players needed to be managed in a diverse setting.

2) Unexpected Uses

The intention of this research is to get students to use videos to assist in class preparation, but is that all that they will gain from the intervention? What other possibly uses could be found when you use videos to teach students? Will they start using videos for other purposes? Since students are known to love technology, it is hoped that many unexpected uses will evolve through the use of the videos for class preparation.

III. PHILOSOPHICAL FRAMEWORK

The work of Herman Dooyeweerd, a Dutch philosopher who developed fifteen modal aspects, stands central to this study. It provides a framework for theoretical thinking and understanding reality and guides the understanding of how reverse instruction through the use of videos can enhance learning within the South African context.

An important part of Dooyeweerd's philosophy is his theory of modal aspects in which he discusses fifteen aspects of reality. Dooyeweerd (1969:4) argues that it is possible to describe all aspects of reality in terms of these fifteen aspects. Table 1 list the fifteen aspects and illustrates each with examples of the types of things qualified by the aspect. Each aspect has a kernel of meaning along with retrocipation and anticipation of other aspects.

Through the retrocipation and anticipation of other aspects, each aspect inherently relates to others. Retrocipation is when an aspect reaches back to an earlier aspect, while anticipation is when an aspect reaches forward to a later aspect. For example, a video can be watched with peers, making it a social activity, but that interaction creates interest and fun (aesthetic aspect) for the users. In this way meaning of an aspect is built in the sense that we have a kernel of meaning with retrocipation and anticipation of other aspects.

Another important part of Dooyeweerdian thinking is the theory of individuality structures. An individuality structure refers to a concrete entity or event which has special qualities distinguishing it from all other individuality structures (Kalsbeek, 1975: 42-43). When we work with individuality structures we always ask the question "What?". With aspects the question is "How?" since aspects are concerned with the manner of being (a mode). That is why Dooyeweerd refers to them as modal aspects.

TABLE 1. Dooyeweerd's fifteen modal aspects of reality listed as types of things by qualifying aspect along with using videos to learn difficult SAD concepts (as discussed by Basden 2008: 25).

Aspect	Example things	Using of videos to learn difficult SAD concepts
Quantitative	Amount, Proportion	Number of participants, number video's
Spatial	Shape, Distance, Angle, Direction	Shape of computer (desktop, laptop), space you are in when watching a video, size of video
Kinematic	Path or route, Flow	Movement while using the device (watching, listening)
Physical	Solids, Fluids, Gases;, Energy, Waves, Particles, Materials, Fields, Forces	Capacity of computer, capacity of network in streaming the video
Biotic	Plants; Organism, Organ, Tissue, Cell; Animals	Interruptions hinders study progress, interruptions motivate much needed break from watching/studies
Psychic	Sound, Colour, Feeling, Emotion, Excitation	Users feel good about using video's for learning
Analytic	Concepts; Distinctions, Deductions, Awareness	Get answers to question – "how do I do this?"
Formative	Goal, Achievement, Forming, Will, Tool, Skill	Structuring of sentences and diagrams
Lingual	Word, Sentence, Book, Writing, Utterance, Diagram, Index	Communicate with student by lecturer, formulating questions and explanations, student's lingual capacity
Social	Friendship, Institution, Status, Respect	A "fun" way to learn, can it be done with peers?
Economic	Resource, Limit, Production & consumption, Money, Management	Using technology resources (only at campus or at home with own resources as well); clarity of video's
Aesthetic	Music, Sculpture, Cuisine, Humour, Fun, Sport, Nuance	Style of video
Juridical	Responsibility & rights, Reward & punishment, Laws	Addressing actual student study needs (which will improve their ability to understand and scaffold)
Ethical	Act of generosity, Sacrifice	Give pupils the motivation they need to understand the subject
Pistic	Religions, Ideologies; Faith, Trust, Loyalty, Worship, Commitment, Ritual	A shared goal to ensure improved systems analysis and design skills among students

Therefore, when an individuality structure is analyzed theoretically, it is crucial to start with the modal aspects. Only then can the investigator understand the entity as a whole. This summary of Dooyeweerd's philosophy provides the conceptual basis for addressing the issues identified above.

IV. EMPIRICAL STUDY

A. Research Design

According to Myers (2011), there are various ways to classify research methodology. Two of the most common are quantitative and qualitative research. Quantitative research was developed to study natural phenomena mostly in the natural sciences environment. Quantitative methods used in the social sciences include survey methods and numerical methods. Qualitative research, on the other hand, was developed to study social and cultural phenomena in the social sciences. Qualitative methods include grounded theory and action research. The reason for conducting qualitative research, as opposed to quantitative research, stems from the fact that there is one aspect that distinguishes humans from the natural world – our ability to talk. The goal of this type of methodology is to build a reality from the multiple realities of participants and qualitative research methods are specifically designed to assist researchers in understanding people, as well as the social and cultural contexts in which they live (Creswell, 1998). Although researchers will in most cases use either quantitative or qualitative research, some researchers often combine these research methods in one study, allowing for the corroboration of findings and the enhancement of validity. The current study makes use of such a combined approach. Quantitative data are obtained from the university LMS, while the qualitative data are collected by applying the Dooyeweerd model aspects in order to understand video use as a form of reverse instruction when studying SAD.

B. Data Collection and Analysis

The LMS used in this study is eFundi and it allows for the collection of statistical data in the form of number of reads (watches) of videos per student. It should, however, be noted that this data does not distinguish between a read that was started, but not actually watched by the student. In addition it does not keep track of how many students watched a video with a friend. Furthermore, it also does not count video watches done by students who download offline versions of the videos. Although the statistical data do not give a perfect count of video watches, they do give an indication of a video's usefulness.

Table 2 demonstrates that students were slightly more reliant on videos during the first semester (1.82 watches per student per video) when compared to the second semester (1.81 watches per student per video). More students chose not to watch videos during the second semester – with 63 out of 69 students watching videos in the second semester as compared to 81 out of 82 during the first semester. In general the pass rate was good during both semesters, with total of 62 of a possible 82 students successfully completing the modules.

From the lecturer's own observation, more work is covered during the first semester than in the second semester. First semester work is also newer to students and covers more theory. In addition, the lecture observed that students evolved from being unsure in the first semester to bold and full of confidence at the end of the second semester. Bearing this in mind, it is encouraging to see that 9 students revisited the first semester videos during the second semester (75 watches).

It is also interesting to note that the highest number of video views per student for both semesters was 12, with one student revisiting a first semester video 4 times during the second semester. This supports the literature (Prensky, 2011).

The lecturer also noted that in previous years some concepts required repeated explanations, however, the introduction of the videos reduced this as students preferred to watch the videos.

TABLE 2. Student watches per video, pass rate.

<table>
<tr><th colspan="4">Watches per video</th></tr>
<tr><th colspan="2">Semester 1 (82 students, 3 did not watch)</th><th colspan="2">Semester 2 (69 students, 6 did not watch | 9 students watched 1st semester video's)</th></tr>
<tr><th>Video topic</th><th>Watches (during 2nd semester)</th><th>Video topic</th><th>Watches</th></tr>
<tr><td>Gantt PERT</td><td>226 (5)</td><td>Cost Benefit Analysis</td><td>153</td></tr>
<tr><td>Expectations management</td><td>215 (6)</td><td>Physical process modeling concepts</td><td>100</td></tr>
<tr><td>Use-case syntax</td><td>142 (7)</td><td>Physical data modeling concepts</td><td>83</td></tr>
<tr><td>Use-case</td><td>141 (5)</td><td>Database capacity</td><td>142</td></tr>
<tr><td>Data modeling concepts</td><td>141 (7)</td><td>GUI</td><td>94</td></tr>
<tr><td>Data model of case study</td><td>146 (7)</td><td></td><td></td></tr>
<tr><td>Normalisation</td><td>150 (9)</td><td></td><td></td></tr>
<tr><td>Process modeling concepts</td><td>118 (7)</td><td></td><td></td></tr>
<tr><td>Process modeling strategy</td><td>122 (7)</td><td></td><td></td></tr>
<tr><td>Data Process Location matrixes</td><td>134 (7)</td><td></td><td></td></tr>
<tr><td>Object modeling concepts</td><td>94 (8)</td><td></td><td></td></tr>
<tr><td>TOTAL</td><td>1629 (75)</td><td>TOTAL</td><td>572</td></tr>
<tr><td>AVERAGE WATCHES (1629/81/11)</td><td>1.82 per student</td><td>AVERAGE WATCHES (572/63/5)</td><td>1.81 per student</td></tr>
<tr><td>MAXIMUM WATCHES</td><td>12 (4)</td><td>MAXIMUM WATCHES</td><td>12</td></tr>
<tr><td>PASS RATE (81 (82) --> 68)</td><td>83%</td><td>PASS RATE (68 (69) --> 62)</td><td>90%</td></tr>
<tr><td>OVERALL PASS RATE</td><td colspan="3">76%</td></tr>
</table>

When students were asked about the value of the videos at the end of their course 45 of the 69 students completed questionnaires. Almost half of them (21) found the videos extremely useful, everybody who used it, found some value in it, while only 3 did not use it – mainly because of time constraints. The numbers are represented on a bar chart below (figure 2):

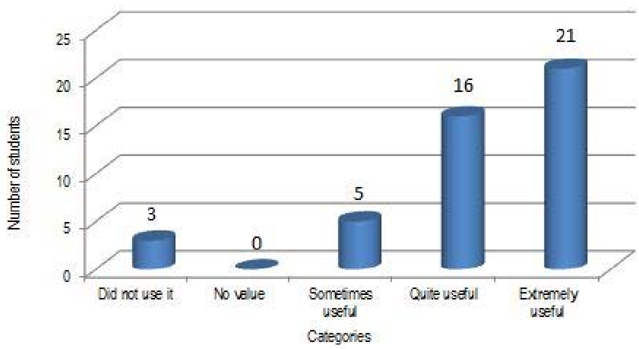


Fig. 2. The value of videos.

In an open question students indicated that it gave them "a good idea of how things are done", it "emphasizes main points", it "clears confusion", it "helps understand practical work" and it is "visually stimulating". Some students asked for more videos. One indicated that a problem experienced was that "I can't ask a video questions"!

C. Dooyeweerd Provides a Useful Framework

This section motivates why Dooyeweerd's philosophy provides a useful framework for this study. This is done by looking at how Dooyeweerd addresses issues relevant to the research.

1) *Dealing with Diversity*

In this study, videos were developed to enhance the learning of SAD and to reverse instruction. It is hoped that the introduction of these videos will encourage students to become life-long learners, who are actively involved in their own learning. Technology keeps on changing and as a result SAD students will need to constantly learn new things. Group work was used to assist with active learning. This also included the completion of a practical project which was worked on outside of class. The diverse approach of giving students assignments to force them to gain knowledge about a topic before coming to class was used. Students were encouraged to voluntarily form diverse groups for their project development. During class groups were formed by the lecturer. The groups comprised male and female students, and black and white students. Although students complained about these groupings, they learnt to work with peers from diverse backgrounds, in terms of culture, skills and capacity. This situation imitates the working environment.

Table 1 shows how Dooyeweerd can help address the complexity or diversity of the use of videos in helping to prepare students for reverse instruction, by allowing us to unpack a complex situation where diversity is prominent.

Using these aspects makes it possible to recognize the distinct importance of each and every phenomenon or factor the researcher might be presented with. Dooyeweerd's aspects therefore address the issue of diversity.

2) *Dealing with Unexpected Uses*

Expected and unexpected uses may lead to unexpected results. As mentioned previously, students had access to computers in a laboratory at the university or they could access the videos through their own computer at home or on campus. Videos could be watched individually or in groups. The computer's capacity was not a huge issue. Although videos were intended to be used to prepare students for class, they were also used to gain knowledge on how to complete an assignment. Videos were watched in class when group work was discussed, and students revisited the videos to prepare for tests and examinations. First semester videos were also used during the second semester to revise related concepts. It is hoped that students will revisit the videos in subsequent modules because the videos on database modeling may be helpful when students start a course on databases.

The modal aspects of particular interest in this study include the lingual, social and juridical aspects. However, it is important to acknowledge that teaching students SAD through the use of videos is not something that can be restricted to a limited number of modal aspects. According to Basden (2008) most aspects will be prevalent to a certain extent. In addition, it is also important to realize that "many things are of multiple aspects", for example a computer is used by most people to create documents. It will also, in an IT course, be used to develop systems using a language such as C# – which is embedded in a particular technology (formative aspect). Dooyeweerd called this a retrocipation – when an aspect reaches back to an earlier aspect. Anticipations occur when an aspect reaches forward to a later aspect, and can help us to understand, for example, when a video may be a tool for social interaction. This interaction also creates interest and fun (aesthetic aspect) for the user. Dooyeweerd's retrocipations and anticipations can therefore address the issue of wider or unexpected usage.

V. CONCLUDING REMARKS

As stated in the title, the implementation of videos to assist in reversing instruction has a good, a bad and an ugly side. Prensky (2011) is of the opinion that the flip-side to videos are that they are "a new way to do an old thing (blackboard teaching)" – a true deduction and a possible negative aspect. This research supports Prensky's (2011) view by stating that students watch videos repeatedly. Unfortunately, some students do that and still perform badly. Although videos allow students to study at their own pace, their use will not guarantee good performance. The implementation of some form of group or peer learning to encourage students to become active learners is crucial to ensure success.

The fact that the lecturer for these modules was not asked by the students to explain difficult concepts numerous times, and in some cases no explanation was requested, is encouraging. Shy students, who would most probably not ask the lecturer a question, are able to watch a video and receive an explanation without any interaction with the lecturer. The existence of videos could also help students who have a legitimate excuse for absence, like illness, to catch up easily. Unfortunately it may also bring about laziness in students and create the impression that it is easy to do the subject by just watching the videos. This could result mean that there is no active involvement of a student with the subject material and could defeat the actual purpose for introducing the videos.

Reversing instruction occurred at the end of the first semester without too many growing pains. Various reasons may be cited for this: students grew during the first semester; their background knowledge was well developed (partly because of the introduction of the videos); they were able to do revision using videos; the second semester built on the first semester's knowledge; students knew the lecturer. This resulted in students being able to focus on a broader range of aspects in the subject, instead of only tests – like they would do at the beginning of a module.

There is also room for improvement and in this study it was felt that students should get more from videos. It was decided to provide an accompanying document for each video. This document provides background information, helping students to know what to look out for in the video. Questions are also listed to assist in the student's focus. Some follow-up questions are provided to help students to build on the knowledge they gained by watching the video. In future the possibility of using software to build these questions and guidance into the video itself, will be investigated.

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Commercial Competency and Computing Students

Using the Skills Framework for the Information Age in Higher Education

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***Abstract*—Commercial acumen has emerged recently as a third aspect of employability which employers expect from computing graduates, in addition to technical capability and "soft skills" (or similar terms like transferable skills). Our experience has been that viewing commercial acumen (or even commercial awareness) as simply one of the soft skills, has failed to meet the needs of local employers, who tell us they seek innovation skills and entrepreneurship. A case study illustrates a structured approach to adding commercial awareness to the computing curriculum, and, more generally, tying the learning experience more closely to the achievement of standardized competency statements. Changes to future provision are discussed following workshop discussion of a draft of this case study.**

This paper will be of interest to computing and engineering academics who seek to increase the commercial awareness of their students, and to those who seek to align their courses with commercial definitions of competency

Keywords—competency frameworks; commercial awareness in computing degrees; innovation

I. Introduction

It has become increasingly desirable for computing graduates to be able demonstrate commercial acumen. Governments and employers state this need in different ways, but our experience is that it is emerging as a third key factor in defining employability, beyond the existing desire for the optimal combination of domain-specific skills (programming, design, etc) and "soft skills" (time and project management, communication). In earlier work [1] we discussed the derivation of a current working set of generic graduate attributes and it was noticeable that only one of the eight components [2] referred to employability. Discussions with local employers suggest that these generic attributes are indeed desirable but more salient are areas such as customer-centeredness, innovation, entrepreneurship, business-awareness, market analysis and customer awareness. However, in an already overcrowded curriculum, how can this additional expectation be effectively integrated?

The growing use of national and global competency frameworks (such as SFIA: the Skills Framework for the Information Age [3]), both in term of job specification and skills gap analysis for individuals and organisations, and the increasing integration of these with the accreditation requirements of professional bodies, provides a potential focus for a solution.

This paper builds on other previous work, first in engagement with the maintenance and enhancement of competency frameworks [4], in arguing for more socially-responsible forms of innovation [5], and an earlier version of this work [6] presented in a workshop organized by an special interest group of BCS, The Chartered Institute for IT.

After discussion of BCS activity in the relevant area, this paper discusses a case study which illustrates generic challenges in embedding SFIA competency statements in higher education learning outcomes, in particular where learners' intended job roles are in a fast-emerging area of computing and thus lack, as yet, formal codification. The case study describes the process of gaining university quality acceptance for a masters-level module (IMD11108 Digital Markets) based on SFIA competency statements, and reviews the first deliveries of the module. The approval process for this module provides a mapping of SFIA levels to higher taxonomies of learning, and illustrates how both students and course leaders construct degree courses. These experiences are contrasted with the experience in other countries, with reference to the BCS workshop [17] and the position statements from other workshop participants (drawn from three continents), each of whom reported on related activity using SFIA. A parallel process, led by BCS Interaction Specialist Group, used this module to define both competency and courses for the relatively new skill of User Experience (UX).

Contrasting experiences with academics from other universities and countries provides evaluation of the module and the approach to create it. It also feeds back into subsequent delivery of the above module, this time to a small but more international cohort of students (from Asia, Middle East, Spain and the UK, drawn from a number of different MSc programs). Here the requirements become more complex, as the learners from different countries start with very different understanding of, and attitudes towards, commercial issues.

The module requires each learner to develop a concept for the digital marketplace, and to identify the nature of the opportunity, commercial viability, and "freedom-to-operate" (for example, whether patents exist in certain jurisdictions). The learners then peer-review each other's proposals, and indicate their preferences for future development, before

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forming into two groups to develop the proposals for an end-of-trimester pitch to established entrepreneurs, who provide feedback as if this was a commercial situation. To conclude, learners must provide a reflective commentary on the project experience as part of their assessment.

This paper discusses approaches to "level up" each learner to the same starting point for the group activity, reflects on the management of the groups and identifies patterns of learner activity and reactions, which can be used to improve subsequent delivery.

II. Background: UX and BCS

The author views the domain of User Experience (**UX**) as encapsulating much if not all of the commercial acumen agenda. UX, as a discipline, arguably has grown out of the **Usability** sub-specialism of Human-Computer Interaction (**HCI**), itself part of a longer tradition of **Human Factors** within **Computing**. UX also grows out of ergonomics, psychology, and marketing. It looks at people's engagement with technology and services, and seeks to ensure that their experience of using the technology is not only problem-free, but also exceeds expectations, delights the user and thus becomes valued by that user. As more transactions are completed online, good UX is fundamental to fitness for purpose. There is a global shortage of these skills, and senior salaries are amongst the highest in any field of computing.

The global professional body, UXPA, has fifty chapters around the world, coordinates the annual World Usability Day in forty countries, and seeks to create a global professional community [7]. The author is a member of IEEE, BCS, ACM and UXPA, and informal contact with other members of UXPA suggests a considerable overlap in memberships across these and other professional bodies, including ergonomics, engineering, psychology, design and marketing. It is difficult to pigeonhole UX into the work of a specific sector skills council (the collective term used in the UK for bodies which define job competency), although UX is an important part of the future of Computing, and thus a key opportunity area for BCS and other professional bodies for the field of computing.

A. BCS and HCI

In 1984, BCS calved one of the world's first specialist groups in HCI, variously known through the years as BCS-HCI, British HCI Group and, now, Interaction Specialist Group (which the author chaired 2009-2011). After a special edition of BCS's Computer Bulletin, this group launched one of the first HCI academic journals [8], which, despite periodic changes in publisher, retains a leading impact-factor (5-year impact factor: 1.455 [9]. The group's annual conference [10] and UsabilityNews.bcs.org web portal also have global impact.

The group worked with the UK government to produce Usability Now (1990), an initiative to embed usability in UK software. Many would argue that the industry is yet to fulfil these values. By the turn of the century, the group worked with the UK government's E-Envoy to ensure accessibility in public websites [11]. Members of the group executive committee and contributed to iterations of SFIA and the BCS's extended version SFIAplus [12], resulting in an increased number of usability roles being recognised from SFIA v3 onwards [4]. Most recently SFIA v5 [3] is the first version to include UX in its skill definitions, shifting the focus from "non-functional requirements" (particularly a misnomer, from a cognitive ergonomics point of view) towards a more holistic understanding of the needs and the experience of the user, in definitions for skills such as:

- User experience analysis (UNAN);
- Ergonomic design (HCEV);
- User experience evaluation (USEV);
- Human factors integration (HFIN).

For example, the latter is defined as: "Achievement of optimum levels of product or service usability, by ensuring that project and enterprise activities take account of the **user experience**."

B. UX Competency Workshops

On behalf of the group, the author led two national workshops, UXCF2010 in London, UK, and UXCF2011 in Newcastle, UK. UXCF2010 attracted around 40, mainly industry, participants, and sought to understand roles and organisational processes in the fast-developing field of UX. While some of these roles are already recognisably part of SFIA (for example Business Analyst, Programmer), others are not, nor are they adequately defined in the national occupation standards (NOS) such as those published by UK sector skills councils such as e-skills, Skillset or CCDesign.

UXCF2011 extended the materials produced in the first workshop in a smaller event involving three academics who design relevant BSc/MSc courses, and three senior UX professionals, supported by other interested parties. Most had contributed to and/or reviewed the recent SFIA revisions. We reviewed an example set of modules against typical UX roles to identify gaps, and to evaluate how well the new module discussed here, IMD11108 Digital Markets, fills any gaps. Elsewhere [6], the author summarises the UXCF activity in more detail. The work with SFIA and UXCF is linked, maintains close coupling between academia and industry and and used to define and evaluate the module described below

III. Case Study: Digital Markets

This section describes the first experiences of running a masters-level module, IMD11108 Digital Markets [13], which was written explicitly to use learning outcomes based on SFIA competency statements. This module lasts a semester, carries 10 ECTS (European Credit Transfer System) credits (one-sixth of a full academic year), with 36 hours of classes and 164 hours of student centred activity including group-work. It addresses UX in the sense that it focuses on entrepreneurship and innovation from a Human-Centred Design (HCD) perspective [5], contrasting different approaches to innovation, in particular what the OECD term "non-R&D innovation" [14,15], which focuses on user-driven innovation, ie demand-led rather than "marketing-push".

A. Quality Approval

The first challenge was to gain university quality acceptance for a module based on SFIA statements. University quality procedures, at least in the UK, reflect a complex set of stakeholders as previously discussed [1]. The module itself was not created for the sake of delivering competency – at best this would be seen as *necessary* but not *sufficient*. Meeting the emerging needs of employers, while providing an opportunity for critical evaluation of different approaches to applying innovation theories, more fully addresses all agendas. The module descriptor runs to several pages [13], but the key points discussed here are the Learning Outcomes (LOs). These are the basis of our quality system: all assessment plans are moderated against the LOs, and all teaching events and directed study are designed to be necessary and sufficient for students to achieve, and demonstrate through assessment, the learning outcomes.

B. Matching Levels and Breadth

The first consideration of the module was in March 2009. The first task was to contrast the language of the different skills levels within SFIA with the required vocabulary of module accreditation at levels 10 (Honours (final year) undergraduate) and 11 (Masters-level) of the Scottish Credit and Qualifications Framework (SCQF) [16]

10	Accurately assess; adapt; analyse; anticipate; appraise; argue; arrange; assemble, attribute; calculate; categorise; classify; combine; compare; compose; conclude; connect; construct; contrast; create; critically reflect; criticise; defend; derive; design; devise; develop; differentiate; discriminate; distil; distinguish; examine; experiment; extract core issues; formulate; generalise; hypothesise; infer; integrate; invent; make effective use of; manage; modify; organise; précis; prioritise; propose; reconstruct; separate; substitute; synthesise; test; validate
11	Analyse; appraise; argue; challenge; conceptualise; conclude; convince; critically appraise; critically assess; critically engage with; critically explore; critically reflect; critique; debate; defend; discriminate; drawn conclusions; engage in critical dialogue; estimate; evaluate; examine the impact; examine the elements of; exercise appropriate judgment; generate ideas; hypothesise; judge; justify; plan; predict; produce; rate; rationalise the use; recommend; resolve; review; test

Figure 1: "Acceptable" verbs to meet SCQF10 and SCQF11 learning outcomes (Edinburgh Napier University internal memo)

Our experience has been that the language in SCQF 10 is found between SFIA levels 4 and 5, and that of SCQF 11 at SFIA levels 5 or 6. Although the question has been asked at open forums for SFIA, there appears to be no definitive mapping between SFIA levels and university learning taxonomies. A typical response is that higher level roles within SFIA require not only knowledge and understanding (as delivered in a degree), but practical experience (seen as not delivered in a degree). One might infer that universities educate at a level well above initial graduate jobs, and that employers are investing in the proven potential of these graduates to progress over 3-5 years to professional roles.

The terminology of SFIA and, more generally, of human resources can be inconsistent, or change over time. Sometimes, words like job, role, skill, occupation, task, activity, competency, knowledge, expertise, and so on, overlap in their usage. For the purpose of this paper, a job involves one or more roles, each of which might be needed at different levels of skill (based on expertise, knowledge and understanding). Our experience was that a single SFIA skill appears to be too narrow a focus for a 200 hour learning experience, and thus two related SFIA skills Emergent Technology Monitoring (EMRG) and Innovation (INOV) were mined to provide sufficient breadth for IMD11108. The language of academic learning outcomes (LOs) is traditionally more concise than that of competency. The relevant statements for SFIA levels 4- 6 in EMRG are (with key wording **highlighted** and commentary in *italics*):

"Maintains awareness of opportunities provided by new technology to address challenges or to enable new ways of working. Within own sphere of influence, works to further organisational goals, by the use of emerging technologies and products. Contributes to briefings and presentations about their relevance and potential value to the organisation". (EMRG4)	*In any case level 4 statements appear to require less synthesis than expected at Masters or even Honours year level. Thus the following LOs were mapped onto* ***EMRG5****, although LO5 goes slightly beyond (as highlighted).*
"Monitors the market to gain knowledge and understanding of currently emerging technologies. Identifies new and emerging hardware and software technologies and products based on own area of expertise, assesses their relevance and potential value to the organisation, **contributes to briefings** of staff and management".(EMRG5)	LO4 Monitor technology markets to gain knowledge and understanding of currently emerging technologies (EMRG5). LO5: Identify new and emerging hardware and software technologies and products, assess their relevance and potential organisational value **and brief** staff, management and investors (EMRG5).
"Co-ordinates the identification and assessment of new and emerging hardware, software and communication technologies, products, methods and techniques. Evaluates likely relevance of these for the organisation. ***Provides regular briefings*** *to staff and management".(EMRG6)*	*Limited possibility for students to "co-ordinate"*

Innovation (INOV) provided the basis for the other learning outcomes. Only two levels currently exist for this:

"Actively monitors for, and seeks, opportunities, new methods and trends in IT capabilities and products to the advancement of the organisation. Clearly articulates, and formally reports their benefits." (INOV5)	*"Monitoring" and "reporting" alone, were judged insufficient to meet SCQF level 11, being more typical of the investigation that an Honours Project student might carry out (SCQF level 10). Thus INOV6 was the basis for the three other Learning Outcomes, although the taxonomy falls midway between levels 5 and 6*
"Recognises potential strategic application of IT, and initiates investigation and development of innovative methods of exploiting IT assets, to the benefit of organisations and the community. Plays an active role in improving the interface between the business and IT." (INOV6)	LO1: Recommend potential strategic application of IT in the digital marketplace (INOV6). LO2: Work in a group to exploit IT assets in an innovative way, to the benefit of organisations and/or the community. (INOV6). LO3: Conceptualise ways to improve the interface between the business (or organisation) and IT. (INOV6).

The UX dimension is notably missing from both LOs, and other SFIA roles were considered including Human Factors Integration (HFIN). While these did not add value to the LOs, the "Overview" section of the HFIN skill is more relevant and thus provides a backdrop to the module:

Human Factors Integration – Overview	"Achievement of optimum levels of product or service usability, by ensuring that project and enterprise activities take account of the user

	experience."

The module was accepted at the second submission to the Faculty Quality process, subject to amendments. One such amendment was to clarify the variety of job roles to which the learning outcomes would lead. This information is fairly vague, even in SFIAplus, and the following was proposed to gain acceptance:

"This module helps prepare learners for the following roles in the Skills Framework for the Information Age (SFIA): INOV6, EMRG5, HFIN5. These roles are found in digital media innovation and new product development teams in larger organisations and relevant job titles include: Digital Media Developer/Designer within an Innovation Team or New Product Development team, User Experience Developer/Designer/ Manager, Imagineer (a Disney Corp. term), Human-centred Designer. This module will also support a potential digital media entrepreneur to develop their concept."

Once accepted, the module then also had to be made attractive to students – the first mandatory running for the integrated masters (MEng) programmes was not until 2011-12. In the meantime it was available as an option for other postgraduates, but there was insufficient demand until the Fall trimester, 2011.

C. *Structure*

The module simulates a commercial innovation cycle. For the mid-term assessment, individual students build up their own proposals for a viable product or service for the digital marketplace. After submission, they peer-review each other's work and select the best of these ideas to develop in groups of 3-4 to the point where they can pitch to local entrepreneurs, as if for around $250k in seed-corn investment (several such programs do exist locally for university spin-out ideas). Their presentations are formally assessed as a group, and their final assignment is to reflect on the group and their own performance. The teaching is front-end loaded to prepare students for working in groups to accomplish the main objectives of the module. At the end of the module students must reflect individually on the experience, which is the opportunity to display their Masters-level capabilities.

Table 1: Time Management advice given to students

Week	Work	Description
2-3	Heavy (20hrs per week)	You have 12 hours of classes and a great deal of directed study to do, meaning you will likely work more on this module than other modules.
4-9	Moderate (12hpw)	No classes - 5 short tutorial meetings: you will be focused on your individual coursework (due week 8) and starting to develop your group for the second coursework. Your only classes will be some individual supervision meetings and then short group meetings with the module leader to discuss group formation and objectives.
10-12	Heavy (20 hpw)	18 hours of classes: you will prepare in a group for, and give, a 15 minute Dragon's Den type pitch for your concept
13-15	Light (10 hpw)	Completion of final 1500-word paper reflecting on the group experience

Table 1 explains the unusual contact time pattern – double the normal contact hours for the first few weeks, brief weekly group supervision meetings in the middle six weeks, and double the normal contact. The expectation was that students would be highly self-motivated and self-organizing, having already gained experience in managing their solo project in fourth year, and in participating in formal group projects in previous years.

D. *Experience of Delivery*

For a variety of reasons, the cohort of undergraduate integrated-Masters students (a five-year degree) who took the module lacked both the highest and lowest performing quartiles of the previous year. The "less average" students had elected to graduate with the more typical BSc (Hons) or BEng (Hons) at the end of their fourth year. Thus the first cohort for this module contained "average students", and so there was little variation in their attainment. We routinely contrast the performance of all students in any module, compared to their collective performance in their other modules. The resulting performance for this module in 2011 was only slightly above average for that cohort. This analysis could not be completed in 2012, as only a single student remained for the fifth year, as a favourable local job market absorbed the rest of the cohort.

In contrast, several one-year MSc students from overseas considered the module in 2011, but elected to take "more technical" subjects instead, expressing worry about the discursive, group and presentation-based assessment regime. In the 2012 delivery, proactive steps allayed such fears, and the resulting cohort, though small, was globally diverse: students from Saudi Arabia, Spain, Egypt, three regions of China, and one local student.

This 2011 instance involved only seven students, four from the MEng Software Engineering and three from the MSci Interactive Media Design. The overall response in student feedback was highly positive and the advice one student gave to future students was interesting:

"Try and create a new idea, as my idea wasn't new or a good business plan, I did not take it further after the module. But with the support of the module, by the end of it, you have a lot of useful information if you decided to create a start up company."

Largely, the module met ambitions. The students did a very good job of each researching a digital market idea and writing a short paper (3000 words) on it, submitting in week 8. Example topics included an on-demand BluRay burning kiosk (an interim solution to slow local broadband rollout), an app for stag and hen parties (in the USA, "bachelor(ette) parties"), and an app that used live geodata and public data about granted collection licenses to detect and avoid "chuggers" – aggressive on-street charity collectors. For the second half of the module, they split amiably into two groups, each adopted one of the latter two ideas, and further developed it, until they were ready to pitch, in week 12, to an audience of six industrialists, entrepreneurial advisers and lecturers:

- The CEO of a successful spin out company now in its second year of trading

- An experienced entrepreneur, business "Angel" and senior advisor to government
- An entrepreneur and advisor for Proof of Concept (PoC) commercialisation spin-out project funding from a local government agency (Scottish Enterprise).
- The director of the university's Moffat Centre, which advises around fifty students each year on how to start their own companies
- An academic who had recently run a PoC
- A professor with responsibility for coordinating faculty-wide research and commercialization

The panel rated each group's pitch in a number of dimensions (although final grading decisions were taken by the module leader). Both pitches, though trenchantly criticised on the day by the expert audience (in a way that the students reported, in the post-presentation discussion session, as "brutal" and "a wake-up call") were also (in the formal feedback sheets) well-received by the experts. No-one rated any aspect less than "adequate", most were rated "good" and some were rated "very good". Since the experts had been asked to judge these on a commercial basis, this alone was a remarkable achievement, and one which suggests that the use of SFIA statements in the LOs was effective in leading to competency, in particular LO5: ("Identify new and emerging hardware and software technologies and products, assess their relevance and potential organisational value and brief staff, management and investors").

E. 2012- second delivery

Only minor changes were made to the timetabling, but these, combined with a delayed start by several of the students, and acclimatisation by those who had recently arrived from overseas (most of the students), meant that the first two weeks class activity did not result in the same level of familiarity with the nature of commercialisation. Additionally some of the students come from cultural backgrounds with very different approaches to investment, legislation, regulation, consumer protection and so on. While the latter was all anticipated, trying to run a crash course in liberal Western economic and business values, at a time of acclimatisation was unwise, resulting in an initial response of culture shock. The relatively poor performance in the mid-term assessment prompted a more hands-on approach during the middle period, something that is feasible with a small class, but would have been problematic with a more typical class size of 20-40.

It became clear that the students needed careful shaping into their groups for the second half of the module to work. The middle section of the module has a lot of activity that does not count for assessment but does build students' abilities to peer evaluate, as well as and providing a mechanism for the groups to coalesce around the most viable ideas.

The planned individual meetings in weeks 4-6 were augmented with two additional weekly meetings of four students at a time (Groups A and B) to develop their own and critique each other's proposals for the first assignment. Since all students had chosen quite distinct topics, there were no plagiarism risks involved in this. Some of the ideas were less well developed than the previous year and often highly derivative of examples provided in-class (travel recommenders, study guides, tourism apps), but others were of a very high standard – a brokerage for statutory recycling of medium value electronic waste, a data scraping app that supplied "key information sets" (a new form of open data about UK universities that has proven costly to collate), an organic food delivery brokerage, personalized location-based M-Commerce services.

Within these groups a strong understanding each other's proposals emerged. This, however, could have compromised the anonymous peer review of each other's papers in weeks 7-9 (which refers students to typical journal and conference reviewing guidelines).

The solution was to give three papers from group B to each student from group A to review, and vice versa. This then meant that each student received three anonymised reviews of their business idea from members of the other group (with whom they otherwise had little close contact). Students then discussed these reviews within their groups. This now meant that all students had a detailed knowledge of all eight potential projects for the group stage. Students received a summary of the positive and negative points of each paper and then were invited to send their project idea preferences for the group stage. Most review criteria were on a scale of 1-5, and reviewers were invited to supply additional free text.

Reviewer 's Expertise	Please rate your own knowledge of the Concept proposed in the paper, how much you think you know generally about Business/Digital Markets and add any comments about your knowledge
Strengths of the Proposal and Potential improvements	Try to identify up to three good aspects of the proposal in this paper, and also three possible improvements
Commercial opportunity and potential barriers to success	Try to identify the profitability and scale of the commercial opportunity described , and the barriers that the proposer would have to overcome
Investment potential	If you had £500,000, would you invest £100,000 in this idea?

The resulting preferences clearly prioritized two ideas, although, curiously, neither of the original authors voted first for their own idea! The final allocation into groups ensured that each student got their first or second choice, while maintaining a reasonable balance of ethnicity and gender, and transfer of members between groups A and B.

Subsequently, the resulting groups successfully presented to a similar audience as in the previous year. Some niggles emerged within groups – a protocol had been advised for resolving group breakdowns, but it's more effective to avert the need for this with regular and detailed group supervision meetings. The grades for both the presentations and reflective statements were slightly better than the previous year, and, again, found to be slightly higher in cohort analysis.

These two experiences, coupled with group discussions at subsequent workshops, and comparison with teaching and learning approaches elsewhere in this subject area, has prompted a rethink of the delivery for next year, in anticipation of larger class sizes. A more traditional contact pattern will be used: three hours a week of contact throughout the trimester, one of which will remain in small groups.

F. Evaluation

The experience of the 2011 delivery was presented at a recent workshop [17], in a session with presenters who had attempted related integration of competency definitions with undergraduate teaching in Chile [18], Australia [19] and England [20]. This provided an opportunity to evaluate the intervention with peers who were attempting related innovations in their own countries.

While national or state governments in Chile and Australia emerged as more developed in mandating the mapping of university courses to SFIA, a clear consensus emerged that basing curricula on competency definitions in SFIA was effective for educators, learners and employers, and a more nuanced approach than for example "Body of Knowledge" (BOK). Other participants confirmed the mismatch between the advanced level of learning that universities require, and the likely lower level of initial graduate employment. Strategies are needed to help learners and graduates understand that, while initial roles may seem menial and to make little use of their advanced learning, their employers are investing in graduates' proven ability for future, more senior, roles. While graduates have always been told that they need to gain practical experience as well as theoretical knowledge, it will be important to define that practical experience. Plainly some quite advanced practical experience can be gained during study, for example using the scaffolded PBL approaches we discussed at FIE2012 [1].

This module illustrates both the possibility and usefulness to build postgraduate teaching around SFIA competency statements. Both the university quality approval and quality enhancement processes proved to be no barrier, and the assessments produced clearly met expectations. The selection of level 5/6 for Masters-level, and 4/5 for Honours-level appear to be generalizable to other areas of computing, although basing a 20-credit module (nominally 200 hours of student work, including classes) on a single role level may be inadequate.

An additional subsequent workshop, organized in 2013 by one of the constituent parts of the BCS Academy, identified many other entrepreneurship and innovation modules in computing-related degrees at a wide range of other UK universities, for example at Queens University, Belfast [21], University of Dundee [22] and the University of Northumbria [23] and around twenty others. Local employers appear in each area to remain unaware both of such modules (notable exceptions are Durham University, where Computing students carry out group projects for external clients, and the University of Kent, which has a student-led computing contracting company). More importantly employers are clearly often unaware that the commercial acumen agenda is very much being addressed by these type of modules.

As well as providing opportunities for students to gain knowledge and understanding well in advance of their first jobs in industry, university study can provide opportunities for developing practice competency to be ready for future opportunities.

IV. Parallel and Future Work

The evolution of this module was done in parallel with the UXCF process described earlier – the author's attempts to build a coalition to call for updates to the most recent version of the skills framework, SFIA, to maintain currency with graduates' skills and emerging UX job specifications, many of which require enhanced levels of commercial acumen that IMD11108 Digital Markets assesses. Space only permits brief coverage here, but uxcf.org has been reserved for more detailed exploration of the work carried out, and for follow-up workshops.

UXCF2010 (BCS Covent Garden, Feb 2010) involved ten papers, half from industry, half from academia, and attracted a further 30 participants mainly from industry. Alternate sessions involved group discussions to identify how organizations and individuals developed competency in UX. As well as discussions, the groups created a number of affinity mappings or other diagrams intended to capture the skills needed in UX practice. By the end of the day much of the discussion was about organizational maturity, both in terms of the UX companies and also their clients. This is consistent with findings of other initiatives eg [24]. In other work we plan to analyse this in more depth.

In the first session, much of the dialogue centred on understanding to what extent definitions of job role or competency were shared across different organizations. In later discussion, groups focused on range of skills, knowledge and understanding required. For the academics present, there was much value in hearing about the different, often highly dynamic, approaches taken by employers to assemble project teams based on sets of skills. For the industrialists, there was growing appreciation of different levels of capability maturity within organizations to deliver UX consistently, and in a commercially sustainable way.

UXCF2011 (University of Northumbria, July 2011) was more focused and specific to the design of degree programs. The individual learning outcomes of existing modules were mapped [6] against the table of professional competencies articulated the previous year. This enabled both employers and academics to agree potential gaps helped identity gaps, and confirmed where IMD11108 would contribute both to meeting existing requirements, but also to giving a new commercial perspective to graduates ensuring that they are indeed ready to "energize the future".

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iQuiz: integrated assessment environment to improve Moodle Quiz

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***Abstract*— Moodle is a well-known open source system to support teaching and learning through the web. It provides Quiz, a tool for learning assessment, which is also adopted by a large community along the world. Another tool that allows automatic assessment within Moodle is the iAssign package. iAssign provides means for integrating interactive Learning Modules (iLM) to Moodle, empowering it with interactive intense activities concerning specific issues implemented in iLM. However, such tools present some limitations that prevent their users to take more benefit of the question types and iLM such as (i) authoring is not a simple task; (ii) iAssign integrates iLM to Moodle without incorporating Moodle questionnaires; (iii) Quiz database for questions and questionnaires is not integrated to a repository with search and retrieving tools; (iv) in the current version of Moodle, Quiz didn't allows the incorporation or exportation of assessment content that follows the IMS-QTI 2.1 (Question and Test Interoperability) specification. In this paper we address such limitations proposing a generic model and its implementation for the Moodle system.**

Keywords— Moodle; Quiz; iAssign, assessment; repository; IMS-QTI 2.1

I. INTRODUCTION

The use of systems to support learning through the web has gained increasing attention in the last decades [1][2][3], mostly with the use of Learning Management Systems (LMS). Among the large family of available LMS, an open source solution is Moodle [2]. Since its first version, Moodle evolved considerably and it presents several functionalities to facilitate the processes of teaching and learning, as well as to manage activities related to them. We can cite some of the more important functionalities as the ones associated with the authoring, interactivity, and automatic assessment of instructional content [4][5][6][7]. In fact, almost a decade ago we could find in the literature some research directions related to increase the types of ways of interacting and assessing multimedia instructional content, including automatic assessment resources [4].

These functionalities allow, while logged in the system, the development of instructional content and the assessment of students' performance while interacting with such content during the learning process. Nevertheless, such content can be stored in instructional repositories and reused whenever needed. Moreover, authoring and assessment are important issues for any LMS. Quiz is the Moodle module associated with authoring and assessment [8]. By using Quiz, one can build questionnaires (quizzes) with automatic assessment resources. The quizzes may adopt several types of questions, including multiple choice, true-false, and short answer. Also, Quiz questions can be stored in a "question bank" to be further reused. Although Quiz provides features to the building of new types of questions, some issues may cause limitation on using them [9]. In addition, this prevents importing or building interactive intense instructional content [7], as the ones provided by iAssign [5] and questions that follow the IMS-QTI 2.1 specification [10].

In this paper we present an integrated model to provide means of authoring, automatic assessing and storing instructional content. Such model is implemented as a Moodle plugin called *iQuiz* (*interactive Quizzes in the Internet*). In section II we describe the model, and in section III we present iQuiz. Some related work is given in section IV and, finally, section V outline our conclusions and suggests future work.

II. AN INTEGRATED MODEL FOR ASSESSMENT WITHIN LMS

Our proposal for improving the scenario described along the introduction is an integrated model that adopts a component-based structure to provide a solution for combining authoring activities with automatic assessment and storage. The model is composed of three main components: authoring, interoperability and repository (see Fig.1).

The authoring component is responsible for providing means to create instructional content to be used during the learning process mediated by the LMS. Such component must provide support for creating interactive intense instructional content with automatic assessing and exporting the created content to instructional format standards. This component is the core of the proposed model since it has its main responsibilities.

Instructional standards are provided by the interoperability component that feeds both, the authoring and the repository component. The compliance with instructional standards must

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be transparent to the LMS, since this component didn't communicate with it.

The repository is responsible for storing instructional content, as well as providing tools for searching and retrieving such content, that must follow instructional format standards to provide interoperability among distributed repositories along the world.

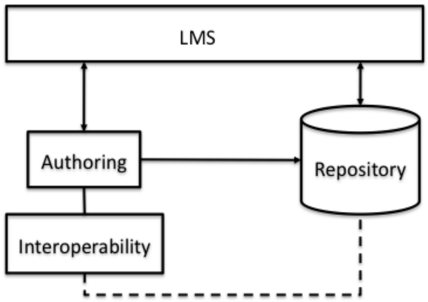

Fig. 1 The model structure

An important feature of the iRepository is its integration with LMS internal data. This means that an item in the repository could be associated with its usage by the end user, usually the students. This feature is important to support future work leading to IRT (Item Response Theory) [11] or some data mine to extract information about the item related to the student performance [12].

In order to validate the proposed model, an implementation of it to the Moodle system was designed.

III. IQUIZ: IMPLEMENTING THE PROPOSED MODEL

The model implementation adopts some Moodle packages to serve as basis for the authoring component; a question and test assessment specification (IMS-QTI 2.1) to deal with interoperability issues and a repository.

The Moodle packages considered are: Module Quiz; the iDCR repository and the iAssign Moodle package. Quiz was aforementioned in introduction and will be further explained. iDCR (Interactive Digital Content Repository) is a proof of concept of a repository that is integrated to Moodle [13]. iAssign is a Moodle free package that allows incorporating Interactive Learning Modules (iLM) [14], and it is available at http://www.matematica.br/ia. Also, iLM provides means for integrating interactive learning tools to any LMS. Usually an iLM is an applet Java.

iAssign is a Moodle package that provides means for authoring interactive intense instructional content since it integrates iLM to Moodle. Whenever an iLM allows automatic assessment, the same is true for the derived interactive intense instructional content. Therefore, iQuiz's underlying idea is to incorporate a new type of question to the Moodle Quiz using the iLM in a similar way iAssign does it.

The IMS-QTI is acronym to Question and Test Interoperability, a specification to promote interoperability between LMS when considering tests [15]. It was initiated in 1999 and is under the responsibility of the IMS Global Learning Consortium (http://www.imsglobal.org/qti.html). The IMS-QTI 2.1 specification can express interactive and parameterized assignment, meaning that any student can get a different instance of the exercise. Additionally, with IMS-QTI 2.1 it is possible to express constraints between interdependent parameters to assure that any instance of the exercise has the same level of difficulty [10].

The last component considered in iQuiz is the repository, an essential tool to easy share any educational content (or Learning Object - LO) [16]. The iQuiz repository component is iRepository, an extension of the iDCR.

Therefore, the authoring component of the model is an extension of Moodle Quiz in order to provide questions of iLM type, which means questions (ideally) with interactivity intense with automatic assessment resources, and interoperable resources. The extension also will allow other types of questions as the ones based in constraints with IMS-QTI 2.1 (e.g. advanced Math [16]). Also, a new user interface will be provided to deal with limitations described in [9]. It is represented by the iQuiz Question Type in Fig. 2.

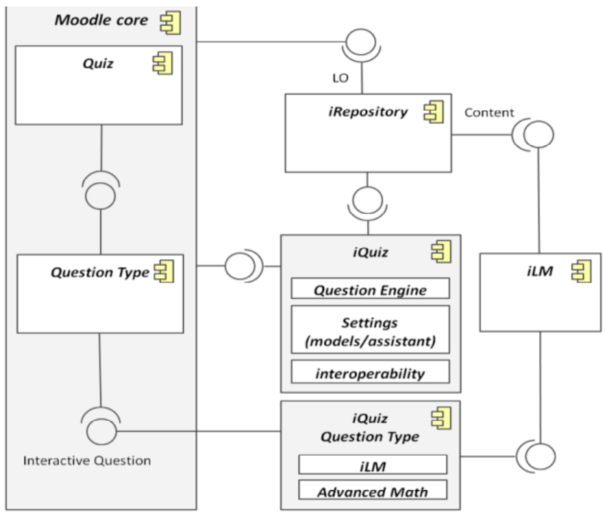

Fig. 2 iQuiz big picture

The interoperability component provides the usage of questions under the specification IMS-QTI 2.1. It feeds the authoring component with information to import and export the questions to IMS-QTI 2.1 specification, through Question Type Component of Moodle (it is represented in component iQuiz of Fig. 2). It also allows the description of questions types that follow Moodle standards, as well as new question types such as iLM and Advanced Math. In addition, it is used by the iRepository to maintain conformance with instructional content standards for content description and assessment.

Fig 2 presents the big picture of the model implementation. The iQuiz core could have several new types of question. In particular, it has the iLM type of question and one type of questions from IMS-QTI 2.1.

IV. Related Work

In [20] is reported the combined use of Moodle Quiz with the WIRIS quizzes, since they are already integrated. WIRIS quizzes (CAS) are developed to enhance the computer-based assessment in mathematics and science when integrated to an LMS. It offers: (i) formula edition at authoring time and formula visualization at presentation time; (ii) WYSIWYG input of formulas in the student answers of an open question; and (iii) formulas are input in the common mathematical notation [21]. Nevertheless, it didn´t provide interactive intense content within questions, since it is an algebraic (symbolic) system. Therefore, questions description looks like in a book and interactivity is just the immediate feedback provided by the automatic assessment resources.

STACK is another open-source system to assess elementary algebra [22], with emphasis on formative assessment. It provides a question type for Moodle Quiz and the STACK questions are the ones whose answers are mathematical expressions. It adopts a computer algebra system to evaluate whenever an answer is right. iQuiz will provide more than one Moodle question type, since each iLM [6][17][18] will define one question type. There isn't any citation about the importation or exportation of STACK question types to IMS-QTI 2.1 as will be for iQuiz.

V. Conclusion and Future Work

In this paper we presented a model for creating and integrating educational assessment content and iQuiz, its implementation as an integrated module to Moodle, one of the most known and used LMS within the world.

iQuiz extends the Moodle module Quiz by incorporating new question types, specially the one which provides interactive intense questions generated using iLM. Also, it provides interoperability resources to encourage assessment content sharing and reuse. Nevertheless, iQuiz is integrated with a repository that provides instructional content storing and retrieving in a granular fashion, meaning that questions may be searched and retrieved in isolation or in group, as a full questionnaire.

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Teaching strategy focused on sensory perception, students' interest and enjoyment:

Successful application in Electrical Engineering (EE) lab for non-EE majors

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***Abstract*—We report the development and successful teaching of new laboratory experiments for a large introductory course in Electrical Engineering (EE) for non-EE majors. Our goal is to create the learning environment that would engage students' senses; provide hands-on experience, to which they can easily relate; stimulate intuitive understanding of EE concepts; foster enjoyment of learning, and eventually, help them succeed in their own fields. The first experiment focuses on applications of Fourier series to the spectra of sounds of music played on a Virtual Keyboard®. In the second experiment, students solder their own filter circuit to serve has low-pass/high-pass audio filters, and then they apply their filters to an excerpt of music, with the goal of understanding effects of the filter transfer function on the audio signal through listening. Both experiments expand the conventional range of application of theory and circuits in introductory courses (usually, only standard waveforms are used, e.g. sinusoidal and square). In the scheme of the entire course, all lab projects aim to introduce realistic, practical applications that pique student interest, show students the relevance of electrical engineering, and help them transfer their newly learned skills and experience to their own fields of work and future studies.**

Keywords— Laboratory instruction; motivation; non-majors; Electrical Engineering; hands-on learning; sensory perception; student interest; student feedback

I. INTRODUCTION

Recent, unprecedented progress of Electrical Engineering (EE) have made it necessary for non-EE engineering students to take at least an introductory EE course in order to be successful in their specialties. Creation and teaching service courses for non-EE majors is a challenge for instructors due to many reasons, starting with the selection of concepts to cover and the ways to present them in the ways that non-EE students can relate to their fields of major. Taking these courses and passing them with success may become a struggle for students, also for several reasons. One of the difficulties is that non-EE students see EE as very abstract and non-intuitive compared to other engineering fields. In Mechanical Engineering, things move, get hotter or colder, break under stress; in Chemical and Materials, samples undergo obvious changes due to chemical reactions, etc. By contrast, what happens in EE is mostly invisible (because electrons are so small) or abstract like a wiggle on the screen of an oscilloscope. Psychologically, the main venue of learning EE is via abstract thinking, while sensory perception remains only weakly involved. Clearly, this style of teaching can be successful only for a few learning styles [1]. As a result, students' interest in the course material and motivation in learning EE can be undermined. Eventually, the students may suffer because they miss valuable learning of EE that may help them advance in their fields of major.

Our goal is to create the learning environment in our introductory EE service course for non-EE majors (average enrollment ~190 per semester) that would engage students' senses; provide hands-on experience, to which they can easily relate; stimulate their intuitive understanding of EE concepts; foster their enjoyment of learning, and eventually, help them succeed in their own fields.

In other reports, we have already outlined the overall structure of our course and its Lab component, and described the results of our detailed surveys of student learning. Here we focus on two new Lab experiments created and introduced in 2012, which help students relate the abstract concepts of Fourier spectra and transfer functions of various filters to their favorite pastime – listening to music and engaging in Internet activities. Noteworthy, this is not mere entertainment: our students perform all "mainstream EE" measurements in the lab, solder their own filter circuits and test their characteristics, and write full-fledged lab reports with printouts of oscilloscope screenshots, etc. Our surveys conducted in Fall 2012 indicate that these experiments were very important for the development of student understanding of the course material and their appreciation of value of EE for their further learning and work.

Other authors also studied various aspects of teaching EE to EE and non-EE majors, including lab projects. For example, Sterian et al. [2] developed a project-based approach to teaching introductory circuit labs with a special focus on intuitive understanding of simple circuits. Unfortunately, their report does not provide information on the enrollment in their course, and includes only a cursory description of the surveys conducted in connection to the newly developed projects. Hajjar and Sobahi [3] described the design of an introductory EE course for non-majors. From communication with universities, professors, research groups, and industry, they identified the need to present application-focused material, multidisciplinary systems with different types of sensors, and familiarity with software used outside the classroom (e.g. LabVIEW) but do not mention the laboratory component. Malik et al. [4] examined the challenges that non-EE students encounter in an introductory EE course and emphasized the need for content that would be more engaging and relevant to students' interests. Northrup [5] reported innovative lab experiments with many interesting and circuits of practical importance including temperature and light sensors, feedback control of motor speed, and music equalizers, but the level of difficulty is seemingly too high for non-EE majors.

Our approach is unique, because it engages students in several types of activities, from learning the theory to working with modern software to soldering a filter circuit to doing measurements of waveforms, spectra, and transfer functions with the oscilloscope. Psychologically, it helps students blend their mental picture of abstract concepts with sensory perception of music and invites them to explore their favorite music using the strategies and skills learned in EE, with test/measurement instruments in the lab and the filters they built themselves.

In this report, we present the contents of experiments, comment on the teaching experience and logistics in a large class, and summarize the students' feedback (obtained through anonymous online surveys in multiple-choice and open-ended question formats). Lastly, we discuss how our lab projects address several ABET General Criteria for Student Outcomes [6].

II. Background

A. Course Overview

The course for which we have developed the lab projects is an introductory Electrical Engineering service course intended for non-EE majors. The goals of the course include:

- ✓ Help non-EE students learn the key EE concepts and skills they can use in projects across many fields of engineering
- ✓ Highlight practical applications in which EE is used
- ✓ Provide a hands-on, insightful, and enjoyable lab experience

The laboratory component of the course includes 8 lab projects, each designed to be 2 hours in length for students working in groups of 2.

B. Student Audience

We first offered these new lab experiments to 156 students in the Fall 2012 term, although we ran a pilot test of many of the innovations in the Spring 2012 term for 34 students. In Fall 2012, the student audience was comprised of 90 juniors, 64 seniors, 1 sophomore and 1 graduate student, with the primary audience coming from Mechanical, Aerospace, and Nuclear engineering departments (see Fig 1).

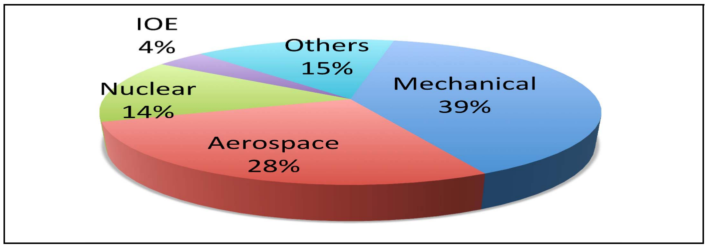

Fig. 1. Student enrollment for this course in the Fall 2012 term

III. Lab Projects

A. Spectra Lab

The Spectra Lab has been developed as 3 modules, in which students explore:

(1) Spectra of standard signals
(2) "Fourier Synthesis" of standard waveforms from their sinusoidal components
(3) More complex spectra, i.e. that of musical instruments

In the first module, students use the function generator to produce standard signals (sine, square, and ramp/sawtooth waves) and the oscilloscope to observe the waveforms and acquire their Fast-Fourier Transform (FFT) spectra. They are then asked to compare their lab data with theoretical predictions. This module follows a traditional and conventional approach to exploring frequency composition and Fourier synthesis of standard waveforms.

In the second module, students continue their studies of Fourier spectra through the use of the **Fourier Synthesizer.vi** – a LabVIEW ® program that builds standard waves as partial sums of harmonics, displays the waveform, spectrum, and analytic formula (see Fig 2). We also incorporate sensory perception by asking students to play the sounds of these signals via a speaker and appreciating the distinctions in what they hear. This aural perception of waveforms enhances students' understanding of the abstract concepts, and it serves to complement their visual observations.

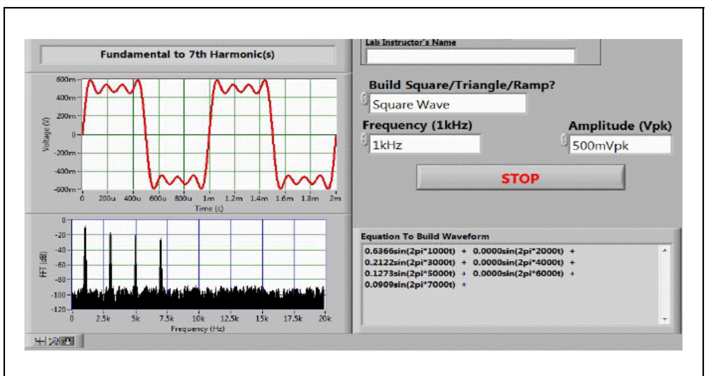

Fig. 2. The front panel of **Fourier Synthesizer.vi** includes the fields to be filled by the user (choice of waveform, frequency, and amplitude) and the windows where the computer builds the desired signal (the waveform, its FFT

spectrum, and the algebraic expression used to calculate the sum of sinusoidal spectral components).

The third module is our most recent innovation within the Spectra Lab, and it extends upon the studies of the frequency composition and Fourier synthesis of standard waveforms to sounds more familiar to students, namely those of common musical instruments. These musical instruments are simulated by a Virtual Keyboard® software program freely available on the Internet (see Fig 3). In the pre-lab, students play the Keyboard and guess how many harmonic components are involved in the sounds produced by various instruments and predict the distinctions in spectra and waveform based on what they hear, e.g. the Flute vs. Bass guitar, etc. In the lab, they play the same sounds and use an oscilloscope to measure the actual waveforms and spectra (an example of a measurement taken in the lab is shown in Fig 4). Students compare their lab data with their intuitive expectations; then they are encouraged to measure the waveforms and spectra of their favorite music, which is the fun part of the lab and provides an opportunity for additional exploration for the motivated student.

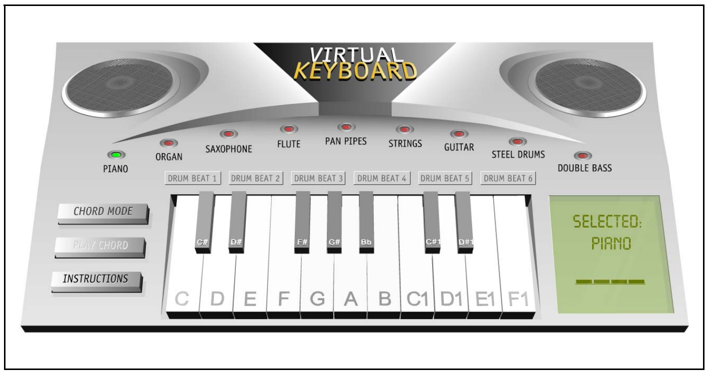

Fig. 3. A screenshot of the Virtual Keyboard software, found on the Internet at http://www.bgfl.org/custom/resources_ftp/client_ftp/ks2/music/piano/. Students have the opportunity to explore sounds produced by a variety of instruments and musical notes.

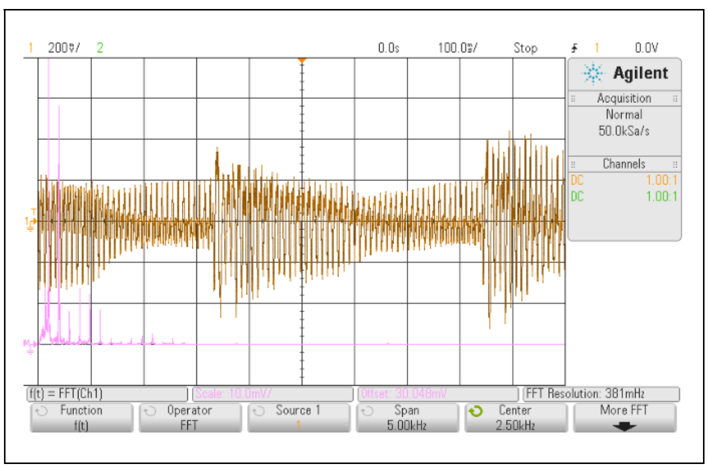

Fig. 4. A screenshot of the oscilloscope screen showing the waveform (orange trace) and FFT spectrum (purple trace) for the signal produced when the note G is played for the Virtual Keyboard's Double Bass instrument.

B. *Filters Lab*

The Filter Lab has been developed as 5 modules, in which students:

(1) Solder their own filter circuits
(2) Apply the soldered circuit as a Low-Pass filter and characterize its transfer function
(3) Apply the soldered circuit as a High-Pass filter and characterize its transfer function
(4) Use their soldered circuits to explore the resonant response in LC and RLC
(5) Apply their Low-Pass and High-Pass filters to the sounds of music

In the first module, gain experience in soldering their filter circuit, for which they are given step-by-step instructions along with numerous photographs. The specific circuit that they build is shown in Fig 5. Students are then asked to perform a few basic measurements to test the connections they have soldered, as this circuit is used in all subsequent modules. The components were carefully chosen so that the circuit can serve as RC Low-Pass and High-Pass filters in the audio range as well as LC and RLC filters that can clearly demonstrate resonant response.

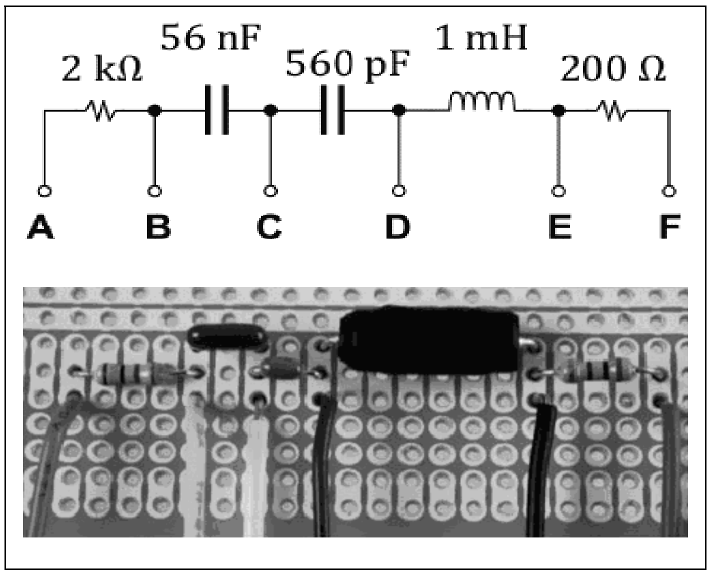

Fig. 5. The circuit diagram (top) is provided to students, and in the lab they are asked to build the circuit according to the diagram. The photograph (bottom) shows the final soldered circuit. The two left-most components, namely the 2 kΩ resistor and 56 nF capacitor, are used for modules 2, 3, and 5, while the remaining components are used for module 4.

In the second/third modules, students connect their soldered circuits as Low-Pass/High-Pass RC filters and investigate the effect of the filter transfer function and cut-off frequency. These two modules follow a more traditional approach to understanding filters, as students apply their circuit filters to sine waves and compare the output response of the filter to theoretical predictions of the frequency response. In addition, students use **Bode Plot.vi** – a LabVIEW ® program that generates plots of the transfer function magnitude vs.

frequency for the specific filter over a user-input range of frequencies (see Fig 6).

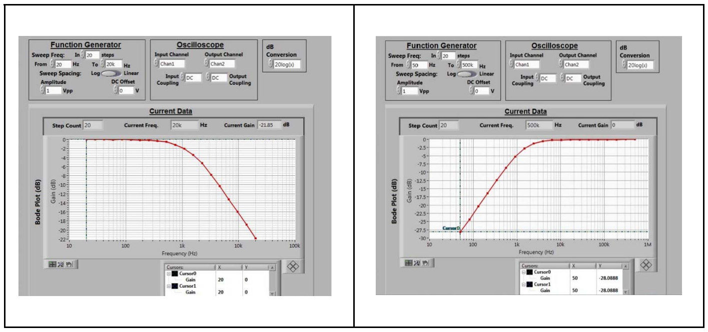

Fig. 6. Screenshots of the front panel of the **Bode Plot.vi**, showing the plotted transfer function magnitudes for the Low-Pass filter (left) and the High-Pass filter (right)

The fourth module addresses the topic of resonant response. Students use the function generator to apply a 30-period "burst" of a sine wave at the resonant frequency of an LC/RLC circuit, and they examine the buildup and decay of the resonant response, noting the distinctions between the LC and RLC circuits. Students are also asked to understand and explain how the phenomenon of resonance is consistent with conservation of energy.

The fifth module is our most recent innovation within the Filters Lab, and it extends upon the studies of the transfer function magnitude and cutoff frequency by applying it to a favorite pastime of students, namely listening to music. The audio clip used in this experiment is an excerpt from the Beatless song *Help!* It was specifically chosen because it is comprised of sounds from sources that occupy three separate spectral regions: bass guitar, vocals, and cymbals/percussion (see Fig 7).

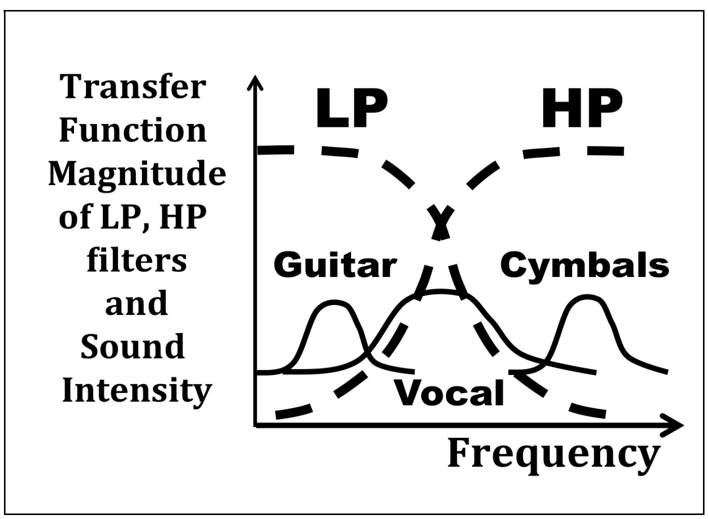

Fig. 7. A sketch that approximately indicates the three spectral regions of the music, relative to the transfer function magnitudes of the Low-Pass and High-Pass audio filters soldered in the lab.

In the Pre-Lab, students use the freeware Audacity® found on the Internet to create digital low-pass and high-pass filters with the same cutoff frequency as the in-lab filters, and listen to the clip through each filter and without filtering. In the lab, they apply their soldered filters to the provided excerpt of *Help!* and listen to the sounds produced with and without filtering. When no filter is applied to the audio, students can clearly hear all three sources of sound. Through the Low-Pass filter, students can no longer hear the high-frequency percussion, whereas through the High-Pass filter, students can no longer hear the bass guitar. Students can then compare the listening experiences with the digital filters from the Internet and with their own soldered filters. By listening to these effects, students can relate their sensory perception to the theory of transfer functions. At the same time, the experiments have been designed in a way that students find fun, relevant, and applicable to the real world.

Lastly, students are given an opportunity to apply their audio filters to their own selection of music. We encourage them to bring their mp3 players to the lab and observe the effects of filters on various types of sounds found in their favorite songs, allowing for open-ended exploration driven by student-specific interests.

IV. Student Feedback

To evaluate the success of our lab development in the context of student learning, we designed and implemented a set of comprehensive surveys for each Lab. Each set of surveys contain multiple-choice and open-ended questions, facilitating quantitative and qualitative evaluation. We used a professional version of SurveyMonkey® to collect responses from students and separately collect their personal information (so that we could provide them a small amount of extra credit for completing the survey) in a way that maintained student anonymity. Here we report a summary of students' responses to survey questions for the Spectra Lab and Filters Lab.

A. Spectra Lab

Our multiple-choice questionnaires for Spectra Lab focused on identifying whether or not students found the labs applicable, interesting, and helpful in reinforcing concepts learned in lecture. We presented the questions in the form of statements for which we asked students to evaluate their agreement (given a choice between "Strongly Agree", "Agree", Neither agree nor disagree", "Disagree", and "Strongly Disagree"). Statistics for five of the statements we asked (see Table I) are highlighted in Fig 8. Between 80-90 students participated in this survey.

TABLE I. Statements for Spectra Lab Multiple-Choice Survey

	Statements for Spectra Lab
Q1	"I feel that my learning in Lab 5 is valuable for what I do outside this course"
Q2	"I had enough time in the lab to think about what I was doing"
Q3	"I understood each step of the In-Lab work"
Q4	"I feel that my learning in previous Labs (1-4) helped me in

	Statements for Spectra Lab
	Lab 5”
Q5	“Lab 5 has been interesting”

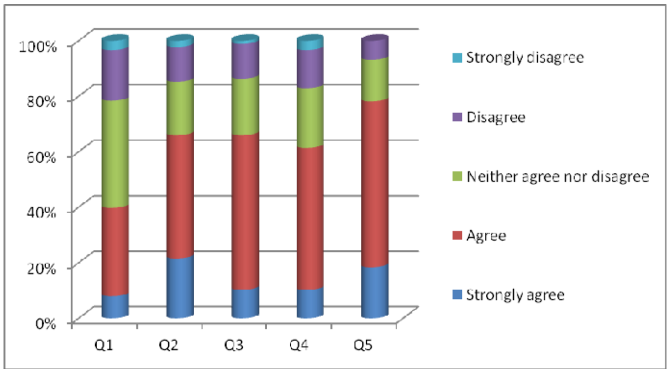

Fig. 8. Distribution of student responses to statements about the Spectra Lab. The statements Q1-Q5 are listed in Table I.

Based on the results of the surveys, we can infer a number of points:

- Nearly 40% of students indicated (via the choices “Agree” or “Strongly Agree”) that they found the Spectra Lab valuable to their work outside the course.
- Over 65% of students “Strongly Agree” or “Agree” that there was enough time to think and understand what they were doing in lab.
- Student interest is one of the major achievements of the Spectra Lab, since over 75% of students responded with “Agree” or “Strongly Agree” for statement Q5.

The open-ended questions provide further insight into students’ experiences in the Spectra Lab. We can also identify common “key words” that different students used when answering these questions. Presented below are a few select student responses that capture the overall student sentiment.

For the question, “What is the most memorable thing about Lab 5?”, more than half of the 91 respondents directly referred elements from the third module. A few representative quotes are provided below:

- “Being able to see the different frequencies and waveforms of the various instruments, it was actually quite interesting to see what we are actually hearing”
- “The most memorable thing was DEFINTELY the experiment about virtual keyboard and the music!! :)”
- “the most memorable thing about the lab was that musical instruments have very different waveforms and spectra than pure tones.”

To better understand student learning in Spectra Lab, we asked “What do you think is the most important thing that you learned in Lab 5?” We found that in general students referred to spectra decomposition and synthesis of waveforms from harmonics. Some answers that we highlight are:

- “Fourier approximations finally make sense”
- “The most important thing I learned in lab 5 was Fourier's theorem. I have seen this in other classes, and now that I have seen a practical application, the theorem is more clear. This theorem is very important for my other classes in my major.”

To see students’ evaluation of the applicability and relevance of Spectra Lab to their work outside the course, we asked “How can you apply your Lab 5 experience to your endeavors outside the course?” Many students referred the understanding of spectra, circuitry bandwidth, and Fourier analysis. However, a number of students felt the lab material, although interesting, was not directly applicable to their engineering work, but rather in musical hobbies. This calls for the need to strengthen the connection between the Spectra Lab material to non-EE engineering applications.

B. Filters Lab

The format of our multiple-choice questionnaires for Filters Lab is identical to that for Spectra Lab, although our set of questions is slightly different. Statistics for six of the statements we asked (see Table II) are highlighted in Fig 9. Roughly 90 students participated in this survey.

TABLE II. STATEMENTS FOR FILTERS LAB MULTIPLE-CHOICE SURVEY

	Statements for Filters Lab
Q1	“Listening to music helped me understand how filters work”
Q2	“I feel that my learning in Lab 6 is valuable for what I do outside this course”
Q3	“I had enough time to think about what I was doing”
Q4	“I understood each step of the In-Lab work”
Q5	“I feel that my learning in previous Labs (1-5) helped me in Lab 6”
Q6	“Lab 6 has been interesting”

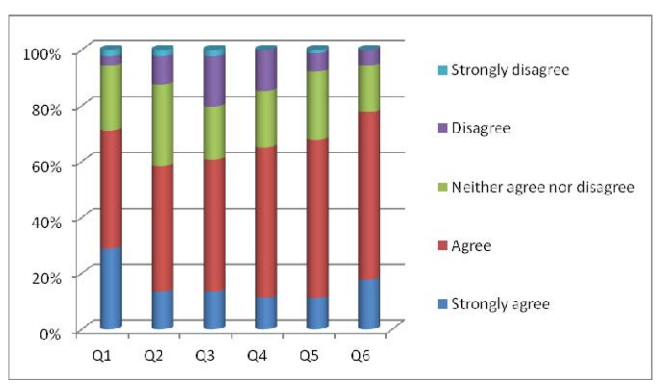

Fig. 9. Distribution of student responses to statements about the Filters Lab. The statements Q1-Q6 are listed in Table II.

Based on the results of the surveys, we can infer a number of points:

- Over 70% of respondents ("Strongly Agree" + "Agree") felt that the music component of the lab contributed to their understanding of filters.
- Nearly 60% of students found the learning experience in the Filters Lab applicable outside of the course, which is significantly higher compared to the 40% for Spectra Lab.
- Again, a major achievement of this lab is in regard to student interest, where nearly 80% of respondents "Strongly Agree" or "Agree" with statement Q6.

For the open-ended survey about Filters Lab, we asked similar questions as we did for the Spectra Lab. We provide highlights of the Filter Lab open-ended survey data below, for which we had roughly 97 respondents.

When we asked, ""What is the most memorable ... interesting ... insightful thing about Lab 6?", over two-thirds of students mentioned soldering experience and about half of the students referred to components of the fifth module, namely applying filters to music. The responses indicate that students enjoyed this lab and particularly liked the hands-on experience. Further, they indicated a sense of accomplishment for having built a complete circuit for which they could perceive its effects and evaluate its functionality in the lab. Some representative quotes from student responses are given below:

- "I really enjoyed soldering my own circuit and seeing/hearing first hand how the high/low pass filters work was great."
- "It was interesting to hear how filters work instead of just trying to understand how they work without any evidence."
- "I liked listening to the Beatles song to see how low pass and high pass filters affected the song. It was a much more memorable and interesting way to sense the frequency."

We also specifically asked students their views on the music aspect of the Filters Lab. In general, we received positive, interesting, and occasionally unexpected answers, for example:

- "This part was very interesting. This was the part that helped me understand the physical aspect of harmonics of waves and their frequencies. The sounds of music was not exactly relevant to my interests, however it did help me understand (just a bit more) the construction of wave functions that apply to quantum mechanics (Nuclear Engineering)."
- "It is VERY cool certainly! I find it amazing that I now have the knowledge to build a music filter, and it is VERY much relevant to the field of study I am interested in. It has helped me to see the effects of what we do in theory on a VERY COOL real life application :)"
- "More coursework should be like this. Engagement = learning."

To evaluate student learning in the Filters, we asked, "Has this lab strengthened your understanding of the connection between theory (both the physical concepts and mathematical formulations) and experiment (what you do, see, hear, and observe in the lab)? If yes, how? If no, then what do you think is lacking?" Nearly all responses were positive, for example:

- "Yes. Before, I only understood it through the formulations and looking at the circuits on paper. Having to build the certain filters and then hearing the sounds and lack of sounds helped put a physical result with what I had thought I knew. It helped legitimize the theory."
- "Yes, the use of the music signal was especially illustrative."
- "Yes, being able to see something happen in electrical engineering is rare, let alone being able to build something. If we could build something in every lab, this would be the best lab ever (as long as we don't have to print a lot of graphs)."

V. Discussion

From our teaching observations and survey evaluations in the course, we find success in our lab development efforts. In particular, we note positive results and experiences in the aspects of student learning, understanding, interest, and motivation. We also see that students have an improved appreciation for the applications of EE concepts to their respective non-EE fields of work.

Our lab development also addresses ABET General Criteria for Baccalaureate Level Programs. Specifically, we highlight our achievements towards 5 criteria for Student Outcomes [6].

(3a) an ability to apply knowledge of mathematics, science, and engineering
(3d) an ability to function on multidisciplinary teams
(3e) an ability to identify, formulate, and solve engineering problems
(3i) a recognition of the need for, and an ability to engage in life-long learning
(3k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Our lab projects have students apply abstract concepts of spectra and transfer function magnitude to the familiar, everyday aspect of music to become comfortable with the EE concepts. They learn valuable EE skills, such as soldering and using various instruments, tools, and components to generate, alter, observe, and analyze waveforms and spectra. Eventually, students learn to connect their understanding of EE concepts to their engineering work as well, and they appreciate the benefit of this life-long learning process. This is in accordance with criteria (3a), (3i), and (3k).

In this course, and particularly in the lab, we establish an atmosphere conducive to multidisciplinary work. Given the diversity in the student audience, student interact with others different majors and backgrounds. Also, the EE lab instructor and the course material and projects are of a different major/discipline than the students. This multidisciplinary environment addresses criteria (3d).

Lastly, these lab projects expose students to engineering problems and solutions that they may encounter in the real-world, in accordance with criteria (3e). Interestingly, many students initially overlooked or at least undervalued the fact that music and other arts have rich engineering applications. These lab projects have the goal of broadening students' perspectives and inspiring them to be open-minded as they look for innovative ways to apply their engineering skills.

VI. ACKNOWLEDGMENT

This work has become possible due to ongoing attention of Khalil Najafi and Dave Neuhoff to undergraduate education, including the lab instruction. We greatly appreciate the support of the Department of Electrical Engineering and Computer Science, ECE, in many aspects, including financial support for S. S. for the course development during the summer 2012. We are grateful to the Center for Research of Learning and Teaching, especially, the Engineering section, for many opportunities to present and discuss our work. We thank Rob Giles and Mike Stander for their excellent help in the lab.

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N-FUELS and SOPRANO: Educational Tools for Simulation, Analysis and Processing of Satellite Navigation Signals

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***Abstract*—In recent years, research activities in the field of Satellite Navigation have boosted worldwide. At the same time, it has become evident that few educational opportunities in the field were available for students and there was a need to develop dedicated tools for hands-on sessions. To partially answer this need, the NavSAS Group has developed N-FUELS and SOPRANO. N-FUELS, a MATLAB®-based signal simulator, allows students to understand the physical layer of the Global Navigation Satellite Systems (GNSS) signals and to learn how to manipulate them via software. SOPRANO, a collection of ANSI C language routines, implements the whole chain of GNSS signal elaboration in post-processing and enables testing and validation of new GNSS signal processing algorithms and architectures. Both tools are used in post-graduate courses at Politecnico di Torino with a high degree of internationalization, which opens interesting points of discussion concerning the introduction of novel educational tools able to meet the demand and the learning styles of students with different educational backgrounds and cultures.**

I. Introduction

In the last decade, research activities in the field of Satellite Navigation have boosted worldwide. New Global Navigation Satellite Systems are under design and deployment, such as European Galileo or Chinese BeiDou, while already existing systems, such as US GPS or Russian GLONASS, are undergoing modernization processes. This has led not only to an enlargement of the GNSS scientific community but also to the birth of companies interested in GNSS-based products and services. As a consequence, a number of new jobs are expected to be available in coming years worldwide in the field of GNSS and its applications. On the other hand, few educational opportunities focused on this topic are presently available for students [1]. This was recognized by the European Commission, that started actions to foster and support initiatives in this field [2] so as to educate the future GNSS engineers and researchers. At the same time, there was a need to develop new dedicated tools which professors could use in courses and hands-on sessions.

This fact was particularly evident to our research group, who has been involved in educational activities on GNSS for almost a decade. One example is the Specializing Master on Navigation and Related Applications [3], a post-graduate programme offered by Politecnico di Torino since 2004, where we teach some modules on Satellite Navigation Systems and Receivers. The Specializing Master is offered in English and this opens it to the participation of international students: on average over 50% of students are from outside Europe. This makes the Specializing Master an interesting melting pot where different educational backgrounds and cultures merge. The result is an international community of people trained in GNSS who are expected to be the tomorrow technical and scientific work force in this field.

II. Two educational software tools for GNSS-oriented students

Learning from experience of many years of courses on signal and system simulation, as well as from the practice of designing and testing algorithms for the core signal processing in GNSS receivers, we felt the need of developing simple and flexible software tools to, on the one hand, simulate a wide variety of GNSS signals at their physical layer; on the other hand, to build a completely open software architecture of a GNSS receiver, modular and simple enough to be used as a training ground for the implementation of functional blocks in real-time architectures, such as those presented in [4]–[7].

The two software tools we have developed are a MATLAB®-based signal generator (N-FUELS, FUll Educational Library of Signals for Navigation), and an ANSI C complete GNSS receiver (SOPRANO, fully SOftware fully Programmable GNSS Receiver for Algorithm testiNg and validatiOn). Their basic characteristics are reviewed in the following subsections. What is worth highlighting right now, is that these two tools have allowed us to provide the students with highly reliable software tools, which overcome the initial difficulty of simulating quite complex signal architectures [8] and propagation effects, as well as realistically reflect the signal flow in a receiver and the logical sequence of the receiver's states.

A. N-FUELS: FUll Educational Library of Signals for Navigation

N-FUELS is a MATLAB®-based signal simulator designed to offer a complete and intuitive software tool which simulates the physical layer of GNSS signals, as they appear at the Analogue-to-Digital Converter (ADC) output of a receiver's front-end, either at Intermediate Frequency (IF) or at baseband [9]. From an already trained user's perspective, it allows neglecting all the issues related to the correct implementation of the signal structure (including spreading code

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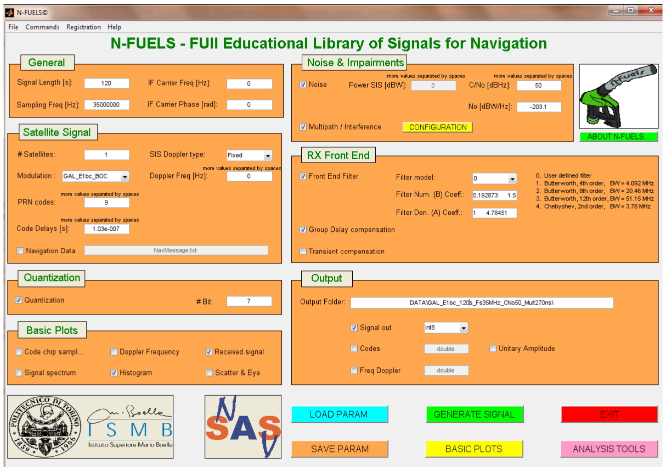

Fig. 1. A screenshot of the N-FUELS graphical user interface.

generation) and of a number of common propagation effects, such as propagation delays, Doppler shift effects, thermal noise, multipath and various models of interference. From a students' perspective, it is a tool that directly and simply puts in their hands samples of the signals introduced of during the lectures; observing such simulated signals, students can get an immediate understanding and a hands-on experience of several signal properties and propagation effects.

The goal of being an intuitive and wide-use tool is pursued without loosing flexibility and generality. Indeed, the GNSS signals supported by N-FUELS are all civil GPS services (including signals under modernization), all open Galileo signals, and the EGNOS signal. The student can control several parameters of the simulation through a very user-friendly Graphical User Interface (GUI), where he/she can act on several settings. Namely, three families of settings are provided:

- *parameters related to the Signal-In-Space (SIS),* including the length of the simulation, the number of simulated signals, the signal modulation, the PRN codes number, the code delays, the Doppler model, and the received signal power;
- *propagation channel parameters,* including Carrier to Noise density ratio (C/N_0), thermal noise spectral density, multipath (a static N-ray channel model is embedded, with selectable N), disturbance models (continuous wave, filtered noise-like interference, pulsed interference, inter/intra-system interference, emulation of a spoofing attack);
- *receiver front-end parameters,* including sampling frequency, intermediate frequency, front-end filter model, possibility to compensate the filter group delay and its transient time, number of quantization bits, format of the output binary file (double, float32 or int8 sample representation).

A screenshot of the GUI is shown in Fig. 1.

In addition, N-FUELS includes a set of simple signal analysis tools for quickly testing and monitoring several signal metrics [10]–[13]: for example, power spectral density estimation, group delay estimation associated to a certain front-end filter model, auto correlation and discriminator curves, multipath error envelope and running average curves, spectral separation coefficients, etc... Again, this set of simple tools for the signal analysis is a fast bridge for students towards the undestanding of the basic properties of the GNSS signals, allowing them to circumvent the "obstacle" of coding, at least at a very early stage.

B. SOPRANO: fully SOftware fully Programmable GNSS Receiver for Algorithm testiNg and ValidatiOn

As the acronym suggests, SOPRANO is an ANSI C-based fully software receiver, which implements the post-processing GNSS signal elaboration. It processes, i.e., acquires, tracks and uses for PVT (Position-Velocity-and-Time) estimation, both the GPS-SPS (Standard Positioning Service) and Galileo OS (Open Service) signals. It accepts as input binary files, containing the ADC output samples, either generated by N-FUELS or recorded from a GNSS front-end, such as for example [14], with up to 8 quantization bits. Thus it can be employed to process either simulated signals in a completely ideal environment or real signals. The current version of the receiver supports only real IF samples, but future releases will also include the baseband elaboration.

SOPRANO has been expressly thought as a lab instrument for signal processing, enabling developers (either trained researchers or graduate students) to describe, test and validate GNSS signal processing algorithms and architectures. It takes also advantage of the processing speed of the C language, differently from other famous software receivers [15]–[17] which employ MATLAB® as modeling language. Similarly to the GNSS Software Defined Radio (SDR) receiver in [18], it aims at being an open-source and public reference receiver, both with educational and training purposes. SOPRANO implements all stages of the whole processing chain, by means of state-of-the-art algorithms only, making it a non-patented and completely free solution. Thus, as N-FUELS, it meets the needs of both trained and student users. While a student can get a deep understanding of the GNSS processing flow, looking how the learned theory becomes practice, the trained user can easily found and modify the desired functions, thus testing his own solutions. The handiness in use of SOPRANO is one of its main features and its crucial point. First of all, its ANSI C structure does not need special libraries, which aids the fully portability among different compilers and different operative systems; furthermore, the user can openly access the entire source code, making the desired changes wherever he/she wants.

The code structure is easy to read: it is organized in a sequence of folders, each one including a list of source and header files, belonging to the same processing stage. For example, the directory entitled "acquisition" collects all functions related to the signal acquisition, while that called "tracking" contains those devoted to implement the tracking loops, and so on. All the signals/data/measurements needed to perform signal elaboration are included in structures which are accessed through the use of pointers, avoiding other less intuitive ways of data access, such as First-In-First-Out (FIFO) data structures, sockets, etc. The name itself of all data structures and functions always refers to their functionality. SOPRANO's flexibility is allowed by the intrinsic nature of its software implementation. In fact, besides working with different IF front-ends, thanks to a simple text configuration file, also several processing setups can be changed via other simple configuration files, for example the number of coherent/non-coherent sums in acquisition, Doppler and code delay resolutions, gain and bandwidth of the frequency and code discriminators, early-to-late spacing of the correlators and so on. This allows the user to quickly create his tailor-made receiver.

III. EXAMPLES OF PROPOSED EXERCISES

In the frame of the Specializing Master on Navigation [3] introduced in Section I, the *GNSS Introduction* course introduces the mathematical description of the physical structure of the GNSS signal, including all the current signals and those under modernization. It also discusses the issues of interoperability and coexistence among different GNSSs.

Another advanced course on *GPS and Galileo Receivers* gives students a knowledge about the fundamental architecture of a GNSS receiver. The course combines theoretical principles about the employed algorithms and hints about their implementation in real GNSS receivers. In order to reach this target, the course combines both theoretical lectures and practical assignments.

In this section, a couple of assignments, proposed to the students during the mentioned courses, are shown as examples of the employment of N-FUELS and SOPRANO in education. The first exercise is focused on the use of the Spectral Separation Coefficient as a tool to theoretically assess inter-system interference. The second exercise is about the algorithms to acquire the GNSS signal in a typical receiver.

A. Exercise 1: Evaluation of Spectral Separation Coefficients

The spectral separation coefficient (SSC) [12] is a theoretical method proposed to assess the level of inter-system interference among GNSS signals (and also between a GNSS signal and an interferer). The SSC is a measure of the spectral coupling between two signals, defined as a sort of inner product of the normalized power spectral densities of the two signals, evaluated over a certain front-end bandwidth. The average SSC is defined as [12]

$$\kappa_{is} = \int_{-B_{fe}/2}^{B_{fe}/2} G_i(f) G_s(f)\, \mathrm{d}f \qquad (1)$$

where $G_i(f)$ is the unit-power power spectral density of the signal i (taken as the interference) and $G_s(f)$ is the unit-power power spectral density of the reference signal s. Once evaluated the SSC κ_{is}, the effective carrier to noise density ratio can be computed, where the interference component is assimilated to an additional noise effect.

Having commented such a metric during classes, it is effective for the students to see examples obtained in simulation. With this aim, a specific assignment based on the use of N-FUELS is proposed in the course. The text of the assignment is reported in Table I.

TABLE I. TEXT OF THE EXERCISE ABOUT SPECTRAL SEPARATION COEFFICIENTS

Exercise 1
Objectives: Understanding the spectral separation coefficient.
Description: The spectral separation coefficient (SSC) is a theoretical metric that measures a normalized level of interference between two GNSS signals (or a GNSS signal and a certain interferer). It is based on the measure of the "overlapping portions" of the power spectral densities of the signals of interest. Here we want to evaluate the SSC between a CBOC modulation and the other modulation formats of the GNSS family (BPSK(1), BPSK(5), BPSK(10), BOC(10,5), BOC$_c$(15,2.5)).
Use N-FUELS to generate 100 ms of each of the above signal formats at the intermediate frequency $f_{IF} = 0$ MHz, sampled at 50 MHz, received at the power of 0 dBW without noise. Set the Doppler frequency to 0 Hz. The receiving filter is ideally flat on the digitization bandwidth and there is no quantization. Generate the estimated Power Spectral Density (PSD) of each signal (*hint:* save your simulations in different output folders, one per configuration, so that you can reuse your data sets).
Superimpose each estimated PSD to that of the CBOC signal and observe the portion of overlapping spectra. Then set the file of the parameters for the SSC analysis (`ParamSSCoefficients.txt`) to produce the SCC for each modulation with respect to the CBOC.
Questions:

1) Use N-FUELS to obtain a table of the SSC for each modulation format with respect to the CBOC one; sort in descending order of SSC value.
2) Observe that the "amount" of overlapping portions of the spectra, as seen from the PSD figures by simple inspection, is compliant with the numerical results put in the table.

TABLE II. SPECTRAL SEPARATION COEFFICIENTS BETWEEN THE CBOC MODULATION DEFINED FOR GALILEO E1 AND OTHER POSSIBLE COEXISTENT MODULATION FORMATS

i	BPSK(1)	BPSK(5)	BOC$_c$(15,2.5)	BPSK(10)	BOC(10,5)
$\kappa_{i,\text{CBOC}}$ (dB/Hz)	-61.94	-69.18	-70.28	-72.60	-73.59

1) Comments about the assignment: The students are expected to comment the result of this assignment during their oral exam. The simulation through a numerical computation of the formula (1) enables the students to fill a table with SSC values for different modulations, with respect to the CBOC one. The comparison between these results and the figures, where the corresponding PSDs are actually superimposed, should ease the understanding of the SSC concept. For example, the table of the SSC values is reported in Table II, while the estimated power spectral densities for the two "extreme" cases of maximum and minimum SSC's are shown in Fig. 2.

B. Exercise 2: SW Implementation and Test of an Acquisition Algorithm for a Galileo E1b/c Signal

In a GNSS receiver, the signal transmitted by one satellite is received using local replicas of the carrier and the spreading code employed by the transmitting satellite. The main task of the receiver is to obtain the alignment between these local replicas and the received signal: the receiver must produce a

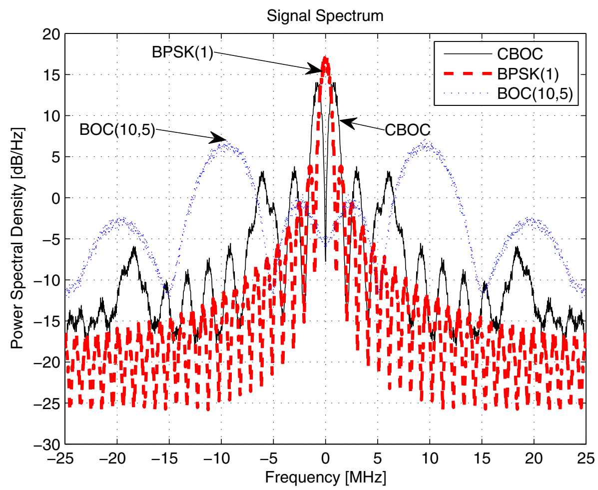

Fig. 2. Power spectral densities of the modulations analyzed in Exercise 1. The minimum separation of the spectra, as measured by the SCC, is obtained between CBOC and BPSK(1), as their main lobes partially overlap. On the contrary, the maximum spectral separation is obtained between CBOC and BOC(10,5), whose main lobes are well separated in frequency.

local replica of the spreading code with the same code rate and delay as the incoming signal, and a local replica of the carrier with the same frequency and phase of the incoming carrier. Such synchronization is the key point that allows to correctly estimate the distance between the satellite and the receiver and, consequently, to evaluate the position. The acquisition stage gives the receiver a first rough synchronization with the incoming signal, whereas the following stage, named tracking, refines and updates the alignment [10] [19].

1) The assignment: After a lecture about the theory of the GNSS signal acquisition, students are required to implement main acquisition algorithms that can be found in literature [15] both in MATLAB® and in C language. The text of the assignment is reported in the Tables III and IV.

2) Comments about the assignment: In Exercise 2a (Table III), students implement acquisition algorithms using MATLAB®. This approach allows the students to focus on the employed algorithms and almost ignore implementation details. In this way, they can acquire a deeper knowledge of the subject if compared to what can be obtained with a pure theoretical lecture. Under these conditions, the use of N-FUELS is a key point. Using signals generated by N-FUELS, students have a perfect control over the unknowns of the acquisition (carrier frequency, code rate and delay): this facilitates the debug of the implementation. Moreover, the use of N-FUELS enables an easy generation of signals at different carrier to noise ratios, making possible the part of the exercise when students verify the effects of noise on acquisition results. Fig. 3 shows a graphic obtained solving Exercise 2a.

The MATLAB® implementation of the acquisition algorithms hides some unnecessary details, but it is very far from an implementation able to elaborate samples of a signal from an antenna or from a hardware signal generator. In order to teach students the architecture of a software receiver able to elaborate real signals, Exercise 2b requires the use of SOPRANO (see Table IV). As stated in Section II-B, SOPRANO does not exhibit the performance required to elaborate the signal from an antenna in real-time, but its architecture directly derives from a real-time fully software receiver able to do it [4]. Consequently, the insertion of the new acquisition strategy in SOPRANO allows the students to understand the architecture of a software GNSS receiver able to elaborate real data. Moreover, they can experience which are the most critical parts of the receiver and why they demand an optimized implementation, in order to cope with performance requirements for the elaboration of a real signal.

TABLE III. TEXT OF THE FIRST EXERCISE ABOUT ACQUISITION

Exercise 2a
Objectives: Implementation of the Parallel Acquisition Schemes in Time and Frequency domain.
Description: Following the MATLAB® given example (SerialSearch.m) for the Serial Search Acquisition scheme, write two functions that implement the Parallel in Time and Parallel in Frequency acquisition schemes.
Use N-FUELS to generate the code and signal sequences necessary to test the behaviour of the SerialSearch function: generate a few ms of a GPS L1 signal (f_{IF} = 4.152 MHz, fixed Doppler shift at e.g. 1.5 kHz, without noise, without front-end filter, without quantization). Then generate 1 ms of the local code (same PRN as before, same sampling frequency, code delay = 0 s, Doppler = 0 Hz, without noise, without front-end filter, without quantization)
Questions:

1) Read from the corresponding data file the code and signal sequences and pass them to the SerialSearch function. Visualize the obtained search space and determine the maximum; determine and verify the corresponding estimated code delay and Doppler frequency shift (acquisition parameters). Plot the 1-D search functions along the delay axis (row of the 2-D search space corresponding to the estimated Doppler frequency) and Doppler frequency axis (column of the 2-D search space corresponding to the estimated code delay)
2) Repeat the generation of the signal sequence, with the insertion of the front-end filter. Repeat the signal acquisition and compare the obtained search spaces and estimated acquisition parameters.
3) Repeat the generation of the signal sequence at different levels of C/N$_0$ (e.g. 33 dBHz, 38 dBHz, 44 dBHz, 50 dBHz). Repeat the signal acquisition and compare the obtained search spaces and estimated acquisition parameters.
4) Repeat point 3 by using the other two acquisition schemes: Parallel in Time and Parallel in Frequency.

IV. Conclusion

The use of N-FUELS and SOPRANO in hands-on sessions of courses in the Specializing Master on Navigation have improved students' understanding of the characteristics of GNSS signals and related processing techniques. On the one hand, providing students with well-structured environments where they can “play” with parameters, such as N-FUELS, allows them to acquire the needed sensibility to deeply understand the structure of GNSS signals and receivers. On the other hand, the SOPRANO tool permits to smoothly move to an open

TABLE IV. TEXT OF THE SECOND EXERCISE ABOUT ACQUISITION

Exercise 2b
Objectives: Implementation of one acquisition scheme in a fully software receiver.
Description: Replace the Parallel in Time acquisition employed in the SOPRANO fully software receiver with a C implementation of the Parallel in Frequency strategy.
In particular, open the file "/acquisition/cafEvaluation.c" and modify the `PerformCaf` function, whose prototype is the following:

```
TCafEvaluationStatus PerformCaf
(TSopranoStruct * r, int channelIndex,
char *data1, int size1, char *data2, int
size2);
```

where:

- `TSopranoStruct * r` is the pointer to the main structure, containing all data structures needed by the receiver;
- `int channelIndex` is the index of the channel assigned to a satellite. This parameter must not be changed;
- `char *data1`, `char *data2`, `int size1` and `int size2` are related to the circular buffer which contains the ADC output samples. The first two parameters are pointers to two different chunks of data, while size1 and size2 are the number of samples available at the location data1 and data2 respectively. All these parameters must not be changed, since they involve the receiver framework.
- `TCafEvaluationStatus` is the type of the return parameter, indicating the status of the CAF evaluation. It assumes one of the following values: {`CAF_EVALUATION_IN_EXECUTION`, `CAF_EVALUATION_SUCCESSFUL`, `CAF_EVALUATION_UNSUCCESSFUL`}.

The `PerformCaf` function has access to the data structure `TCafEvaluation *caf`, needed by the acquisition and contained in `r`, as clearly appears looking at this assignment: `caf =&((r->channelArray[channelIndex]).caf)` where `channelArray` is the vector of channels, each one assigned to a different satellite. All the variables that you need to employ to implement the "Parallel in Time" strategy are contained in that structure, while the acquisition parameters are read from the file "configurationFile/acquisitionParameters.txt" and stored in `TAcquisitionParameters *acqPars` structure.

Questions:

1) Repeat simulations performed in Exercise 2a, and compare the obtained results.
2) Discuss the strategies employed in the software receiver in order to reduce the complexity of the employed algorithm.
3) Perform an execution time profiling of the code and list the most critical points that must be further optimized in order to enable a straight execution with samples from an antenna.

In order to be compliant with SOPRANO, input files described in Exercise 2a must be generated using 8 bits per sample.

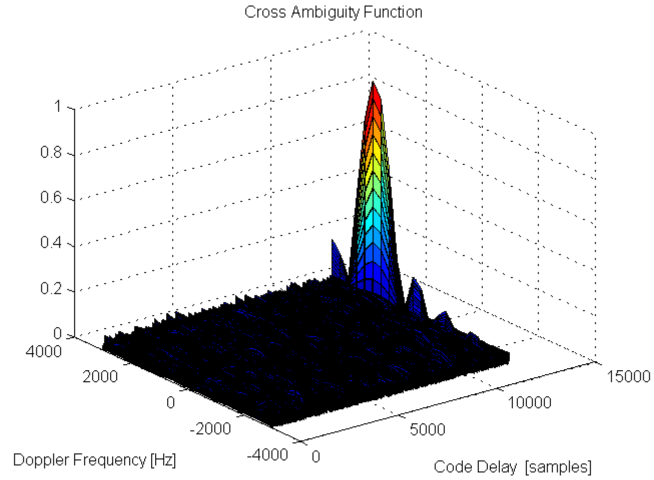

Fig. 3. Graphic representing the result of the acquisition procedure implemented in Exercise 2a. The position of the peak reflects actual values of Doppler shift and code delay.

environment, where students can start experiencing receivers implementations which are more similar to those available in real-time software receivers.

In the on-going edition of the Specializing Master on Navigation we have used for the first time both N-FUELS and SOPRANO in our classes. With respect to past years, when only N-FUELS was used together with a collection of MATLAB® routines, we have appreciated an easiest conduction of hands-on sessions, and a better understanding and acquired knowledge by students. As a matter of fact, being the geographic origin of our students quite variegated (from Africa to Australia passing by South East Asia and, of course, Europe), their background knowledge is not always homogeneous. The use of the two tools allowed us to better overcome lacks of background in programming which we sometimes verify in some of our students. In addition, the exercises discussed in previous subsections proved to be effective for increasing the motivation and the satisfaction of our students, encouraging them in improving their programming skills and providing a practical feeling about GNSS signals and receiver algorithms. At the end of the courses, we received positive and encouraging feedbacks from our students about their experience with N-FUELS and SOPRANO: in detail, we received positive comments from anonymous questionnaires and multiple expressions of interest for possible internships in our research group.

In consideration of the positive results achieved, we are planning to extend the use of these tools to other courses on GNSS in the M.Sc. in Telecommunication at Politecnico di Torino.

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Teaching Electric Circuits Using a Modified Flipped Classroom Approach

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***Abstract* - This paper describes our initial effort to implement a flipped classroom approach to teach an Electric Circuits course. Prior to each scheduled class meeting, students are required to watch a recorded short lecture, which covers the topics in details and includes simple worked out problems. We have used Tablet PC in combination with PowerPoint, OneNote, and Camtasia as the capturing software, to produce the short-recorded lectures. We have also produced a set of narrated dynamically worked-out problems, with different difficulty levels that students are encouraged to watch. These recorded worked-out problems will complement the recorded lectures and help students with their problem solving skills. A typical lecture consists of a quick review of the concepts followed by solving more challenging problems, related to the lecture material. A more detailed discussion of this approach and the advantages and disadvantages of such a scheme are presented. The preliminary evaluations of the proposed approach by a group of students have been encouraging.**

***Keyword* – Filliped classroom, Electric Circuits, Multimedia, Problem Solving.**

I. INTRODUCTION

"Flipping the classroom" is a pedagogical concept that replaces the standard lecture-in-class format with an opportunity to explore concepts and to review materials from outside of class. This can happen in many forms, but the underlying premise is that students review information outside of class and, instead of simply receiving information from the instructor, come prepared to discuss concepts. The "flipped classroom" approach has received considerable attention in recent years in many subject areas but not as much in engineering [1]-[3]. In this work, we describe a modified flipped classroom approach that we have started using to teach an electric circuits course. We first start with a brief background information that would explain the reason behind choosing electric circuits for the implementation process. Electric Circuits (EE 210) is a required course for all Electrical and Computer Engineering students at Penn State. Like most other institutions, EE 210 is the first course in electrical engineering and gateway for subsequent EE core courses. Our statistics indicates a direct correlation between strong performance in electric circuits (i.e. B and above) and subsequent success in the follow-up courses in the EE curriculum. Problem solving has always been the key to success in engineering, it is imperative that all students enrolled in this course obtain a strong foundation in the key theoretical circuit analysis concepts and solution techniques. In this regard, our experience with this course, and similar type courses, indicates that the major instructional problem faced by instructors is that students have difficulty knowing where and how to start a given problem as opposed to the mechanics of problem solving. In order to address these challenges, in our previous works [4]-[6] we reported the development of a set of dynamically worked-out problems, so that students could obtain a greater understanding of the subject matters and increased competency in their ability to analyze basic circuits using the appropriate tools and concepts. Since the proposed approach is not intended to eliminate the lecture portion, we have called it a "modified flipped" classroom approach. We believe the proposed approach enables the instructor to focus more on improving problem solving skills, and consider it as the natural extension of our previous works in this area.

II. PROPOSED APPROACH

The main resources for the proposed approach include (i) recorded short lectures, (ii) a set of recorded dynamically worked-out problems, and (iii) a set of challenging problems for in-class discussions. These resources are made accessible to students via ANGEL [7], our course management system. Prior to the beginning of the semester, based on our previous experiences, we prepared a detailed course schedule including weekly agendas and the other required materials, organized in different folders in ANGEL. The weekly lecture folders contain lecture material and in-class problems, in PowerPoint format. Another folder contains a set of dynamically worked-out problems [4]-[6]. The recorded lectures are produced by using Tablet-PC, Microsoft PowerPoint and OneNote, and Camtasia [8] for recording the auditory explanation and capturing the annotations. We have avoided including challenging problems in order to keep the length of each recording no more than 30 minutes and focus on explaining the concepts. The dynamically worked-out problems were developed based on step-by-step, expert, think-aloud process to model the details of the problem solving process, and thereby scaffold student problem solving. The hypothesized outcome of the narrated engineering problems is the following: Students who listen to and watch the narrated problems will better understand the steps necessary for successful completion. A typical worked-out problem contains links to similar but different complexity level problems.

III. A TYPICAL LECTURE

A typical lecture consists of a quick review of the concepts followed by solving "in-class" problems. These problems are more challenging than the ones in the pre-recorded lectures and are similar to the advanced problems in our dynamically worked-out problems. In order to encourage students to take advantage of the dynamically worked-out problems, we introduced in-class team based problem solving exercises, bonus points were awarded to the first group that would come up with the right answer during the class.

In order to achieve our main goal of enhancing students' problem solving skills, we made sure that the following points are emphasized/covered in every in-class problem:

- Recognizing/identifying the 'type' of problem that is being considered.
- Identifying the tools/laws/concepts that can be used to solve the problem.
- Identifying the most appropriate and efficient approach/tools to solve the problem.
- Setting up the problem given the problem constraints.

IV. MEASURING PROJECT SUCCESS

- We have been able to increase the number of problems that we normally cover in a typical lecture and accommodate more in-depth discussions.
- We have observed that students are more engaged in the classroom discussions and problem solving.
- We have observed a modest increase in the homework and exam grades.

Summary of these comments will be presented at the conference.

V. FUTURE WORK/REMARKS

The following items represent a few of our observations and directions for our future work:

- Watching the pre-recorded lecture should be treated as a course assignment and part of the grading system.
- A process needs to be set up to make sure that students have watched the pre-recorded lectures. Including a set of questions at the end of each lecture is recommended.
- Use of Tablet PC or touch screen devices would enhance the lecture delivery.
- Use of communication tools such as Adobe Connect [9], would enhance the lecture delivery, enables recording of the lecture, and facilitating active student participation.

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Embedded Systems Design Curriculum Conversion from Quarters to Semesters

An Opportunity to Improve an Already Successful Course Sequence

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***Abstract*— In this paper we present a vision of how a sequence of three embedded systems design courses currently being taught for computer engineering technology students will be adapted from a quarter based delivery to a semester based delivery. The conversion brings the opportunity to revise the course contents, platforms used and make changes that will prepare students with a more up-to-date skill set and a robust industrial training. In this work in progress we will present some of the new ideas that will be implemented in our semester courses. After offering these courses multiple times, feedback will be gathered from students and industry, and a future study will be presented outlining the achieved outcomes as compared to our intended outcomes for curriculum continuous improvement.**

Keywords—Embedded Systems Design; FPGA; System on a Chip; SoC; Real Time Operating Systems; RTOS

I. INTRODUCTION

While the Embedded Systems Design (ESD) course sequence that is currently being taught in the Computer Engineering Technology program [1] is in a reasonable steady state, RIT is transitioning from a quarter system to a semester system. This transition provides the opportunity to revise the complete course material, the embedded platforms being used, the contents of the laboratory exercises and the overall type of projects and skills the students will acquire. By listening to our industrial partners, and the trends of academia, this opportunity is being taken to bring more meaningful content in terms of hardware computer architectures as well as to incorporate the latest electronic design automation (EDA) software tools and methodologies.

Previously, the ESD sequence had a significant revision in fall of 2008 when an Altera field programmable gate array (FPGA) platform was adopted as the development platform for the sequence of courses. Additional courses in digital design were also modified for a total of six courses using a single hardware platform development system. The change proposed this time is not as drastic as only the ESD courses will switch platforms. Ultimately, the question that we are trying to answer in this paper is: “For ESD courses, is five years a good time gateway to look into industry practices and update the course contents, platforms, skills, and engineering practices?”

In recent years, ESD courses in our program have been centered on FPGAs and soft-core [2] processors. However, to better provide the skills our students must have to join the workforce, a switch to using FPGA and hard-core processors will be implemented and evaluated. In addition, the new curriculum will further be enhanced with the addition of a course in Real Time Operating Systems (RTOS) and additional background in Digital Signal Processing (DSP).

II. BACKGROUND: STATE OF THE CURRENT PROGRAM

The current quarter-based capstone sequence in Embedded Systems Design consists of three 10-week courses taken in the student’s fourth and fifth year [1]. The focus of these courses is to prepare strong students in both digital hardware design and embedded software design. A wide range of topics are covered in these three courses exposing the students to many facets of embedded design. In these intensive hands-on courses, students gain experience with embedded C programming in both a hard-core ARM Cortex M3 [3] and a configurable soft-core Altera NIOS-II processor [4]. Along with programming skills, students develop embedded hardware design proficiency by creating custom intellectual property (IP) cores and hardware acceleration modules for a System on Programmable Chip (SoPC).

The first course, ESD-I, focuses mainly on computer organization [5]. While the labs focus on a SoPC system, a newly introduced series of homework assignments are performed on a rapid prototyping SoC platform with an ARM processor. These programming assignments create an application platform for investigating topics such as LCD control, pulse width modulation, servo motor control, serial communications, and basic cryptography. Embedded hardware development along with hardware/software tradeoffs are the emphasis of ESD-II. In this course students create their own IP cores to be included on the SoPC. One of the advantages of using a soft-core processor in this course is the ease in which hardware can be developed and integrated into the processor for the investigation of hardware/software tradeoff concepts. The deliverable for the final course in the sequence, ESD-III [6, 7], is an innovative open-ended project targeted to a particular market segment or need. Students are given freedom in choosing their team, their project and their development platform. Some projects are developed with

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industry partners or other academic units within RIT, while others are purely student-driven.

III. Platform Convergence: Industry & Academia

In choosing the best platform and tools to use in our embedded systems sequence, we must consider which skills will be necessary for students to be productive in industry upon graduation. Unfortunately, when it's in a high-tech field knowing what skills they will need can be a moving target. Current industry reports show a trend towards 32-bit processing. 32-bit processors can allow more performance and functionality while maintaining good code efficiency, low cost, and low power consumption. This is evident in the ARM architecture-based processors implemented by a vast number of semiconductor companies. Today, ARM is the most widely used microcontroller architecture in the world. ARM processors can be found in products ranging from smartphones to automobiles to giant neutrino detectors and are especially popular in portable communication devices. ARM powers 90% of the smartphone processing market and has 31% market share in mobile computing. Additionally, ARM has a 60% market share in embedded systems and that is expected to grow to 68% by 2016. Using an ARM based development system will keep students abreast of the most current technology as well as give them a competitive advantage when applying to the myriad of companies using an ARM based processor.

For an ESD course the ideal platform is an FPGA since it is versatile in terms of programmability and re-configurability. However, an FPGA has some drawbacks. Traditionally, FPGA platforms, including the one currently being used in the ESD sequence, have lacked native analog interfaces for communication with external analog interfaces. In recent years, some manufacturers of programmable SoC devices have taken steps to embed analog processing into the platform [8, 9]. The new generation of programmable SoCs, consist of an FPGA platform containing a high performance hard-core processor with one or multiple cores and a large number of digital peripherals. Some platforms now include analog peripherals as well. The two major manufacturers of FPGA devices have announced SoC devices in the current and next generation programmable devices [10, 11].

Given the current state of the industry, it seems logical to evaluate the most up-to-date tools and to offer our students skills on a programmable SoC with ARM architectures, analog interfacing and the capability to design accelerators and coprocessors using a hardware description language (HDL). Evaluation of such development platforms is currently ongoing.

IV. Future Plans: Semester-based Sequence

The conversion from a quarter system to a semester system has provided the catalyst to make improvements to the courses to meet the demands of today's ever-changing technological society. The first change is in the course offerings. Instead of simply converting 3 quarter classes into 2 semester courses, the sequence has been expanded to 3 semester courses. ESD-I, will still focus on computer organization but will include content on performance enhancement and IP core development in an HDL. Concurrent with ESD-I, students will take a course in RTOS. The final course in the sequence, ESD-II, will be a 15 week project-based course

In addition to changes in the curriculum structure, changes are being proposed for the development platform and course content. The soft-core processor development board that is currently being used in ESD-I and ESD-II provides many advantages but is limited in its lack of analog peripherals. Since students will be entering the sequence having already taken a digital signal processing (DSP) class, analog peripherals will broaden the possible content for laboratories and mini-projects. Background experience with analog and DSP will help to make the students more well-rounded embedded designers.

V. Course Outline Proposals

A. Embedded Systems Design 1 (Studio Format)

This course will focus on the architecture and design of embedded systems. Microprocessor, as well as system level design principles will be investigated from both hardware and software perspectives. Fig. 1 below illustrates how parallel activities will be used to comprehend, apply and analyze concepts in peripheral interfacing and industry-standard communications protocols.

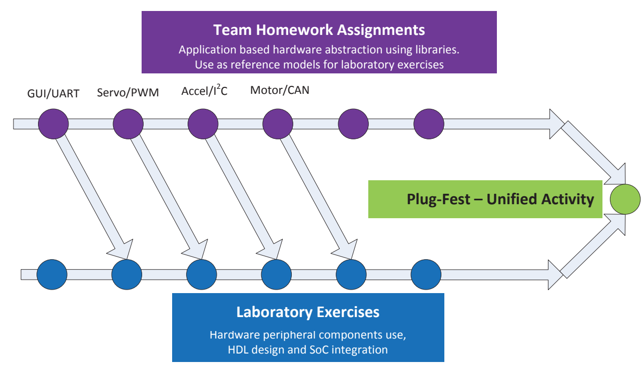

Fig. 1. Sequence of activities to comprehend, apply and analyze the concepts covered in the course.

Both an ARM based rapid prototyping system and the course's FPGA ARM-based development board will be used. Students will first comprehend the concepts by creating applications based on the hardware abstraction, using libraries in the rapid prototyping board. These will be used as a reference as the same applications will be created and analyzed using hardware peripherals; some of which will be written by the students in HDL. A "Plugfest" during which the teams will collaborate to achieve board-to-board communication will be the integrating and culminating experience.

In addition to interfacing, signal datapath algorithmic design will be studied in depth. Hardware/software co-design and partitioning will be investigated and HDL will be used to create hardware accelerators. Upon successful completion of the course, students will be able to design and debug hardware and software systems, evaluate design trade-offs and choose the best design solution, and perform functional and timing analysis of an embedded system.

B. Real Time Operating Systems (Studio Format)

According to the 2013 Embedded Market Survey, 72% of current embedded projects use an operating system, an RTOS, a kernel or a scheduler. With this in mind, we felt it was crucial to add a course in RTOS to our embedded systems curriculum. The RTOS course, currently being developed, will provide students with an introduction to operating systems (OS) theory and practical problem solving approaches to real-time systems. An embedded RTOS will be used as the foundation for a variety of programming projects. To avoid long pre-requisite chains in the curriculum, this course will not be a prerequisite for the ESD I or II courses. Students on schedule will complete the course prior to taking ESD-II and thus will have the option of including an RTOS in their capstone project.

One of the challenges in designing this course from the ground up is the plethora of available textbooks, embedded platforms, and RTOS providers. While the first half of the course will be focused on OS in general, the second half will focus on a specific RTOS and a development platform will be necessary. We are currently soliciting recommendations from our industry advisory board as well as from companies that are willing to support the course with hardware, software, and teaching material. A similar course offered in the College of Engineering will be reviewed for the purpose of leveraging on their experience, but our course must be developed as a hands-on experience as required by engineering technology standards.

C. Embedded Systems Design 2 (Capstone)

This project based course will be an enhanced version of the current quarter-based ESD-III course [1]. The fifteen-week project will represent a culmination of the Computer Engineering Technology curriculum and will include product ideation, Agile and traditional project/resource management techniques and best practices, system level specification, modeling, partition and design, team collaboration and communication, best documentation practices, industry level coding practices, hardware and software co-design methodologies, design reuse and IP creation, design verification and validation, and design sign-off. Students, will have an industry-like embedded system product design experience, starting by developing the vision for a product, including the voice of the customer, and progressing through the phases to develop a complete product prototype. In addition, the students will track and present their progress, make use of version control systems, participate in design and code reviews, demonstrate their product and highlight product differentiation. At the end of the course students will give a formal presentation, product demonstration, deliver professional documentation, review lessons learned and suggest future improvements.

Given that students will have already acquired the knowledge on embedded system design, lecture topics will include project management, team collaboration and best design practices. This course will concentrate on the capstone experience to emulate a real industrial environment and ideation of a novel product from vision through prototyping and demonstration. Students will be free to choose design platform as well as development languages.

VI. CONCLUSIONS

As an opportunity to revise and revamp the curriculum in Embedded System Design the present work in progress present some of the changes proposed to a series of three courses by identifying opportunities where the sequence can be improved and modernized. Trends in industry and technology have resulted in the need to converge to common processor architecture while at the same the main FPGA manufacturers have also come together with a unique solution to the above industry trend. These changes come as a reflection of the last major revision five years ago where a drastic modification was done to these courses and the curriculum in general. If the courses are heavily dependent on training and developing skills for students to join industry, then it is prudent to establish a framework to update highly technological reliant courses every four to five years.

While at this moment it is difficult to propose a single platform, it is intended to explore different FPGA platforms and to come with the best trade-off between the intended learning outcomes and the platform used. The RTOS course could leverage on this decision or it can be set as a standalone course covering the principles using a hard-core processor platform and an embedded RTOS.

It is planned to present the results of the decisions presented here backed up by statistical data, student and industry surveys, as well as by a retrospective of the faculty involved in this work in progress.

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Computer-Aided Instruction for Introductory Linear Circuit Analysis

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***Abstract*—A step-based tutoring system for linear circuit analysis is being developed with the capabilities to automatically generate circuit problems with specified characteristics, including randomly generated topologies and element values. The system further generates fully-worked, error-free solutions using the methods typically taught in such classes, and accepts a rich variety of student input such as equations, matrix equations, numerical and multiple-choice answers, re-drawn circuit diagrams, and sketches of waveforms. A randomized, controlled study was conducted using paid student volunteers to compare the effectiveness of two of our tutorials in comparison to working conventional textbook-based problems. The average learning gain was only 3/100 points for the textbook users, but 29/100 points, about 10 times higher, for the tutorial users. The effect size on the post-test scores was 1.21 pooled standard deviations (Cohen *d*-value) and was statistically significant. A motivational survey administered to these students yielded a 0.53 point higher rating for the software than for the textbook (on a 1-5 scale). The system is being used in Spring 2013 by over 340 students in EEE 202 at Arizona State and two community colleges. About 99% of these students rated the system as "very helpful" or "somewhat helpful."**

Keywords—linear circuit analysis; computer-aided instruction; step-based tutoring

I. Introduction

Linear circuit analysis is a foundational topic for electrical engineers, but is also widely studied by other engineering majors. For example, this course is taught to over 600 students a year at ASU in 11 sections, about 90% of whom are non-majors. Students frequently struggle with this material, due to such factors as delayed or inaccurate feedback on their homework, inadequate use of active and cooperative learning strategies, an insufficient (from the student's perspective) supply of worked examples of carefully graded difficulty, and failure on the part of instructors to recognize persistent misconceptions about basic electricity that students frequently bring into these classes [1-3]. Traditional lecture-based instruction offers only a single pace to all students, regardless of prior knowledge and ability, and inevitably leaves some students bored and others unable to keep up. One method to address these issues is to supplement conventional approaches with computer-aided instruction, which has been employed in a number of prior studies [4-35]. While useful, many of these studies have developed only incomplete or partial prototypes, or have not carried out rigorous evaluations to determine their effectiveness in increasing student learning. There has been little sustained, widespread usage of previously developed systems, and most have not had the ability to generate new circuit problems, which can be a tedious and error-prone task when done by hand.

Publisher-based web sites as supplements to textbooks have been more widely used in recent years. Whereas these sites provide additional resources to students and can be used to automate grading, they mainly provide algorithmic problems, in which some of the element values are varied in a given problem. They are typically answer-based tutors, which provide rapid feedback on the correctness of an answer, but do not accept a sufficient amount or variety of student input to diagnose the reason for a wrong answer (they lack sufficient "bandwidth" in the language of intelligent tutoring systems). A recent meta-analysis by VanLehn concludes that the typical effect size (Cohen's *d*-value) of answer-based tutoring systems is around 0.31, compared to 0.76 for step-based tutors and 0.79 for expert (expensive) human tutors [36]. Thus, we have undertaken to develop a potentially more effective step-based system that can do a better job of analyzing a wide variety of student inputs [37, 38]. Further, we automate the process of generating problems and solutions, eliminating both human error that can result in great frustration to students and the temptation to misuse solution manuals that are widely available on the Internet. This type of system can provide rapid, accurate feedback and an unlimited supply of problems, examples, and solutions of any desired difficulty and complexity.

II. Software design and features

A. Circuit Generation

The algorithms we use to generate circuit problems and solutions have been described elsewhere in detail [37, 38]. We generate circuit layouts rather than netlists to ensure that our circuits are planar so that mesh analysis can be applied. Briefly,

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the circuit generation process involves a series of three steps, to avoid the prohibitive combinatorial issues involved in trying to place circuit elements in a purely random way. We first generate a “topology” with the desired number of meshes, consisting of only shorts or opens placed on a square grid with the desired number of rows and columns. The generation algorithm ensures that it is fully connected and has no “dangling” shorts. It is checked to ensure that it is not “hinged” (i.e., it cannot be drawn so that two parts of the circuit are connected by only a single wire, and therefore constitutes effectively separate circuit problems). In the second step, the desired number of shorts are replaced by generic circuit elements, leaving the others as shorts and leaving all opens permanently as opens. In doing so we place at least two elements on every mesh including the “outer” mesh around the circuit periphery, to ensure that no element is shorted and that there are no meshes of shorts (which would reduce the true number of meshes below the desired value). We then check that this “populated topology” has not become hinged as a result of element placement (which includes shorted elements. If the result is not acceptable, the process is restarted.

In the third step, the generic elements are replaced with actual circuit elements of the desired types. To avoid insoluble (inconsistent) problems, we first find all or many trees of the populated topology. Voltage sources and inductors are placed exclusively on the twigs of a randomly selected tree, and current sources and capacitors are placed exclusively on the links of that tree, thereby avoiding insoluble problems involving loops of only voltage sources or stars consisting only of current sources (resistors can be placed anywhere). The placement algorithm also allows us to limit the number of voltage sources in series and the number of current sources in parallel, and can optionally prohibit passive elements of the same type in series or parallel with each other. Further, it optionally avoids creating problems where a given circuit element is “redundant” and has no significant impact on the rest of the circuit (such as any element in series with a current source or in parallel with a voltage source). The algorithm also has the ability to create a desired (feasible) number of floating supernodes (i.e., supernodes that do not include the reference node), through a combination of source repositioning and/or choice of specific reference nodes. Circuits can also be automatically selected having a desired number of supermeshes. The user also has the option to reject circuits whose node voltages are all controlled directly by voltage sources, or whose mesh currents are controlled directly by current sources, since such problems are relatively trivial to solve. Control variables for dependent sources are randomly selected in accordance with rules described elsewhere [37]. Element values including dependent source gains are then randomly generated within specified ranges, and the circuit is checked and modified as necessary to ensure that it is soluble.

To specify the type of circuit to be generated, the user specifies the number of squares in the grid in both x and y-directions, the number of nodes, the number of meshes, and the number of each type of circuit element to be used. However, any one of the last three quantities is determined by the other two, so that the user has the choice of which two to specify [37].

Once a circuit has been generated, the program randomly selects a user-specified number and type of “sought quantities,” or values of unknowns for which the student is asked to solve. These may be branch voltages, branch currents, non-branch voltages (i.e., voltages that do not appear directly across any one circuit element), or branch powers. We avoid specifying quantities that are trivial to determine (such as a branch current for an element in series with an independent current source). Alternatively, the student can be required to solve for all node voltages or all mesh currents.

B. Solution Generation

The system currently generates and displays complete sets of node or mesh equations and solves them using matrix methods. Equations are automatically adjusted based on a user-selected choice of reference node. There is an optional “pre-simplification” step prior to this solution, in which independent voltage sources in series and independent current sources in parallel are combined into single sources of each type, and in which any passive elements of the same type that are in series or parallel with each other are combined. The circuit diagram can be automatically re-drawn after each such simplification step to illustrate the process to the student. Work is currently in progress to implement a number of other common solution methods, such as use of voltage and current division, superposition, source transformation, and use of Thévenin or Norton equivalent circuits. We also plan to extend the system from its current coverage of DC resistive circuits to cover steady-state AC phasor analysis and transients using both differential equation and Laplace transform approaches. A sample automatically-generated circuit and its solution by mesh analysis are shown in Fig. 1.

C. User Input Modules

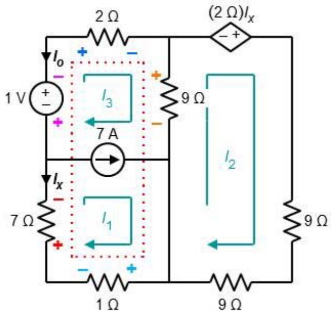
Students input node or mesh equations using a specially designed template interface as shown in Fig. 2, in which they are offered a palette of properly formed terms from which to choose [depending on the type of equation, such as a voltage constraint equation, Kirchoff’s current law (KCL) equation, dependent source control variable equation, etc.]. They can drag these terms into the equation area as needed, and easily reposition or delete them. In Fig. 2, for example, the user has dragged the various terms needed for a KVL equation for mesh 3 from the upper palette into the equation entry area below, and is about to check the equation for correctness. Once the user selects the appropriate templates, they complete each term by filling in the numerical values and subscripts. Students appear to find this interface to be highly intuitive and easily adapt to using it with little or no instruction. The program then indicates immediately if the equation is correct, and optionally displays the correct solution if it was not. In the latter case, the student then has to work an additional problem of the same type to proceed.

Simplified forms of the algebraic equations are entered on a special form designed for that purpose, as is the matrix form of the equations. They are provided with feedback at each stage, so they do not waste time and become frustrated by proceeding to the next stage when they have already made a mistake (as

Circuit Diagram with Mesh Analysis

Compute the following 2 quantities for this circuit:

V_o; I_o



Each colored +/– symbol pair corresponds to a term in KVL equation #1 of 2.

Current constraint equations:

$I_1 - I_3 = 7$ A

KVL equations for each mesh or supermesh:

$I_1(7\ \Omega) - 1\ \text{V} + I_3(2\ \Omega) + (I_3 - I_2)(9\ \Omega) + I_1(1\ \Omega) = 0$

$(I_2 - I_3)(9\ \Omega) - (2\ \Omega)I_x + I_2(9\ \Omega) + I_2(9\ \Omega) = 0$

Equations for control variables of dependent sources:

$I_x = -I_1$

Matrix form of mesh equations:

I_1	I_2	I_3	I_x			
1.000	0.000	-1.000	0.000	I_1		7.000
8.000	-9.000	11.000	0.000	I_2	=	1.000
0.000	27.000	-9.000	-2.000	I_3		0.000
1.000	0.000	0.000	1.000	I_x		0.000

Solution:

$V_o = 3.42$ V; $I_o = 3.58$ A

$V_1 = 3.42$ V; $V_2 = -9.60$ V; $V_3 = -23.9$ V; $V_4 = -22.6$ V; $V_5 = -22.9$ V; $V_6 = -15.8$ V;

$I_x = -3.42$ A

$I_1 = 3.42$ A; $I_2 = -1.45$ A; $I_3 = -3.58$ A; $I_x = -3.42$ A

Fig. 1. Example of an automatically generated problem and solution using mesh analysis.

they would do in typical answer-based tutors). Numerical answers are accepted in a tabular format, and multiple choice responses can also be processed.

Some types of circuit solution (such as superposition, or simplification by combining elements) require students to re-draw the given circuit diagram prior to writing any equations. We have therefore constructed a graphical circuit editor function in which students can modify a given circuit in any required way (or even create a new circuit from scratch). By checking if this step has been completed correctly, we will again be able to avoid letting the student waste time by writing equations for an incorrect diagram.

We are also currently constructing a web-based graphical waveform sketching tool that students can use to draw waveforms as a function of time. This module will be useful when students are given the current through a capacitor and asked to sketch its charge or voltage as a function of time, for example (or similar problems involving inductors). The tool is similar to a vector graphics drawing tool, but will include various scientific functions such as exponentials, sinusoids, piecewise linear functions, and so on. The student input will be checked automatically against a correct solution, without requiring that problems be of a multiple choice format.

Some problems of a more qualitative nature are also being developed, to help dispel typical student misconceptions. An example is one in which a circuit diagram is displayed and students are asked to input lists of which elements are in series or in parallel in the circuit (or which form wye or delta connections). Students typically have difficulty in doing this at first, particularly for the parallel case, which can lead to many other errors in quantitative analyses.

D. Pedagogical Features

We have included a number of items to help students understand and visualize the methods by which circuits can be analyzed. For example, different nodes can optionally be color coded, to help visualize the nodes. The circuit elements can even be temporarily blanked out, leaving only the wires, to help students understand the definition of nodes. We also illustrate sets of elements in series or parallel (or forming wye or delta connections) by selectively highlighting each set in red in turn. Nodes and mesh currents can be automatically labeled and numbered. There are also features to help students understand the origin of node or mesh equations. For example, the currents leaving a selected node or supernode can be automatically labeled with color-coded arrows, in which case the terms of the KCL equation are correspondingly color-coded to match. Similarly, the path around which a KVL equation is written for a supermesh can be labeled automatically, and voltage drops around any selected mesh or supermesh can be labeled with color-coded +/– signs, with corresponding color-coding of the terms in the KVL equation. In Fig. 1, for example, the first KVL equation is the one that has been selected for highlighting, so the supermesh path and +/− signs appear around meshes 1 and 3, which form a supermesh. (In this view, the unknown voltage V_o is not shown.)

E. Tutorial Modules

To date we have implemented three software tutorial sequences on the topics of identifying elements in series and

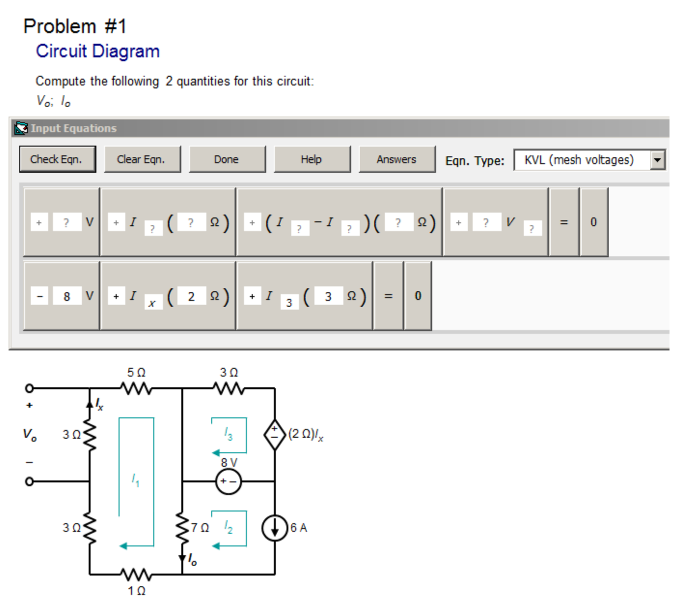


Fig. 2. Equation entry interface.

parallel and on writing node and mesh equations. The series/parallel tutorial includes a sequences of illustrations and examples with associated interactive questions, followed by the option to view examples and complete exercises at four different levels of difficulty. The node and mesh equation tutorials present a brief set of instructions, followed by the opportunity to view worked examples and do exercises at five different levels. Student activity in each tutorial is logged to a server to record their progress, allowing them to stop or re-start at any time. The results can be viewed and downloaded by the instructor. Students are required to complete the highest level of difficulty in each tutorial before receiving full credit. At the completion of each tutorial, a one-question survey is administered and the student can enter comments to provide feedback.

We are also developing scripts for future tutorial sequences, which will be implemented later in software using a planned tutorial scripting and execution interface. A total of 14 scripts have been generated to date, including 5 on node analysis, 5 on mesh analysis, and 4 on basic electrical concepts such as current, voltage, power, KCL, KVL, etc. The scripts outline sequences of instructional material together with interactive questions and exercises that will be posed to the students.

III. LABORATORY-BASED STUDY

To test the effectiveness of our software in improving student learning, a laboratory-based study was conducted in December 2012 using 33 paid student volunteers, all of whom were either enrolled in the relevant course (EEE 202) or had completed it within the last year. Students were given a pre-test and a post-test using two different test forms that were randomly assigned and similar in difficulty. The two topics were identification of series and parallel circuit elements and writing node equations for DC resistive circuits. The students were randomly assigned either to use two of the corresponding software tutorials for a total of one hour (for 25 min. and 35 min., respectively), or to work on similar textbook problems, as they would normally do in the course. All students were given a copy of the course textbook [39] and advised that they could consult any relevant material in it as needed. After completing the post-test, both groups of students were asked to complete the Instructional Materials Motivation Survey (IMMS) developed by Keller to assess the effects of the different instructional approaches on student motivation [40].

The pre-test and post-test data for both groups are summarized in Table I. Both groups had very similar pre-test scores (averages of 59% and 58%), as would be expected from the randomized experimental design. The textbook users had only a small average increase in average score up to 62%, about 3 points higher. The software users saw an approximately 10× larger improvement, to an average of 86% on the post-test. The effect size (Cohen *d*-value) of the experimental condition on the post-test scores was found to be 1.21 in units of the pooled standard deviation of those scores. The difference was statistically significant assuming independent samples (but not equal variances, as they are substantially different) at the 95% confidence interval, $t(19.7) = 3.303$, $p < 0.05$. We therefore conclude that the tutorials are much more effective than conventional homework assignments

TABLE I. LEARNING GAINS IN LABORATORY STUDY

	Exptl. Group	Pre-Test Score	Post-Test Score	Gain
Average	Textbook*	58.6	61.6	2.9
Median	Textbook	60.5	67.0	1.5
Std. Dev.	Textbook	25.3	28.0	14.1
Average	Software**	57.8	86.4	28.6
Median	Software	57.0	85.0	30.0
Std. Dev.	Software	22.1	11.5	14.9
Std. Dev.	Pooled	23.0	20.5	14.1

*16 users. **17 users.

in terms of immediate learning gains. We attribute the difference to the step-based nature of the tutoring process, the rapid feedback provided to the student, their ability to practice or view examples as many times as needed (within the available study time), and the pedagogical features that help them learn to understand the formation and structure of the equations.

The results were better for both the qualitative (series-parallel identification) and quantitative (node equation) topic, suggesting that this approach may be effective for a wide variety of course topics when fully developed. The mean post-test scores for the series-parallel identification were 68% and 91% for textbook and computer users, respectively, and were 57% and 83% for the node equation topic for the two corresponding groups. In particular, the easier node analysis problem (having only independent current sources and resistors, with four nodes) on the post-test yielded a remarkable average score of 98% for the computer users (and only 70% for textbook users), suggesting near-perfect mastery of that level of the topic after only 35 minutes of automated instruction. It is unlikely that most students were able to complete the tutorials during the allotted time, so results on more difficult problems could be even better given more time.

The results of the IMMS are shown in Table II. Overall scores were determined (where 1=least favorable and 5=most favorable response) as well as scores on four subscales corresponding to the attention-relevance-confidence-satisfaction (ARCS) factors proposed by Keller to model the effects of instructional materials on student motivation [40]. The mean score was higher for the software on every scale, though the difference was statistically significant only for the total scores and attention and satisfaction subscales. The relevance factor showed the least difference, which makes sense as both the textbook and tutorials addressed the same topics and the students seem to be making appropriate connections between the practice problems and real-world engineering applications in both cases. The degree to which the software engaged students' attention and especially their overall satisfaction were the biggest differences (the latter being nearly a full point higher for the software users, with a large effect size of 1.27 pooled standard deviations). We believe that it was the ability to repeat exercises and examples without limitation for practice, and the rapid feedback provided on student errors, that led to the higher satisfaction rating. The Cronbach alpha coefficients we measured for the total score,

TABLE II. RESULTS OF INSTRUCTIONAL MATERIALS MOTIVATION SURVEY (SCALE = 1-5, 5=BEST)

Group	Statistic	Total	Attention	Relevance	Confidence	Satisfaction
Software Users	Means	3.54	3.44	3.22	3.94	3.62
	Std. Dev.	0.40	0.49	0.60	0.52	0.66
	Medians	3.57	3.54	3.11	3.83	3.75
Textbook Users	Means	3.01	2.84	2.99	3.51	2.65
	Std. Dev.	0.77	0.80	0.83	0.99	0.91
	Medians	3.01	2.88	3.00	3.72	2.33
Comparisons	Diff. of Means	0.53*	0.60*	0.23	0.44	0.97*
	Pooled Std. Dev.	0.58	0.64	0.70	0.75	0.76
	Cohen *d*-value	0.91*	0.94*	0.33	0.58	1.27*

*Statistically significant difference with $p < 0.05$.

attention, relevance, confidence, and satisfaction scales were 0.932, 0.851, 0.756, 0.855, and 0.838, suggesting good reliability and consistency of the survey instrument, though it is marginal on the relevance scale.

IV. CLASSROOM TRIALS

Preliminary trials were conducted on a voluntary basis in Summer 2012 and Fall 2012 in our course EEE 202, but sample sizes (in either the control group or the experimental group, depending on the class section) were not large enough to make statistically significant evaluations of the effects of the software (though favorable effects were suggested by the data). A much larger trial with strongly encouraged or mandatory participation is being conducted in Spring 2013 with over 340 students in five sections with five different instructors. Assessment of the impact of the software on student learning is in progress, but of course it is challenging to isolate the effects from variations in instruction and students from semester to semester. However, student satisfaction with the tutorials appears to be quite high. At the completion of each tutorial, students were asked to rate the tutorial as "very helpful," "somewhat helpful," "not very helpful," or "a waste of time," and were given the opportunity to enter comments. About 98.5% of students gave favorable ratings of "very helpful" or "somewhat helpful," and 74% rated them as "very helpful." Some sample student comments (verbatim) are shown in Table III. Most negative comments (relatively uncommon) asked for better instructions on the user interface (which we will add), or complained about platform compatibility, as the program currently runs only on Windows with Microsoft PowerPoint installed. A future web-based version is planned to address that issue. Some students requested more detailed feedback on their errors, which could be added in a later version.

TABLE III. SAMPLE STUDENT COMMENTS ON TUTORIALS

Good job on the game! It was actually fun going through it and trying to do a good job! Thanks for making this.
Worked as intended, didn't take too long, kind of fun, and I feel like it helped!
I HAVEN'T EVEN LEARNED IT YET BUT IT WAS REALLY EASY TO GRASP USING THIS! YAY
I really thought it was awesome; it was very helpful. I understood the concepts, but this helped me develop a thought process on it.
I like how you are not marked off for getting on wrong, you just get to try again. You only really fail if you give up, and that is reassuring.
These modules honestly do help me learn circuit analysis. I feel that it is extremely helpful to have a good amount of practice problems, and a system that provides instant feedback. This helps me learn the correct techniques and master
I AM A PRO AT THIS. Major self-confidence booster. Really though, I feel like I'm talented at this node analysis!
It definitely helped me understand supernodes, I think this was more usefull than book work
This exercise helped me understand loop analysis very well. The assignment was great.
I would prefer to have a statistics page showing # of correct and incorrect attempts and possibly even a ladder [leader?] board showing how well different students did as opposed to everyone getting a congratulatory gold medal for doing thier hw
Wow is all i can say... This is the best, better than any hw I have done so far

Some limitations are that the topical coverage is not yet large enough to have a major impact on the overall class (though additional development is in progress), and retention of material from the time of the tutorial completion until the time of exams may be an issue. Refinement of the tutorial to require regular "refresher" exercises is planned to try to address retention. The DIRECT concept inventory [1] is being used as a pre- and post-test, but post-test results for Spring 2013 are not yet available. Additional analysis of the effect on student grades is planned, as is additional usage in future semesters. Ultimately we hope to assess if the students can transfer the knowledge gained using this software to work in subsequent courses and to real-world engineering applications.

V. CONCLUSIONS

Our progress in developing a system to automate the generation of problems and solutions for linear circuit analysis has been described, as well as initial incorporation of these modules into a tutorial system that can be used for homework assignments in this type of course. The rapid feedback characteristic of a step-based tutor, pedagogical features, and unlimited practice opportunities appear to be very popular with students and increase learning in laboratory-based trials compared to conventional textbook exercises by a factor of about 10. Additional work is needed to expand the scope of material covered by the system, and to refine the user interface and platform compatibility. The modular system is designed to be very flexible, so that it could be used, for example, to generate homework problems and solution manuals for a conventional textbook, to automate the generation and grading of individually customized homework assignments, to generate problems for examinations and quizzes, and to create problems for interactive in-class exercises. The overall approach of this system may be extendable to a number of other domains in engineering education as well where students must solve problems of well-defined types, such as logic circuit design, statics, and so forth.

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First-Year Students' Understanding of Direct User in Open-Ended Problem Solving Activities

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***Abstract*— This paper presents an investigation into First-Year Engineering (FYE) students' ability to identify the direct user in open-ended client-driven problem solving activities. To guide FYE students in formulating an open-ended problem, students are asked a series of questions about the stakeholders, the direct user of the solution, and its needs. The purpose of these questions is to help students think about the problem individually by listing stakeholders including the direct user and the stakeholders' relationships to the problem and its solution prior starting to solve the problem in teams. One hundred (out of ~1600) students' responses to three open-ended problem solving activities during two successive semesters were randomly selected and analyzed. Results showed improvement in students' ability to identify the direct user over time. The majority of students' responses shifted from identifying non-users instead of direct user in the first MEA, to identifying indirect-users in the second MEA, and to identifying direct user correctly in the third MEA. This shows a clear improvement in students' ability to understand these problems over time. However, even for the third MEA, only 60% of students identified the direct user correctly, raising concerns about comprehension of the problem by about 40% of the students.**

Keywords — first-year engineering; open-ended problem solving; model-eliciting activities; direct user

I. INTRODUCTION

In two required First-Year Engineering (FYE) courses at Purdue University, students are engaged in open-ended problem solving activities referred to as Model-Eliciting Activities (MEAs). MEAs were originally created for research in mathematics education [1]. MEAs are realistic problems, lead to generalizable solutions, and require students to engage in mathematical modeling, self-assessment to improve their solutions, and document generation to communicate their solutions [1]. These principles are used to design MEAs for the FYE program at Purdue University [2]. In the FYE program, MEAs are completed by student teams through an iterative solution process. The completion of MEAs requires communication, team working, critical thinking skills, and problem formulation.

Problem formulation is a primary and an essential step in solving open-ended problems such as MEAs [3] and design problems [4]. One of the goals of problem formulation is to develop effective problem solving strategies [5]. Some scholars (e.g., Voss & Post [6]) believe problem formulation can affect the success or failure of the entire problem solving process. Because of its importance, problem formulation has been studied in the context of open-ended problem solving, especially design problems.

Studying the differences between expert and novice designers using a novice-expert conceptual framework [7] reveals that experts spend significantly more time on problem formulation compared to novices [4, 8, 9]. Beginner designers tend to skip this step and try to solve the problem and generate solutions immediately [10]. Compared to beginner designers, informed designers tend to do research about the problem and the users [11] leading to a better understanding of the problem [12] and consequently a better problem formulation and higher quality solutions. Since beginner designers are used to solving problems with one best answer [10], they apply the same methods to solve a design problem. They tend to solve the design problem without any research about the problem or looking for any additional information [4, 13]. Asking students explicit questions about the users of the problem solution and their relationship to the problem and reporting their results as a preliminary step, before solving the problem, can help students gather related information and achieve a better understanding of the problem [3, 4].

In the context of MEAs, similar to design problems, doing research about the problem and its users may help students to understand and formulate the problem. In the FYE MEAs, the primary step is a careful reading and mental sorting and processing of the problem text. Identifying the user of the problem solution and obtaining additional information can help problem solvers achieve a better understanding of the problem, its relationship with stakeholders, and find a solution [4]. Research studies (e.g., [3, 4]) identify problem formulation and acquiring relevant information as an important step in solving open-ended problems such as MEAs. Solving a MEA under specific constraints, within a context, and to meet clients' needs requires understanding of problem complexity and having background knowledge about or experience relevant to the problem [3].

Similar to beginner designers, first-year engineering students tend to skip problem formulation and acquiring

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information, and attempt to solve the problem immediately as a problem with one best solution. Some scholars (e.g., Salim & Diefes-Dux [3] and Crismond & Adams [4]) suggest asking students explicit questions about users as a teaching strategy to guide students in problem formulation and information gathering activities.

To guide FYE students to formulate the problem and acquire necessary information to solve a MEA, students are individually asked to answer a few questions before solving the problem in teams. The questions include the following:

- List stakeholders who may be impacted by your deliverable and explain the relationship between the stakeholder, the problem, and the deliverable.
- Consider list of stakeholders. Who is the direct user of the deliverable?
- What does the direct user need? (Remember to describe the deliverable, its function, the criteria for success, and constrains.)

The purpose of these questions is to help students think about the problem individually by listing stakeholders, including the direct user, and their stake in the problem or solution before starting to solve the problem in teams. The direct user is an individual or team (typically inside the client company) who will use the students' solution. By answering the first question, students should think about all related stakeholders and the impact the deliverable will have on them. This listing of stakeholders prior to answering the question of "who is the direct user?" was added to the set of problem formulation questions in Fall 2011 when in prior semesters it was found that students struggled to answer the direct user question. The aim of the second question is to identify the person(s) that would use the product. The purpose of the third question is to enable students to describe the problem in some details including the deliverable, its function, and the constraints.

Although answering all three questions is important for students' understanding of the problem, identifying the direct user is a primary and important step in solving the problem. If students are not able to identify who uses their solution (the direct user), it is less likely that they know what the direct user needs and will not be able to develop a high quality solution. Therefore, in this study we focus on students' understanding of the direct user.

II. Research Questions

This paper investigates first-year engineering students' understanding of the direct user in MEAs by answering the following research questions:

- Who do first-year engineering students identify as the direct user in open-ended problem solving activities?
- Does students' ability to identify the direct user change over time (with solving multiple MEAs)?

III. Methods

A. Participants/Settings

In Fall 2011 in a required FYE course with about 1700 students one MEA, the *Travel Mode Choice* MEA was implemented. In Spring 2012, in the consecutive required FYE course with about 1600 students, two MEAs, the *Just-in-Time Manufacturing* MEA and the *Shredded Document* MEA, were implemented. Prior to starting the *Travel Mode Choice* MEA, students received classroom instruction on how to answer these questions for a sample MEA. From students who enrolled in both courses and participated in all three MEAs, 100 students were randomly selected. The selected students' responses to the questions of "who is the direct user?" in the three MEAs were extracted and analyzed for this study. The followings are brief descriptions of each MEA.

1) Travel Mode Choice MEA

The *Travel Model Choice* (*TMC*) MEA [14] was the only MEA implemented in Fall 2011 and the first MEA that students participated in. This MEA is about student transportation to University of Central Florida's (UCF) campus. A consultant company, E3 Trans Consultants, has been hired by the Department of Physical Facilities Management of UCF (indirect user) to develop the next campus master plan. FYE students are asked to help the planners group within the consultant company (the direct user) by developing a model to predict UCF students' travel mode choice. See Appendix A for the E3 Trans Consultant executive director's (indirect user) memo to students.

2) Just-in-Time Manufacturing MEA

The *Just-in-Time Manufacturing* (*JITM*) MEA [15] was the first MEA in Spring 2012 and the second MEA for the FYE students in the 2011-12 cohorts. This MEA provides students with potential shipping companies that can be used by the client company, D. Dalton Technologies (DDT), to deliver product between two subsidiaries (Ceramica to Bowman) in a Just-in-Time fashion. Data consist of a record of the shipment delays for each shipping company. CEO of DDT (indirect user) asks students to develop a procedure to rank the shipping companies using this data. This procedure will be used by the DDT logistics manager (direct user) to rank potential shipping companies. The data sets provided to the students are not normally distributed, encouraging close examination of the distribution of data in addition to central tendency and variance to solve the problem [16]. See Appendix B for DDT company CEO memo to the students.

3) Shredded Document MEA

The *Shredded Document* (*Shred*) MEA [14] was the second MEA implemented in Spring 2012, and the third and last MEA for FYE students. In this MEA, Federal Security Services (FSS) is a freelance security consulting firm with numerous governmental contracts including high profile cases. FSS needs to develop software to recover the documents that have been shredded. The evidence document manager (indirect user) of FSS asks students to develop an algorithm to help the software development team (direct user) by developing an algorithm to be used in the software.

See Appendix C for the FSS Company evidence document manager memo to the students.

B. Data Analysis

Following a coding scheme developed by Salim and Diefes-Dux [3], students' responses to the question of "who is the direct user?" for all three MEAs were coded. The coding scheme includes the following codes:

- Direct user: who will use the deliverable.
- Indirect user(s): who may need to understand, evaluate, or use the deliverable indirectly.
- Non-user(s): who will not use the deliverable or unknown responses.
- Mix: any combination of the previous codes.

IV. RESULTS

A. Travel Mode Choice

The *TMC* MEA was the only MEA in the Fall semester and the first MEA students were exposed to. In this MEA, in answering the question of "who is the direct user?", about two-third of students identified non-users or unknown entities instead of the direct user (Table I). Less than one-third of the students correctly identified the direct user. A few of the students identified indirect users or reported more than one entity. Table I shows the number of students' responses in each code category for the *TMC* MEA and a sample response for each category.

B. Just-in-Time Manufacturing MEA

The *JITM* MEA was the first MEA in the Spring semester, and the second one that students participated in. In this MEA, more than two-third of the students identified indirect users instead of direct users (Table II). In this MEA, and similarly to the first MEA, less than one-third of the students correctly identified the direct user. A few of the students identified non-users instead of the direct user. Table II shows the number of students' responses in each code category for the *JITM* MEA and a sample response for each category.

C. Shredded Document MEA

The *Shred* MEA was the second MEA in the spring semester, and the third (and last) one that students participated in. Unlike the two previous MEAs, in answering this MEA, about two-third of the students identified the direct user correctly (Table III). However, about one-third of the students identified indirect users. A few of the students identified non-users instead of the direct user. Table III shows the number of students' responses in each code category for *Shred* MEA and a sample response for each category.

TABLE I. NUMBER OF STUDENTS' RESPONSES AND A SAMPLE RESPONSE FOR EACH CLIENT TYPE FOR *TMC* MEA.

Client Type	Description	Sample Response	Number of Responses
Direct User	Planners group at E3 Trans Consultants	"The direct user is Planners Group. They are a division of E3 Trans consultants".	27
Indirect Users	Departmenr of physical facilities and its manager, E3 Trans Consultants and its executive director	"University of Central Flori[d]a's Department of Physical Facilities they will take our predictions into account to improve the transportation services on campus".	7
Non-Users	Any entities not listed above including but not limited to students, faculty, UCF (in general), bus company, and its staff	"The direct user of the deliverable will be the students and faculty at University of Central Florida that use the bus system everyday to get around campus faster and more efficiently".	65
Mix	Any combination of direct, in-dierct and/or non users	"1.Planner Groups 2.other universities campuses 3.federal, state and local government"	1
Total			100

TABLE II. NUMBER OF STUDENTS' RESPONSES AND A SAMPLE RESPONSE FOR EACH CLIENT TYPE FOR *JITM* MEA.

Client Type	Description	Sample Response	Number of Responses
Direct User	DDT logistics manager	"The Logistics Manager of DDT will be the direct user of our procedure as it is his job to choose a shipping company using the deliverable".	24
Indirect Users	DDT company including Ceramica and Bowman, DDT CEO	"Devon Dalton, CEO of DDT (D. Dalton Technologies), is the direct user".	69
Non-Users	Any entities not listed above including but not limited to manufacturer, shipping companies, and customers of DDT	"The direct user is the manufacturer because they are the ones who will control the time it takes to produce and ship the products to the costumers."	4
Mix	Any combination of direct, in-dierct and/or non users	"DDT, cust[o]mers, shipping company"	3
Total			100

TABLE III. NUMBER OF STUDENTS' RESPONSES AND A SAMPLE RESPONSE FOR EACH CILENT TYPE FOR *SHRED* MEA.

Client Type	Description	Sample Response	Number of Responses
Direct User	FSS software development team	"The direct user is the FSS Software Development Team".	61
Indirect Users	FSS and its Evidence Documents Manager	"The FSS's Evidence Document Manager, Dorothy Belding, is the direct user".	34
Non-Users	Any entities not listed above including but not limited to prosecutors, alleged criminals, and alleged victims	"authorities who need to un shred documents"	2
Mix	Any combination of direct, in-dierct and/or non users	"The direct user is the firm, Federal Security Services, and specifically the Software Development Team".	3
Total			100

D. *Students' responses over time*

Table IV summarizes the students' responses to the question "who is the direct user?" over time for the three MEAs. In the first MEA, *TMC*, students mostly indentified non-users. In the second MEA, *JITM*, students mostly identified indirect-users. In the third and last MEA, *Shred*, students mostly identified the direct user. These results show improvement in students' responses over time with solving more MEAs. However, after participating in two MEAs, about 40% of students could not identify the correct answer in the third MEA. Overall, 33% of students never identified the correct answer in any of the three MEAs.

TABLE IV. SUMMARY OF STUDENTS' RESPONSES FOR THREE MEAS. (GRAY CELLS SHOW THE MAJORITY OF RESPONSES FOR EACH MEA).

Client Type	MEA		
	TMC	***JITM***	***Shred***
Direct user	27	24	61
Indirect user	7	69	34
Non-user	65	4	2
Mix	1	3	3
Total	100	100	100

V. DISCUSSION

Analysis of students' responses to "who is the direct user?" shows improvement in responses across the three MEAs. Students' responses to the first MEA indicate a poor understanding of the problem and its stakeholders, which most likely leads to a low quality solution. In the second MEA, while the number of correct answers (identifying the direct user) was similar to the first MEA, students' responses shifted from non-users to indirect users. This indicates an improvement in students' understanding of the problem and its stakeholders from the first to the second MEA. In the third and last MEA, students mostly identified direct users correctly, a clear indication of improvement in the comprehension of the problem.

The findings of this paper confirm previous research suggestions, such as Salim and Diefes-Dux [3] (in the MEA context) as well as Crismond and Adams [4] (in the design context). Asking students direct questions about the user of their solution encourages them to read the problem statement (including the provided memo) more carefully, think about the users, and try to understand the context of the problem in order to be able to answer the questions. This helps the students understand the problem and prevents them from starting to prepare a solution without fully understanding the problem. The improvement in students' responses over time indicates that, similar to other skills, practice is necessary for problem formulation.

While students' responses improved over time, even in the last MEA the percentage of correct responses was about 60%. In other words, after participating in the two MEAs, 40% of the students could not identify the direct user in the third MEA correctly. In addition, one third of the students never identified the correct direct user in any of the three MEAs. Thus only asking questions about the stakeholders may not be sufficient for understanding the problem. Salim and Diefes-Dux [3] suggest direct instruction and constructive feedback in addition to asking questions about the users may help students to improve in problem formulation. While teaching assistants provided feedback on students' responses, it may be advisable to review students' responses to these questions with the class during or following each MEA.

One of the limitations of this study is the content and context of the MEAs. In some MEAs, direct users may be easier for students to identify compared to the other MEAs (e.g., familiarity of students with the context, clarity of the memo, number stakeholders woven into the problem). Thus, the design and context of the MEA may have influenced the results. These issues need to be evaluated in future research.

While the results of this paper illustrate improvement in identifying the direct user over time, it also shows a lack of understanding of the problem for some of the students. Thus, future research is needed to improve problem formulation instruction to beginner (first-year) engineering students. Further analysis is required to investigate students' responses to identify direct user's needs and problem constraints. For future research, analyzing students' responses to the other individual questions including identifying stakeholders, their relation to the problem, and direct user's needs could help shed light on students' understanding of the problem. A continuation of this study also might look at the nature of the TA feedback received those students who improved over time versus those that did not. It might also look at the relationship between the stakeholder list question or the direct user's needs question to the responses to the direct user question. This would inform instructor training on MEA feedback.

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Appendix A - *Travel Mode Choice* MEA

Internal Memo

To: Engineering Team
From: Ollie Fiji, Executive Director, E3 Trans Consultants
Re: Student Travel Mode Choice

Our firm has been hired by the University of Central Florida's Department of Physical Facilities Management which is working with the UCF Board of Trustees to develop the next Campus Master Plan. In general, the UCF Board of Trustees wants to improve transportation facilities and services. UCF estimates that within the next 10 years the student population will increase from approximately 40,000 to 50,000. Without planned and scheduled improvements to the transportation and transit systems, the campus and surrounding roads could become congested. In an initial survey of UCF students, the Planners Group (a unit within E3 Trans Consultants) received comments including:

"Take the bus? No way, I'd prefer to just drive and park on campus."

"I like the bus; it's so convenient."

"I need the exercise, I just walk or roller blade to my classes."

Now the Planners Group needs a model developed that they can use to predict students' travel mode choice on this and other university campuses. The Planners Group is interested primarily in trips between home and campus. Home, in this study, refers to a student's residence during the semester. About 15% of students live in residence halls and the remaining students live off-campus in the Orlando area. This study is important in planning for the growth of the UCF and the future of LYNX but may be useful to transportation and transit designs at other university campuses.

Based on research from other universities, we have identified several variables that may have an effect on travel mode choice. In a second survey of UCF students, such data was gathered regarding students chosen modes for trips from home to campus. A portion of the survey data is stored in an Excel file **travel_mode_data_partial.xls**. The travel mode options for each student are walking, driving, or taking the bus/shuttle. Each trip starts when a student leaves the door of his/her homes and ends when s/he arrives at the door of the campus destination. The data provided includes these variables and the actual travel mode used by the student. The table below describes the data.

Column	Description	Value or units	Notes
car	Car ownership	y=yes, n=no	
ttimewalk	Travel time for walking	minutes	
ttimeauto	Travel time for driving	minutes	
costauto	Cost of parking	$ per semester	
ttimebus	Travel time for bus or shuttle	minutes	Some students do not have the option of taking UCFS
costbus	Bus or shuttle fare	$ per one way ticket	UCFS is free, students pay for LYNX
freqbus	Frequency of bus, time between buses	minutes	
busstop	Distance from home to bus/shuttle stop	blocks (1 block = 1/8 mile)	
mode_used	Mode selected by the student	bus, walk, or drive	

Your team is responsible for creating and evaluating a general procedure to predict the most likely travel mode for a given student. Your model must be able to predict the travel mode choice of additional non-surveyed students for whom similar data can be obtained.

Your team's general procedure should strive to reflect the relationship between the data and actual student mode choices in the campus survey results. So, as your team develops your model, you will need to analyze the accuracy of your model. That is, your team must *quantify* how well your model predicts the actual student reported chosen travel mode. Your team should use this information to improve the level of accuracy of your model.

In a memo addressed to me, please reply with the following information:

- Your team's general procedure for predicting student's choices of transportation given similar data. Be sure to clearly state the reason for each step, heuristic (i.e. rule), or consideration in your procedure.
- **The results of applying your revised general procedure to the data provided.**
    - **Your team must report quantitative results for *all* students with the predicted mode and the actual mode.**
    - **Your team must quantitatively assess the ability of your model to predict a student's travel mode choice. You must be able to quantitatively answer the question, "how accurate is your team's model?" Further, your measure(s) of accuracy should identify weaknesses in your model (e.g. is your model good at predicting the driving mode but not the bus/shuttle mode?)**

Thank you,
Ollie Fiji

APPENDIX B - *JUST-IN-TIME-MANUFACTURING* MEA

Interoffice Memo

To: Applications Engineering Team
From: Devon Dalton, CEO
RE: Shipping Issues
Priority: [Urgent]

Our company operates a just-in-time manufacturing system. After several years of shipping with Pathways Transit (PT), it has come to my attention that PT has not been meeting our shipping needs. We are having problems with late arrival times. The fact that PT is not consistently arriving at the time they have promised is causing D. Dalton Technologies (DDT) production problems. This means that our Logistics Manager needs a method to identify a new shipping company.

I want to make use of your team's analytical expertise. DDT is small; therefore, we need your team to serve in an engineering project management function on this project. Your team's task is to design a procedure to rank potential shipping companies. My assistant has collected historical data on several potential companies for you. Eight shipping companies have been identified as able to transport materials directly from Ceramica to Bowman. As you know, arrival time of materials is a big issue for DDT. Since the piezoelectric materials are designed specifically for each custom order, it is imperative that the delivery of materials occur just-in-time for Bowman to begin the manufacturing process that uses all of the shipped materials. Because we operate with a small workforce and only one shift, minutes to a few hours can make a difference in our ability to complete devices for our custom applications by our contracted delivery date. This makes arrival time of materials of great importance. We have in excess of 250 data points for each shipping company. At this time, the data for only four companies is available. This data is stored in a file called jit_data_partial.txt. The four shipping companies are Iron Horse Expeditors (IHE), Delphi Shipping (DS), ShipCorp (SC), and United Express (UE). The data is in hours late for shipping runs from Lincoln, Nebraska to Noblesville, Indiana.

Your team should brainstorm different ways in which to analyze the shipping data. Then, your engineering team will use the sampling of data provided for the four shipping companies to develop a procedure to rank the shipping companies in order of most likely to least likely able to meet our timing needs.

In a memo to my attention, please include your team's procedure and the rank order of the shipping companies generated by applying your procedure to the sample data. Be sure to include additional quantitative results as appropriate to demonstrate the functionality of your procedure. Please be sure to include your team's reasoning for the each step, heuristic (i.e. rule), or consideration in your team's procedure.

Please send your complete memo to me by next week.

DD

APPENDIX C - *SHREDDED DOCUMENT* MEA

Memorandum

To: Engineering Team
From: Dorothy Belding, Evidence Documents Manager, Federal Security Services
Re: Shredded Document Recovery Process

Federal Security Services (FSS) is a freelance security consulting firm with numerous governmental contracts. Due to the recent increase in illegal business practices, state and federal government prosecuting teams have been contacting us to aid in their investigations. We need to develop a structured method for the recovery of shredded documents. The high profile nature of many of these cases has resulted in more intense scrutiny of how evidence of this nature is obtained and recovered. Currently, few formally documented processes exist for the recovery of shredded documents, causing key documents to be excluded as evidence due to the potential for tampering. FSS would like to develop a computer-based tool to handle document recovery.

The picture shown in Figure 1 is a digitized, grayscale image. This image happens to be a view seen in an optical microscope. Similar images are currently being created of scanned document strips. An image is stored as a data file which contains an array of numbers. Each number refers to the grayscale value for each pixel of the image. A sub-sample of the complete Figure 1 file is shown in Figure 2 and Table 1. This sub-sample shows the grayscale values for the square superimposed on Figure 1 and exploded in Figure 2.

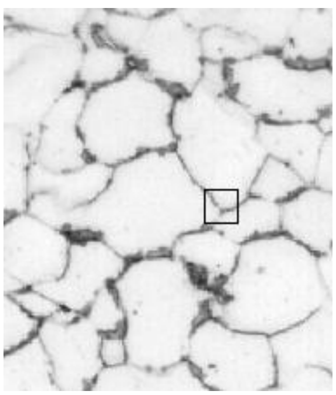

Figure 1. Micrograph of crystals with sub-sample shown.

Figure 2. Sub-sample of micrograph shown in Figure 1.

In a true black and white document, such as a text-only document, the grayscale values present will be limited to 0 (black) and 255 (white). A perfectly black and white image will contain ONLY 0's and 255's. Grayscale values range from 0 for black to 255 for white.

Table 1. Digital file for sub-sample from micrograph of crystals shown in

128	160	221	221	221	241	241	234	241	255	241	241	241	241	255
178	153	178	178	227	234	234	234	255	241	234	234	234	241	241
234	192	192	178	221	227	234	234	255	241	234	241	234	241	234
241	204	178	134	192	221	234	227	234	234	234	241	234	255	234
234	234	215	153	160	215	234	227	227	234	234	241	234	255	234
227	241	221	153	150	192	234	234	234	234	234	234	234	241	234
234	241	221	192	153	178	204	221	234	234	227	234	234	241	227
241	234	227	227	160	153	153	192	227	227	221	234	234	227	221
241	234	234	227	215	160	178	192	234	221	227	227	227	227	227
241	234	234	234	227	215	215	192	204	204	215	192	204	204	192
241	241	241	234	227	241	234	204	160	160	160	153	134	134	150
241	241	241	234	227	234	227	221	153	134	134	153	119	128	153
241	241	241	234	234	227	221	221	160	150	153	192	204	215	234
241	241	241	234	241	234	227	215	178	178	192	221	227	227	234
241	241	234	234	234	234	234	204	192	204	227	227	241	234	234
241	234	234	234	234	227	234	221	227	221	234	227	227	234	234
234	241	227	241	221	215	221	227	227	227	234	241	234	234	255
234	234	241	204	215	204	204	215	227	234	227	227	255	227	241

The grayscale value of each pixel is accessible information that can be used to make decisions about whether or not document strips fit together.

Last week, a government raid on a major automotive company resulted in the seizing of 8 bags of shredded documents. Though the majority of the documents are most likely legitimate confidential business memos, there is evidence to suggest that some documents were shredded to cover up indications that a high ranking vice-president was aware of poor product performance which resulted in a number of deaths.

I would like your engineering team to develop an algorithm that the FSS Software Development Team will use to reassemble documents that have been shredded into full length strips. The FSS Software Development Team will take your written description and translate it into a computer-based tool. Because the FSS Software Development Team is still evaluating several potential computer-based means of implementation, *you should avoid using any specific computer tool language to describe your procedure.*

Dorothy Belding

Case Studies: First-Year Engineering Nanotechnology-based Design Projects

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***Abstract*— Nanotechnology as a research field presents many new opportunities and challenges for educating the next generation of engineers. In this paper, we attempt to understand the impact of this research team's initiatives to increase engineering students' awareness and understanding of nanotechnology. This is a case study of how four student teams changed their iteratively-developed design solutions for a nanotechnology-based design project. The goal is to investigate how first-year engineering (FYE) students developed their demonstrated knowledge of nanotechnology. We found that all four teams discussed nanotechnology concepts from the beginning of their solutions. Although they had difficulty relating their nanotechnology applications to science and mathematics concepts, they had consistent ideas for the nanotechnology-specific content they wanted to focus on throughout their project. The results show that all four project cases have a clear potential connection to a field of engineering. Connecting nanotechnology to potential engineering fields may present a better content focus than science and mathematics concepts.**

Keywords—first-year engineering; nanotechnology; design projects

I. INTRODUCTION

First-year engineering students know very little about nanotechnology [1,2], which is a field that is changing many aspects of our world [3] and offers many new learning and discovery opportunities [4]. Design projects offer opportunities for students to explore the topic of nanotechnology. A partnership between faculty teaching a required First-Year Engineering (FYE) course at Purdue University and the NSF-funded Network for Computational Nanotechnology (NCN) resulted in a FYE design project to address multiple course learning objectives and improve students' awareness and knowledge of nanotechnology. For this project, FYE student teams were challenged to create a simple interactive tool (using MATLAB) to enable high school students to learn about nanotechnology through relevant state-standards for science and mathematics. This study is driven by this research question: How do student teams' knowledge about nanotechnology change over the course of a nanotechnology-based design project? An investigation of student teams' solutions to the design challenge will reveal whether or not and how the design project facilitated FYE students' learning about nanotechnology. The purpose of this study is to unpack the successes and shortcomings of our initiatives and to enable others to more effectively incorporate nanotechnology concepts into their courses.

This work was made possible by a grant from the National Science Foundation (NSF EEC 1227110).

II. LITERATURE REVIEW

Nanotechnology is science, engineering, and technology conducted at the nanoscale (1 to 100 nanometers) [2]. The scale of nanotechnology is difficult for students to grasp [5, 6]. Previous research has found that students have trouble discerning the difference between micro, nano, and atomic scales [7]. Although the nanoscale is a difficult concept to grasp, it is important that education about nanotechnology not focus only on the nanoscale. It was found that students that learned about nanotechnology in an educational environment typically learned only about the nanoscale and were not educated about its potential impacts and applications [2]. This connection to potential applications is vital for student motivation and engagement in the topic. Nanotechnology is an area of research that is in high demand of professionals [8] and presents opportunities for students to learn in multidisciplinary [9] and interdisciplinary [10] environments.

In a previous qualitative analysis of 28 teams' executive summaries of their final design projects, it was found that the teams that anchored their project in a specific nanotechnology product appeared to have the greatest understanding of nanotechnology [5]. For this study, four teams, each having a different science and/or mathematics foci, were identified from the 28 teams as demonstrating a greater understanding of nanotechnology and an ability to relate their topic to a nanotechnology product [5].

III. METHODS

A case study is used to examine a phenomenon (i.e. the "case") in its real-world context [11]. The purpose of these analyses will be to investigate what led to the success of these identified teams. The success will be determined by their ability to represent their knowledge of nanotechnology through their design project solution. Although these teams were somewhat uncommon instances of greater understanding, they may help inform instructional design to encourage deeper understanding in future nanotechnology-based design projects.

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A. Participants and Setting

At Purdue University, all students in the FYE Program are required to complete two sequential 2-credit hour courses that focus on learning objectives associated with problem-solving, design, computer tool skills, teamwork, and communication. In Spring 2012, 1651 students were enrolled in 15 sections (up to 120 students per section) of the FYE Program's second semester course. Of these 15 sections, four sections implemented a nanotechnology-based design project. The focus of this study is on the nanotechnology-based design project completed by student teams (with 3 or 4 students per a team).

B. Nanotechnology Graphical User Interface (GUI) Project

The nanotechnology graphical-user interface (GUI) project was introduced in Week 11 of the semester (16 week semester) with a memo from the project partner and a short presentation by the instructional team that highlighted available nanotechnology resources. Students were also given access to NCN's interactive online data and research sharing environment (nanoHUB.org) to learn about nanotechnology. The environment has 64,659 interactive users and primarily consists of online simulations for those interested in nanotechnology. NCN's mission is to support the National Nanotechnology Initiative by creating and operating a cyber-platform for expanding and supporting the formation and growth of the nanotechnology community by sharing computational simulations and educational resources. NCN served as the client and set the goal and the criteria by which the project solutions could be judged for success. The goal was for student teams to create an interactive learning module relating nanotechnology to grades 11 or 12 science and mathematics topic as listed in the state standards. The five criteria for success stated that the student teams' solutions must:

1. Clearly show how the rationale for this project will help students learn nanotechnology,
2. Clearly address one state science standard for the targeted grade level,
3. Clearly connect the science or engineering topic to math activities that are appropriate for the targeted grade level,
4. [Be] highly stimulating and interactive for targeted grade level, and
5. [Be] easy to use and operate.

To achieve these goals, students were asked to plan and create a fully developed GUI utilizing MATLAB [12]. This project was to be completed in six milestones. These milestones served to help the teams develop their solution along a predetermined timeline and use design concepts learned in the prerequisite course. The students received feedback from the instructional team or the project partner for every milestone submission. The milestones were as follows:

1. Brainstorming (Week 11): This involved brainstorming 30 potential ideas for a solution to the Nanotechnology GUI project and then going through concept reduction using a decision matrix. The deliverable was a memo to the project partner describing two design ideas the team felt were worth pursuing.
2. Project Storyboard (Week 12): The team selected one idea and used PowerPoint to create a prototype of their solution for the project partner.
3. Project Layouts and Flowcharts (Week 14): The team fully develop the GUI layout in MATLAB and flowcharted the algorithms that would need to go behind each layout to achieve desired functionality.
4. Project GUI Beta Version 1 (Week 15): Teams began to convert their flowcharts to MATLAB code. The instructional team provided students with detailed feedback during team demonstrations.
5. Project GUI Beta Version 2 (Week 16 – Class A): Teams presented a complete and improved solution to the instructional team. This version was evaluated by the project partner during a class demonstration.
6. Project Final Demo and Executive Summary (Week 16 – Class B): Teams gave a final demonstration of their solution to the instructional team and submitted their written documentation in the form of an executive summary. This GUI version was evaluated by the instructional team during a class demonstration. Project reports had to demonstrate how the feedback from the client was incorporated into the final design.

C. Data Collection and Analysis

Four teams from one section were selected for this case study based on previous research in which all 28 teams' executive summaries from one section were analyzed [5]. Based on the previous study, half of the teams incorporated a nanotechnology application into their project (including the four selected teams) and over half of the teams that did not admitted that their greatest shortcoming was Criteria 1 [5]. The analysis found that teams that incorporated some application indicated greater confidence in their projects' ability to teach others about nanotechnology. The four selected teams each included some nanotechnology application and selected a different approach to connecting nanotechnology to a science and/or mathematics concept to fulfill Criterions 2 and 3. The purpose of this study was to examine characteristics of their approaches that may have led to their greater success in exploring nanotechnology. This qualitative analysis focused on the changes that the teams made and the consistencies that the team maintained across all six milestones. The results section consists of an analysis of each team individually and the discussion section communicates the found commonalities between the changing and consistent concepts of the four teams' project solutions.

IV. Results

In the sections that follow, changes to each of the four team's solutions are discussed. The solutions submitted in Milestones 5 and 6 were very similar for all four teams, so the GUI submitted for Milestone 6 is the only one discussed. From Milestone 5 to 6 there were primarily interface improvements and reformatting without much content change.

A. Team A

The two ideas proposed by Team A for Milestone 1 were: (1) biomedical nano-sensors and (2) identifying cancer cells. Their science focus was proposed to be biology, specifically cellular structure and reproduction. In Team A's memo to NCN, they discussed "nano scale", "nano-particles", and "nano-sensors".

For Milestone 2, they settled on the idea of using biomedical sensors as the anchor for their solution. They continued to focus on biology with the addition of chemistry; their proposed topics were cellular chemistry (biology) and behavior of gases (chemistry). Their proposal became more specific at this point. They proposed challenging (high school) students to "compute various pressures within the blood stream" using "[evaluation] models of sensors on varying scales (visible, micro, and nano)" and demonstrating "improved accuracy data obtained from these nano-sensors". They dropped the discussion of "nano-particles" in this milestone and added the discussion of other scales larger than the nanoscale.

For Milestone 3, the team presented layouts of the actual GUI generated in MATLAB. They continued to add greater detail about how the interface would present nanotechnology-focused information; the team did not discuss the science and mathematics focus in this milestone. Three scales were used to describe the application. The visible scale would discuss the "blood pressure measured by stethoscope and sphygmomanometer". The microscale would focus on a specific technology called MEMS: "MEMS, micro-electro-mechaical systems, can be used to measure blood pressure more accurately… [and] can be implanted in patients who have blood pressure problems." The nanoscale would discuss information and calculations related to a "nano pressure sensor".

For Milestone 4, the team remained consistent regarding all of the biomedical measurements; however, the team changed their science and mathematics focus at this point. The team transitioned to a mathematics focus regarding linear equations and physics of motion and forces.

For the executive summary submission of Milestone 6, the team only discussed the mathematics focus of the project (i.e. linear equations); they no longer explicitly related the project to a science concept. For the GUI solution that Team A submitted for Milestone 6, the team continued their focus on the biomedical applications of nanotechnology through an organization similar to what they previously discussed in Milestone 3. First they incorporated an interactive window to input blood pressure information obtained from a "stethoscope and sphygmomanometer". The next window described MEMS with text similar to that presented in Milestone 3. The GUI also included three windows that discussed carbon nanotubes, piezoelectric effect, and construction related to nano-pressure sensors. Each topic informed the "user" through written text and images. After this nanotechnology-specific information, the GUI went to an interactive page that challenged the user to calculate the slope and y-intercept "to discover the desired trendline [of the given] test data" supplied through a "nano-wire strain test". A screenshot of this portion of the GUI is shown in Figure 1. (This figure was formatted to better fit in this paper and does not represent the actual layout of the GUI. In the original window, the "Best Fit Line" and "Experiment Data" boxes were to the right of the "Nano-Wire Experiment" box.)

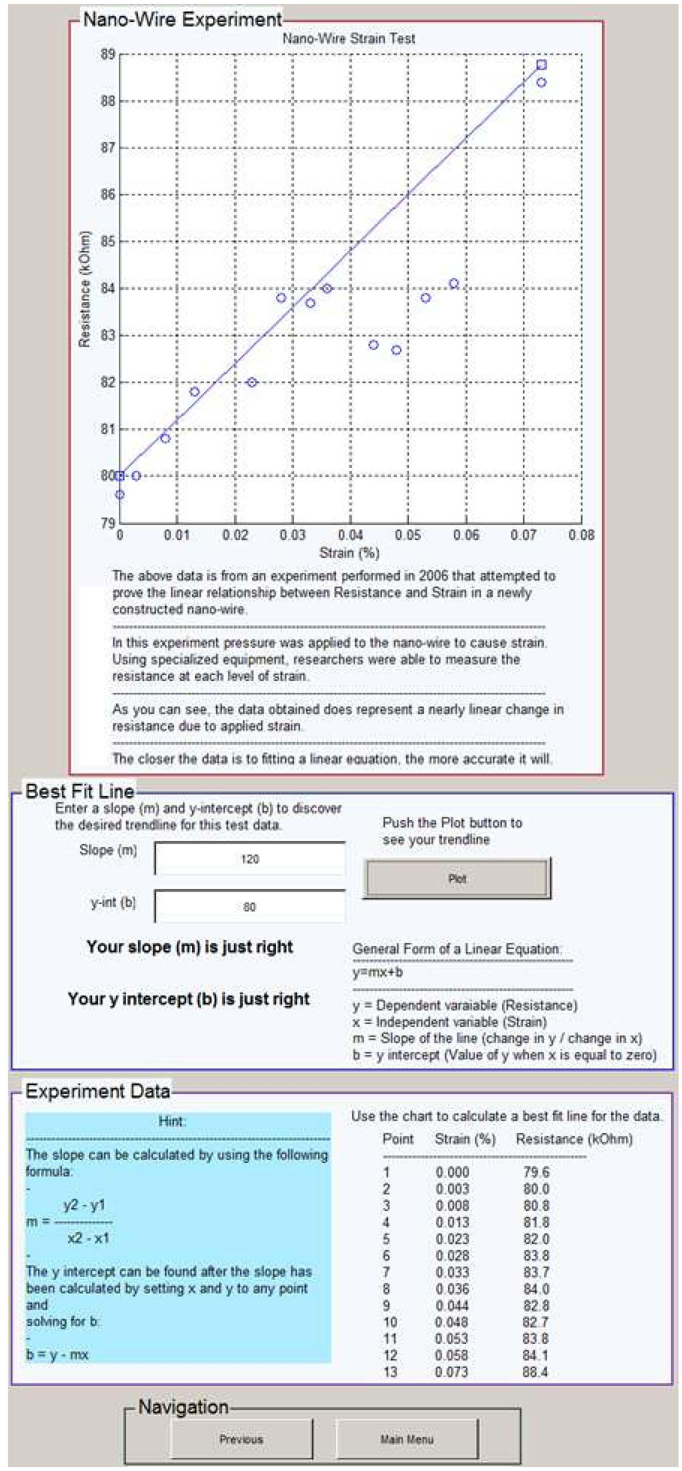

Fig. 1. Screenshot of the nanotechnology-specific, interactive portion of Team A's GUI.

B. Team B

The two ideas proposed by Team B for Milestone 1 were: (1) quantum physics/light behavior and (2) acid-base titration. The team elaborated on the first idea by stating, "Quantum physics relates to nanotechnology through a particle called quantum dots." This statement includes all of the nanotechnology vocabulary included in this milestone. The team's focus for this idea was on physics concepts "explaining the relationships among wave characteristics like frequency, amplitude, etc." and some basic mathematics skills, including unit conversions (e.g. "grams and moles") and "various formulas". In this milestone, the team discussed "quantum dots", a nanotechnology application.

For Milestone 2, the team further developed the quantum physics idea by explaining their physics and mathematics foci. The physics focus was on "electromagnetic spectrum", "electromagnetic waves", wave properties (i.e. wave speed, wavelength, frequency of period, and amplitude), and "light properties" (i.e. absorption, emission, and transmission). The mathematics focus was on "antiderivatives" (i.e. velocity and acceleration), "graphing technology to find approximate solutions for polynomial equations", and plugging values into formulas and conversions (i.e. frequency, wavelength, and amplitude). Their proposed GUI included lessons on "the concepts of light behavior and how they apply in the designing and making of engineering innovations and nanotechnology in different fields."

For Milestone 3, the team discussed the same topics as in Milestone 2 without any clear details of how the plan would be executed or communicated; this submission was actually less detailed than Milestone 2.

For Milestone 4, the team included more details regarding nanotechnology. The team stated, "Nanotechnology refers to any kind of technology or science that functions in the Nano scale. It includes the manipulation of matter and their properties at the Nano scale. Through nanotechnology we can manipulate matter, its molecules and properties at an atomic level and create new matter with unique properties." The team discussed a specific activity they planned to include in their GUI, "In one of the activities, the user learns various properties of light including wavelength, frequency and more. The user then has the chance to calculate, manipulate and experiment with different wavelengths and frequencies measured in nanometers as well as observe a visual display of how the different changes in each affect light."

For the executive summary submitted in Milestone 6, the team stated the science and mathematics foci. The science focus was still physics, specifically light properties; the mathematics focus was simplified to only address algebraic problem solving. The nanotechnology focus was still quantum dots, which was initially discussed in Milestone 1. The GUI submitted for Milestone 6 consisted of four main activities (i.e. "wave generator and properties", "electromagnetic spectrum", "photon emission", and "light and nanotechnology"). Each activity had some interactive component and definitions that defined and discussed pertinent information on the topic. The nanotechnology-specific activity consisted of primarily text discussing quantum dots. A screenshot of this activity is shown in Figure 2.

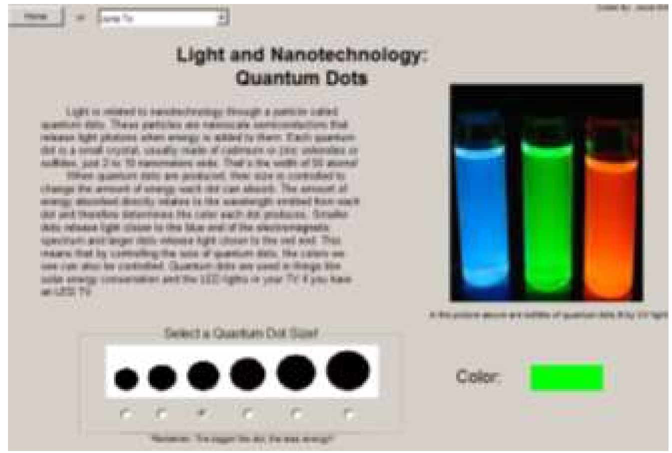

Fig. 2. Screenshot of the "light and nanotechnology" activity in Team B's GUI.

C. Team C

The two ideas proposed by Team C in Milestone 1 were: (1) carbon nanotubes and their application and (2) molecular geometry used in practical applications of nanotechnology (e.g. Rain-X rain repellant). The foci for their first idea were "organic chemistry and biochemistry" (e.g. carbon atoms bonding) and creation of graphs to visualize mathematics concepts. In this milestone, the team used the following nanotechnology vocabulary: "nanoparticles", "nanotubes", and "carbon nanotubes".

For Milestone 2, the team selected carbon nanotubes along with their strength and utility. The science focus was still chemistry; they focused on "organic chemistry and biochemistry" (i.e. properties of carbon allotropes and bonding) with the addition of atomic structure (i.e. valence electrons). The mathematics concept was changed to problem solving strategies through interpretation of Young's Modulus. The team explained this, stating: "The activity will tie together problem solving skills to mathematically show that Young's Modulus is that same for a material no matter what the stress or strain." The team proposed a GUI that focused on material properties challenging "users" to calculate stress and strain; they also incorporated atomic structures that discussed allotropes.

For Milestone 3, the team focused on the same chemistry and mathematics concepts as proposed in Milestone 2. The proposed plan for the GUI consisted of a more detailed plan on how to incorporate ideas for material weights, Young's Modulus, stress, strain, allotropes of carbon (i.e. graphite, diamonds, and carbon nanotubes), and bonding orbitals.

For Milestone 4, the team had the same content with a clear path of how they planned for the "user" to progress in their GUI. The established path consisted of physics and mathematics concepts, Young's Modulus, carbon nanotubes, engineering applications, and then structure of carbon nanotubes.

For the executive summary submitted in Milestone 6, the team focused on a physics topic (i.e. material properties), chemistry topics (i.e. hybridization and atomic properties), mathematics topics (i.e. algebraic problem solving and variable manipulation), and a nanotechnology application (i.e. carbon nanotubes). The final submitted GUI consisted of an interactive component that prompted the "user" to input required values to calculate stress, strain, and Young's Modulus. The majority of the submitted GUI consisted of text that required some minor interaction through pushing various buttons; the text incorporated some nanotechnology-specific ideas. An example of a few of these interfaces is shown in Figures 3 and 4. Figure 3 shows a window in the background with a "Carbon Nanotubes" button that navigated to the "Carbon Nanotubes" window in the forefront of the figure. Figure 4, presented in the same format, is about hybridization.

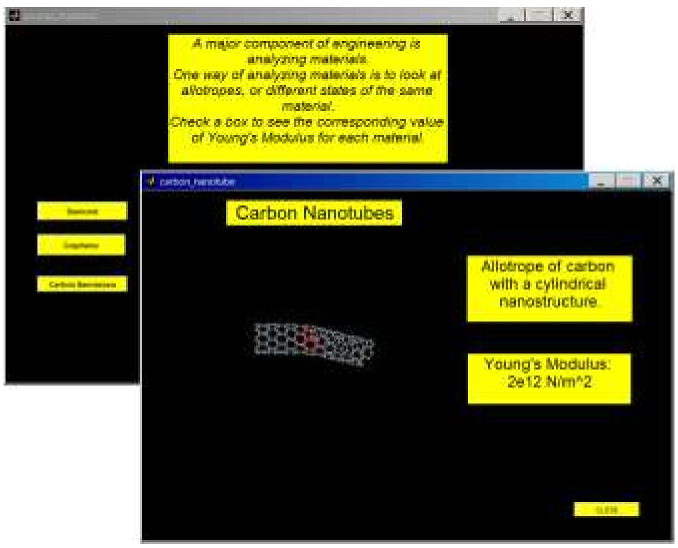

Fig. 3. Screenshot of the "Young's Modulus" screen along with the "carbon nanotubes" selection in Team C's GUI.

Fig. 4. Screenshot of the "hybridization" screen along with the "sp^2 hybridization" selection (peritinent to carbon nanotubes) in Team C's GUI.

D. Team D

In Milestone 1, Team D expressed their two ideas as: (1) "fractal silver structures are really effective in photovoltaic energy harvest" and (2) "carbon nanotubes are used as a catalyst in extraction". The first idea was related to mathematics, specifically "using recursion to describe fractals". The second potential concept was related to "catalysts in biology".

For Milestone 2, this team focused on "practical fractals", specifically harvesting photovoltaic energy through fractal silver structures. They discussed how there topic related to physics (i.e. correct units in describing common physical quantities), chemistry (i.e. how an atom can acquire an unbalanced electrical charge by gaining or losing electrons), and mathematics (i.e. recursion to describe fractals). They proposed a path for their GUI projectthat consisted of "how fractals are made", "how fractals are used in nanotechnology", and then to fractals "in photovoltaic energy cells". They proposed that the application of fractals would demonstrate that "fractals greatly increase the density of a given area".

For Milestone 3, the team maintained their fractals and photovoltaic energy idea and a similar plan for the GUI development. The mathematics concepts were converted to fractals as iterative functions. The science focus was changed to harvesting light at the molecular level. In this milestone, the team began discussing "photovoltaic energy cells". The photovoltaic energy had been discussed in previous milestones, but at this point the team began discussing "cells".

For Milestone 4, the team related their project to the same science and mathematics topics discussed in Milestone 2; the team dropped the different science concepts discussed in Milestone 3. The ideas for the GUI were the same as described in Milestones 2 and 3.

In the executive summary submitted at Milestone 6, the team related their project to biology (i.e. photosynthesis), mathematics (i.e. algebraic problem solving and geometry), and a nanotechnology application (i.e. "solar panel cells"). For the final submission of the GUI project, the team created a selection of interactive activities that taught users about fractals (i.e. graphical representations of fractals, quiz about examples of fractals, and calculating the length of a fractal) and the application of fractals in measurement. The final GUI did discuss fractals, but the team no longer identified this as the mathematics concept that they were connecting their project to. The final portion of the GUI consisted of an image and text that described how fractals related to nanotechnology; a screenshot of this is shown in Figure 5.

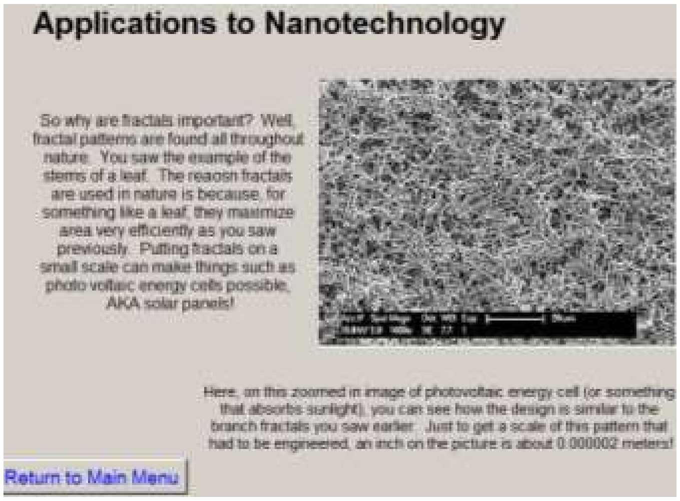

Fig. 5. Screenshot of the "Applicationss to Nanotechnology" portion of Team D's final GUI project.

V. DISCUSSION

All four of these teams consistently discussed the same nanotechnology application throughout the entire project. Table I shows each of the teams nanotechnology application discussed across each milestone. Team A and Team D changed some of their wording for how they referred to the nanotechnology application between Milestone 2 (M2) and Milestone 3 (M3), but discussed the same application.

TABLE I. NANOTECHNOLOGY APPLICATIONS IN DESIGN PROJECTS

Teams	Nanotechnology Applications across 6 Milestones (M)				
	M1	M2	M3	M4	M6
TeamA	Biomedical Nano-sensors		Biomedical Nano Pressure Sensors		
TeamB	Quantum Dots				
TeamC	Carbon Nanotubes				
TeamD	Photovoltaic Energy		Photovoltaic Energy Cells		

All four teams did not discuss the same science or mathematics concept throughout the entire project. The teams were required to have a connection to a science and mathematics concept in their project, but even with the requirement the teams did not discuss this connection in some milestones.

This variation of science concepts across the six milestones can be seen in Table II. Team A is a clear example of a team that struggled to find a science concept connection. The team stated that their project related to biology, chemistry, and/or physics at different milestones and did not connect to any science concept by Milestone 6 (M6). Team C and Team D also had some variability in their idea of how to connect their project to a science concept. Team B was the only team that seemed to have a consistent connection to a science concept throughout their project development (i.e. physics).

TABLE II. SCIENCE CONCEPTS IN DESIGN PROJECTS

Teams	Science Concepts across 6 Milestones (M)				
	M1	M2	M3	M4	M6
TeamA	Biology	Biology + Chemistry	Not discussed	Physics	No science concepts
TeamB	Physics (wave properties)	Physics (wave and light properties)			Physics (light properties)
TeamC	Chemistry (carbon bonding)	Chemistry (carbon bonding and atomic structure)		Physics (material properties)	Chemistry + Physics
TeamD	none	Physics + Chemistry	Harvesting Light	Physics + Chemistry	Biology (photo-synthesis)

The variation of mathematics concepts across the six milestones can be seen in Table III. Team B and Team C had different ideas about how to connect their project to mathematics concepts across the six milestones. Team A did not even discuss a connection to a mathematics concept for the first three milestones and only connected their project to linear equations in the final milestone (M6). Team D was the only team that had a somewhat consistent connection to a mathematics concept. Although they do not explicitly state that there project is about fractals in the final milestone, it is clear that their project is still connected to this concept.

TABLE III. MATHEMATICS CONCEPTS IN DESIGN PROJECTS

Teams	Mathematics Concepts across 6 Milestones (M)				
	M1	M2	M3	M4	M6
TeamA	No mathematics concepts			Linear Equations	
TeamB	Unit conversion	Anti-derivatives	Not discussed		Algebraic problem solving
TeamC	Creation of graphs	Problem solving strategies (Young's Modulus)			
TeamD	Fractals				

Throughout the project, it appears that the teams are connecting their project to a science and mathematics concept based on the established criteria. This idea does not seem to help give the teams' projects a clear direction. Only the two discussed examples of Team B's connection to light properties and Team D's connection to fractals show a solution development that may have been driven by a connection to science or mathematics. Although these required connections change, all four teams have a clear connection to a nanotechnology application throughout the entire project; this connection seems to provide the primary direction for the teams' projects.

Although the teams do not explicitly discuss a connection to a type of engineering, there seems to be a potential connection between each project and a type of engineering. Team A's project explicitly discusses biomedical applications of nanotechnology and clearly connects to biomedical engineering. Team B's project explicitly discusses electrical applications of quantum dots and clearly connects to electrical engineering. Team C's project explicitly discusses material properties of carbon nanotubes and clearly connects to materials engineering. Team D's project discusses photovoltaics and clearly discusses nanotechnology in alternative energy engineering applications.

VI. Conclusion

The results of this study support the findings of previous studies that state that nanotechnology should be taught through nanotechnology applications [2,-5]. A commonality between all four teams' projects is that each team had a selected nanotechnology application in the beginning of their project and discussed this same application throughout their entire project. The connection to science and mathematics concepts did not seem to give teams an effective platform to connect nanotechnology concepts to. Although the teams did not explicitly state their connection to an engineering field of study, this seems to be a potential context that appeared in all four projects. Based on these and prior findings, the Spring 2013 project description, goal, and criteria for success was updated. The criterion regarding focusing on high school science and mathematics topics was removed. A new criterion was established that required the team to connect their project to an engineering field/s of study of their choice with their peers as the target audience. Earlier in the course and before the start of this updated project, each student was also challenged to complete a context setting assignment that encouraged them to investigate how nanotechnology applies to their engineering field of interest; students' responses to this assignment were investigated in another study [13]. The effectiveness of these changes will be studied in the future after their implementation in Spring 2013. As for implications for teaching practice, a greater focus on nanotechnology applications and how the various fields of engineering are related to nanotechnology present two potential paths for enabling students to engage in discovery learning of nanotechnology to enhance their understanding and awareness.

Acknowledgment

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A Community Learning Component in First Year Seminar

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Abstract— **This Work in Progress paper describes current efforts to engage Liberal Art College freshman to the Engineering discipline and its impact to the broader community, through a topic-based, writing-intensive seminar course. In this particular seminar developed by the author, we aim to discuss the role of engineers in tackling challenges in the Community around the Hartford area and beyond. While students enrolled in the seminar course in this paper are mainly "undecided" students, we believe by emphasizing technologies applied to the immediate community around our students and humanitarian applications, we can inspire students' interest in Engineering and show students how the skills they will be learning can have a positive impact on the quality of life for the surrounding community. The seminar was assessed by gathering student comments concerning each major course components.**

Keywords—first year seminar, community learning, service learning

INTRODUCTION

Orienting first year students to engineering is an important topic in Engineering Education. Many new practices have been researched recently on this topic. For example, Jenkins and colleagues [1] reported a first year engineering seminar at the University of Southern California. Their topics include the engineering problem solving, the social and historical context for engineering activities, and professional ethics. Taylor and colleagues [2] discussed an integrated freshman industrial engineering seminar at Rochester Institute of Technology. The course introduces students to campus life, engineering ethics, with team building activities. [3] reported a zero credit first year seminar at the University of Pittsburgh, taught in small groups by student mentors to assist student in the academic and personal transition from high school to college. Another group of educators at University of Southampton reported a similar program that orients freshman in the week prior to their incoming semester using student mentors [4]. Three first year seminars at Purdue University are described by Montgomery, Follman, and Diefes-Dux in [5]. These seminars are offered in different formats including large lecture with faculty presenters from individual disciplines, smaller group sessions led by upper-level student mentors, as well as a faculty member on specific engineering topics.

Complementary to the related work above, this Work in Progress paper describes current efforts to engage Liberal Art College freshman to the Engineering discipline and its impact to the broader community, through a topic-based, writing-intensive seminar course. While many excellent educational ideas have been reported in Engineering freshman seminars recently, implementation of these research ideas, especially for service based learning, has not been widely tested in writing intensive seminars and in the contexts of small liberal art colleges.

Trinity College is a small liberal arts college with about 500 freshman each year. They are divided and placed into seminars taught by faculty from different disciplines. In this particular seminar developed by the author, we aim to discuss the role of engineers in tackling challenges in the Community around the Hartford area and beyond. While students enrolled in the seminar course in this paper are mainly "undecided" students, we believe by emphasizing technologies applied to the immediate community around our students and humanitarian applications, we can inspire students' interest in Engineering and show students how the skills they will be learning can have a positive impact on the quality of life for the surrounding community.

COURSE STRUCTURE

This one-credit course is divided into three modules. In the first introductory module, all students sit in circles meet together in seminar format and are introduced to the engineering discipline and the engineering design process, start with the design process of preparing a family dinner. We also blend in a 15 minute module in each class meeting. Half of these modules discuss topics including campus life, time management, and curriculum issues. Half of these modules discuss transitions from high school to college level writing. Weekly writing assignments of about five to ten pages in length are performed. These strategies help students in the following dimensions:

This work is sponsored in part by the Community Learning Initiative at Trinity College, Hartford, CT.

- Get a basic understanding of the Engineering field.
- Get familiar with the Engineering design process using everyday examples.
- Encourage students to consider the cause-and-effect of design decisions.
- Find common grounds and sharing perspectives with each other.
- Get a smooth transition to College level writing.

Module 2 features more focused Engineering topics around our everyday lives. Digital technologies are emphasized with two particular themes of digital music and digital images. These themes are taught in both hands-on sessions and discussions. Simple Matlab scripts are introduced to help students analyze digital music and images. This way we energize the seminar classroom sessions by providing a context for small and large group discussions, followed by writing intensive assignments. Students were required to reflect on and to respond in writing to encountered problem solving issues. Some responses were formulated in groups to stimulate group discussions among students.

Fig. 1. In module 3, students are working on otoscopes for diagnosis of otitis media at Connecticut Children's Medical Center.

Module 3 focuses on a few specific themes that tie together several Community learning projects in the engineering context. Example projects offered in Fall 2012 semester include:

- In collaboration with the biology department, we initiated a citizen science venture to identify wildlife visiting residential compost piles in eastern Connecticut. The goal of this experiment is to determine whether or not the addition of animal-based kitchen scraps really does affect wildlife visitation to compost piles. Through citizen science, we are challenging students to reach this goal by identifying animals from images collected from the field site.
- In collaboration with Connecticut Children's hospital, we initiated a community based learning project for the accurate diagnosis of acute otitis media, a common disease for small children around the Hartford area. With the established experimental apparatus, students are challenged to analyze images collected from ears (with IRB approval). Figure 1 shows the students students are having hands-on experience with otoscopes for diagnosis of otitis media at Connecticut Children's Medical Center.

This third module encourages students to see themselves as capable of pioneering creative problem solving for the community, rather than simply as implementers. The carefully selected themes promote the notion of problem solving that focuses on real world applications rather than textbook exercises. When students participate in projects that involve client interactions, they are also required to consider the cause-and-effect of design decisions.

ASSESSMENT

Assessments for this class include in-class hands-on activities and out-of-class project assignments. While in-class activities are mostly interactive, discussion-oriented, out-of-class project activities are writing intensive and based heavily on community learning. We also made an effort to blend basic engineering design and analysis concepts into the community learning case studies.

While the student evaluation response has been positive, a limiting factor to analysis has been the small sample sizes. Future offering of the course would allow us to analyze the effectiveness of community learning in Engineering first year seminar more comprehensively.

ACKNOWLEDGMENT

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Development of a Multiple-Choice MATLAB Theory and Syntax Exam

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***Abstract*— Examinations in programming courses that require students to write code to solve a problem are an excellent method for testing how well a student has mastered language syntax, programming theory, and problem solving technique. However, if a student struggles with problem solving, it is often difficult for students to demonstrate any understanding of syntax or theory. To address this situation, faculty for a freshman engineering MATLAB-focused introductory programming course at a private southeastern STEM+Business-only university have been giving exams that are a combination of practical programming problems and multiple-choice questions. This research is focused on performing an item analysis of the questions appearing on those exams with the immediate goal being a multiple-choice exam with both topic coverage and documentation of it's ability to properly discriminate knowledge.**

Keywords—MATLAB, Exam, Item Analysis, Multiple Choice

I. Introduction

Introductory programming courses are a common part of first-year engineering curricula. Learning computer programming requires students to simultaneously understand language syntax, programming theory, and problem solving technique [1]. Language syntax is the language-specific formatting of programming statements. Programming theory represents computer programming specific concepts such as looping and decision structures, arrays, and file I/O. Problem solving is the ability to filter a problem statement into the relevant information and organize a solution using the theory and syntax elements.

Examinations in programming courses that require students to write code to solve a problem are an excellent method for testing how well a student has mastered all three aspects of programming. However, if a student struggles with problem solving, it is often difficult for students to demonstrate their understanding of syntax and theory. To address this situation, faculty for a freshman engineering MATLAB-focused introductory programming course at a private southeastern STEM+Business-only university have been giving exams that are a combination of practical programming problems and multiple-choice questions. The practical problems allow students to demonstrate problem solving and language syntax, while the multiple-choice portion allows students to demonstrate theory and syntax knowledge. The multiple choice portion of those exams have varied wildly in length, content, and topic coverage.

The immediate goal for this project is to develop a multiple choice MATLAB exam that meets the following goals as well as possible:

- Assesses the breadth of topics covered in the course.
- Adequately discriminates high from low performing students.

A secondary goal is to highlight topics that are being inadequately covered for various reasons.

The long-term goal for this project is to develop a set of generalized question models for an introductory MATLAB course that help assess student knowledge about syntax and programming theory independent of their problem solving ability. These models, after appropriate testing, can then be used, modified, and reused with minimal impact on their discrimination or difficulty, allowing instructors to create the appearance of a "new" exam with reduced concern about the exam's ability to identify differing knowledge levels.

II. Relevant Framework and Contribution

A. Framework

The framework for this analysis will be a modified form of the Item Analysis used in Classical Test Theory (CTT) as described in [2]. The modifications and their justification are described within the methods section. The two key mechanisms discussed are the problem difficulty and problem discrimination.

B. Contribution

This research-to-practice WIP is utilizing a widely accepted approach for psychological test development and applying it to a more traditional curricular content exam. Though this has been done before, there are shockingly few discussions of how it was done and even fewer instruments available. The immediate results of this research (e.g., the final exam document) will be provided at the presentation and will be available by emailing the author.

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III. Methods

A. Course

Enrollment in the Introduction to MATLAB for Engineers course is typically 200-300 students per semester. Sections of the course are limited to 28 students, with multiple faculty members teaching both the lecture and lab portions of the course. Sections are combined for the lecture and given in a large lecture hall, co-taught by the faculty members assigned to those sections. Course grades are set at 50% for 3 equally weighted exams, 20% final project, 20% homework assignments, and 10% quizzes. Faculty have individual control of specific items within each grade area, but often collaborate or use the same general methodologies.

B. Data

Since 2009, final examinations in the course have consisted of a multiple choice portion and a lab practical programming poriton. The multiple choice portion typically has consisted of both common questions for all students in the course and questions specific to each faculty member. Exams have varied wildly from semester to semester both in length and topic coverage.

Exam questions, students' answers, and students' final course grade (of which the overall final exam score including the lab practical portion represented 16.6% of the course grade) were collected. Data was converted to a common format and identical questions/answers from different semesters were grouped together, allowing for larger data pools for some questions. Each question was then reviewed by the author to identify both the correct answer(s) and what course topic(s) the question was addressing. Incomplete data (typically because final grades were unavailable) or invalid questions (typically because of typos that made the question invalid) were removed from the data set. The author acknowledges that final grades are not necessarily an accurate measure of course knowledge and that grades are not wholly independent of exam performance.

The remaining data set can be described as follows:

- 49470 responses by 777 students to 271 unique questions.
- Each question had between 21 and 777 responses, with a mean of 181 responses and a median & mode of 200 responses. Only 44 of the questions had fewer than 50 responses each.
- Final Grades were distributed as follows:
  - A – 29%
  - B – 30%
  - C – 23%
  - D – 10%
  - F – 8%

The top-heavy grade distribution is in part because students who D/F the course rarely attempt the final exam.

C. Analysis

Each response was rated as correct (1) or incorrect (0). Item difficulty was calculated as the average score of all participants on the item. Each response was also classified as either "High Performance" if the student obtained an A or B in the course or "Low Performance" if the student obtained a C, D, or F in the course. Average scores on each question were calculated for both high and low performers. A discrimination index was calculated as the difference in average score between the high and low performing groups.

Note that the above analysis is a modified version of the Item Analsysis described in [2]. Responses were grouped into only high and low performers to ensure a large enough sample for each question. With this grouping strategy, only 16 of the 271 questions had fewer than 15 responses in one of their performance groups, and the average performance group had 90 responses. The use of overall course grade (as opposed to only the overall exam grade) was done because different exams were given to different students, resulting in item weighting and relative item difficulty being inconsistant between students. While overall course grade is also inconsistant, the breadth of sources the final course grade includes represents a more wholeistic measure of student understanding than the single exam score.

D. Item Selection

Items were ranked by their discrimination index. For each of the topics, a top-ranked item was selected from the corresponding category. Items were screened to make sure that, when possible, they had a moderate to easy difficulty index (0.3 or above), though a few topics had no discriminating items that were not difficult (specifically variables and low-level files). The average difficulty level is 0.631, while the average discrimination index is 0.241. Final topics, along with the difficulty and discrimination indices are shown in Table I, presented in the order typically used during the course.

IV. Results & Next Steps

A. Primary Goal Results

30 Questions were selected with high discrimination to span the topics covered. A subset of the items are shown in Table II. The complete set of items can be obtained by contacting the author and will be provided at the presentation.

B. Secondary Goal Results

The secondary goal was to identify topics that may not be receiving adequate instruction. In sorting the questions by discrimination index, six items demonstrated negative discrimination (i.e., low-performing students performed better than high-performing students). The question with the most negative discrimination is "True/False: Microsoft Windows is an example of computer software." While the question is flawed (because Windows is both software and an operating system, resulting in confusion by students who can distinguish applications from the operating system), the item highlights that a more involved discussion of what is and is not software is important.

C. Next Steps & Remaining Work

Questions/answers to the selected items will be generalized to create a similar exam, resulting in a new set of questions that should still meet the desired goals. The resulting form will be given as a common final exam during the Spring 2013 semester. The results will then be compared to other course items, including final course grades to identify if the generalized items represent an adequately discriminating exam.

TABLE I. COURSE TOPICS AND SELECTED ITEM DIFFICULTY/DISCRIMINATION INDICES

Course Topic	Item Difficulty	Discrim. Index
Basic Computers (Hardware, software, etc.)	0.528	0.292
Problem Solving Technique	0.960	0.111
MATLAB Scripts	0.870	0.160
Basic Math in MATLAB	0.580	0.181
Variables	0.249	0.171
input	0.365	0.253
fprintf	0.321	0.180
Relational operators (<, >, <=, >=, ~=, ==)	0.694	0.424
Logical operators (&&, ‖, ~)	0.383	0.199
If structures	0.740	0.217
Switch-Case structures	0.765	0.118
Library functions (sin, sqrt, abs, etc.)	0.714	0.261
Random numbers	0.734	0.349
Rounding numbers	0.852	0.322
Mod	0.819	0.227
While loops	0.754	0.107
For loops	0.936	0.124
Arrays	0.524	0.333
Math using Arrays	0.504	0.249
Accessing array elements	0.820	0.269
Slicing, augmenting, etc. Arrays	0.657	0.345
Functions for arrays (min, max, etc.)	0.383	0.245
Plotting	0.505	0.131
xlsread	0.362	0.361
Dialog and message boxes	0.739	0.271
Cell Arrays	0.702	0.163
Programmer defined functions	0.720	0.517
Strings	0.809	0.164
String functions	0.735	0.222
Low level files	0.217	0.281

D. Next Steps & Remaining Work

Questions/answers to the selected items will be generalized to create a similar exam, resulting in a new set of questions that should still meet the desired goals. The resulting form will be given as a common final exam during the Spring 2013 semester. The results will then be compared to other course items, including final course grades to identify if the generalized items represent an adequately discriminating exam.

TABLE II. SAMPLE EXAM ITEMS

<table>
<tr><th>Course Topic</th><th>Item Difficulty</th><th>Discrim. Index</th></tr>
<tr><td>Relational Operators</td><td>0.694</td><td>0.424</td></tr>
<tr><td colspan="3">Which one of the following is not a relational operator?
a) = =   b) &&
c) =   d) | |</td></tr>
<tr><td>Programmer Defined Functions</td><td>0.720</td><td>0.517</td></tr>
<tr><td colspan="3">A function call includes three parts, they are:
a) function name, arguments to the function, and collection of return values
b) function definition, arguments to the function, and collection of return values
c) function definition, function call, and collection of return values
d) function name, function definition, and collection of return values</td></tr>
<tr><td>Slicing, augmenting, etc. Arrays</td><td>0.657</td><td>0.345</td></tr>
<tr><td colspan="3">Suppose that x is a normal MATLAB matrix that looks like this:
<code>1 3 5 7</code>
<code>2 4 6 8</code>
<code>9 10 11 12</code>
<code>13 15 17 19</code>

What will be contained in y after this command is executed:
<code>y = x(2:4, 1:3)</code>

a) <code>2 4 6</code>
<code>9 10 11</code>
<code>13 15 17</code>
b) <code>2 1</code>
<code>4 3</code>
c) <code>3 5 7</code>
<code>4 6 8</code>
<code>10 11 12</code>
d) None of these</td></tr>
</table>

ACKNOWLEDGMENT

The author wishes to thank his colleagues at Embry-Riddle Aeronautical University for providing the majority of the data.

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Engaging Early Engineering Students (EEES)

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***Abstract*—Undergraduate STEM student enrollment has declined substantially over the last decade. Specifically there has been a steady decline in retention of early engineering students working through the first half of their degree programs. Student "leavers" typically fall into two categories (i) those facing academic difficulties and (ii) those that perceive the education environment of early engineering as hostile and not engaging. The Engaging Early Engineering Students Project (EEES) is a collaborative effort between Michigan State University (MSU) and Lansing Community College (LCC). EEES functions through the integration of four component programs designed to ease the transition of high school students into engineering undergraduate programs, and, by making the transition smoother, to increase retention at the College of Engineering (COE). The programs are: (a) Peer-Assisted Learning, (b) Connector Faculty, (c) Diagnostic-driven Early Intervention and (d) Cross Course linkages.**

Keywords—Early Engineering Students; Peer-Assisted Learning; Supplemental Instruction.

I. Background & Theoretical Framework

There is a national growing concern among industry, government and educational leaders about the need to increase the number of students graduating from science, technology, mathematics and engineering (STEM) disciplines [1]. In 2006 a report from the National Science Board (NSB) indicated that the production of STEM degrees in the USA is lagging compared to similar economies. In particular NSB indicates that there is a national need to increase the numbers of engineering graduates [2].

In his Interactionalist Theory of student departure Tinto (1993) introduced the concept of academic integration to link the students' experiences both social and academic, that influence their decisions to persist and graduate from college. Academic integration includes a range of experiences both inside and outside of the clasroom such as academic succes, informal contact with faculty and social and community participation [3, 4, 5]. Ohland et al., (2009) indicate that there is a 40% departure rate of first-year engineering students [6]. In a seminal study Seymour and Hewitt (1997) indicated that these early "leavers" typically fall into two categories (i) those that are facing academic probation and (ii) those that perceive the academic and social environment of early engineering as hostile and not engaging [7, 8]. More recently, Marra et al. (2012) also concluded that academic factors such as curriculum difficulty and poor teaching and advising as well as non-academic factors such as "lack of belonging" contribute to students' decisions to leave engineering [9].

The theoretical framework guiding our reseacrh project is based on Tinto's therory and includes elements from Seymour and Hewitt (1997) studies on student attrition among STEM students. Our objective is to consider the student experience as defined by their academic and social experiences. To achieve this objective the EEES project integrates four component programs that address both categories of leavers-- those facing academic difficulties and those that perceive the education environment as hostile and not engaging.

In this work-in-progress we present preliminary results from the implementation of the Peer-Assisted Learning (PAL) and Supplemental Instruction (SI) programs at MSU and LCC respectively.

II. Project Overview

The project components and their interactions are depicted in figure 1 and include: a) Connector Faculty program to engage engineering faculty with early engineering students, b) PAL/SI to aid student learning in traditionally challenging courses, c) Dx-driven Early Intervention to provide formative assessments (gateway exams) in key courses with follow-on tutorials and d) Cross Course Linkages program to develop and exploit connections between key courses. In the following sections we will describe the implementation and preliminary outcomes associated with the PAL and SI program components.

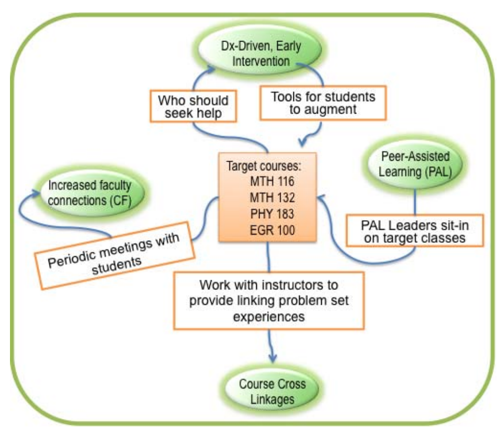

Fig. 1. The EEES Project Components: An Integrated Structure

A. *Supplemental Instruction & Peer-Assisted Learning*

The EEES project peer-tutoring programs are based on the supplemental instruction model of voluntary participation developed at the University of Missouri-Kansas City that integrates course content with active student learning in the context of peer-facilitated study sessions [10, 11]. PAL and SI target traditionally challenging courses that are barriers to student admission or transfer to the COE. Student leaders regularly schedule informal review sessions to discuss course materials. While working together in an environment that fosters discussion and collaborative work, students learn to integrate course content and study skills. The target courses at MSU include: Physics, Pre-Calculus, Math 116 (College Algebra) and Math 138 (Calculus I). LCC has had a strong and effective SI program for close to two decades. Funding from the EEES project resulted in the expansion of the courses originally covered by SI to include STEM targeted courses necessary for transfer to engineering at four-year institutions. These courses include the Calculus series (5 Math courses in total), Physics (2 courses) and a MATLAB & numerical methods course (CPSC131).

B. Data Collection and Analyses

Our data collection includes student and faculty surveys to measure participants' awareness of the program, expectations of program success, and experiences with program participation. We also collect standard course data on student learning outcomes, course grades, and attendance data including number of tutoring sessions and number of contacts. We used SPSS V 19 for all analysis and performed 1000 bootstrap iterations to estimate confidence intervals for all regression coefficients, using a 95% confidence interval for significance.

III. RESULTS

To understand what, if any, differential impact there was for participating in PAL and SI we compared the academic outcomes for students who participated vs. those who did not while controlling for other variables. To determine if there are interactions among variables that impact outcomes, we performed regression analyses for each of the target courses in both PAL and SI programs. For all regression models we used academic indicators such as math ACT, first math gateway score, math placement or prerequisite course scores, as well as PAL/SI attendance, gender and ethnicity categories as independent variables. Results include data collected since Fall 2008 through Spring 2011.

A. Supplemental Instruction (SI) at LCC

SI has been implemented at LCC in a large number of courses for several years before the EEES project; the program has been institutionalized and most students are aware of it. While participation in SI varies widely by course (between 41% and 81%), participants tend to attend frequently, suggesting that they find these sessions worthwhile. We analyzed the impact of SI on student academic outcomes for eight courses enrolling 1288 students. For Math 121, 151, 253, and Physics 251, the Beta for SI was significant ($p < .05$), meaning that when controlling for academic ability, SI participants perform better in these courses than non-participants (Table I).

TABLE I. SUMMARY ANALYSES FROM SI COURSES AT LANSING COMMUNITY COLLEGE

Course	Regression Model (R^2)	Beta for SI	Average increase in number of 2.0+ grades for SI participants	Average increase in course grades for SI participants not withdrawing
Math121	.197[2]	.071[4]	3%	.21
Math122	.173[2]	.003[1]	N/A	N/A
Math151	.292[2]	.360[2]	18%	.56
Math253	.408[2]	.272[4]	11%	.42
Phys251	.340[2]	.210[4]	10%	.34

1. Not Significant; 2. Significant $p < .000$; 3. Significant $p < .01$; 4. Significant $p < .05$

B. Peer-Assisted Learning (PAL) at MSU

The participation rate for students who had attended at least one PAL session ranges between 18% and 26% across the target courses. After controlling for academic and demographic variables, it appears that the impact of PAL is very modest, ranging from a small impact in Math 116 and Physics 183, to no-impact in Math 132. Given that the regression models account for only 16% to 23% of the variance, there are many other factors that are not being measured that may impact students' outcomes. However, the overall differences in student outcomes are slight (Table II).

TABLE II. SUMMARY ANALYSES FROM PAL COURSES AT MICHIGAN STATE UNIVERSITY

Course	Attended at least one PAL session	Women enrolled (PAL attendees)	Regression model (R^2)	PAL attendees course grade[a]
Math 116 (n=111)	12.9%	49.4% (66%)	16.4% ($R^2 = .164$)[b]	0.08 higher (beta = .072)
Math 132 (n=28)	2.3%	31.3% (64%)	23.2% ($R^2 = .232$)[c]	Not significant
Physics (n=452)	4.6%	23% (19%)	19% ($R^2 = .19$)	0.1 higher (beta = .011)

a. After controlling for all other variables.

b. Significant variables: ACT (beta = .176), Gateway score (beta = .255), MSU Math Placement score (beta = .086), White (beta = .152), and Gender (beta = -.165).

c. Significant variables: Math Gateway score (beta = .214) and Math ACT (beta = .134), Math Placement score (beta = .271).

IV. SUMMARY AND FUTURE DIRECTIONS

Our preliminary results indicate that:

- At LCC, SI is well attended and appears to have significantly positive effect on learning outcomes in most pre-engineering courses.
- At MSU, PAL is poorly attended and appears to have no significant effect on learning outcomes in most pre-engineering courses.

There is much debate on the impact of voluntary SI programs on student outcomes. It is not clear if the improved student outcomes are due to students who are more academically capable attending SI more frequently. However, reports in the literature that substantiate this viewpoint are difficult to locate. Our plan is to investigate the institutional and programmatic characteristics that promote success in voluntary peer tutoring and that might contribute to the differential success of the PAL and SI programs.

ACKNOWLEDGMENT

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Real-World Problem Solving in Entry-level Programming Courses

A Case Study on the Deepwater Horizon Oil Spill

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***Abstract*—In teaching introductory computer programming courses, problem solving with computers is an important topic and algorithm design is essential. We developed a team-based project to teach students solving real-world problem. Students are provided with six satellite images of the Deepwater Horizon oil spill in the Gulf of Mexico and asked to develop computer programs to outline oil contaminated areas. Working on the project in a team, students conducted initial analysis of the problem, identified patterns of oil slicks by visualizing satellite images, and designed algorithms to delineate the oil slicks. The open-ended problem allowed the students to gain experiences in user interface design, use of arrays, decision-making, and repetition with hands-on experience. The project has also been adapted in teaching classes of computer science general education and digital image processing.**

Keywords—problem solving; software development; first-year sequence; image processing; oil spill;

I. INTRODUCTION

The use of real-world projects in teaching STEM (Science, Technology, Engineering, and Mathematics) classes is not new. Research in education has shown the benefits on student comprehension and retention of projects that solve real-world problems [1] [2]. Furthermore, student's ability to see engineering's potential social contributions can stimulate female students' interest. However, real-world problems have seldom been brought in classes for incoming freshmen in Computer Science (CS) and Computer Engineering (CE). Rather, real-world projects are mostly used in junior-level CS/CE classes such as software engineering. Moore and Brennan have created a "real world lab" in their software engineering classes to foster industry-university collaboration [3]. Preston extended the labs to Information Technology education [4]. These projects have helped students to solidify and deepen their knowledge of project management, customer relations management, requirements elicitation and management, software development, database technology and communication skills.

Most real-world problems are open ended. Newman and Daniels et al. [5] have argued for the use of open-ended group projects to supplement the conventional lecture and laboratory teaching approaches. They showed that the projects can successfully get the students to think about how the ideas can be applied in practice. The use of such projects improves student learning, but, challenges exist pertaining to the assessment of team-based learning. For example, Sabin noticed the issues related to the assessments where both individual and collective contributions from students are taken into account [5].

Over the last ten years, many CS programs have seen less interest in computer science among high school graduates. Many students want to work in a field to allow them making a meaningful social contribution. It is obvious for those students to see such connections for disciplines like political science, art, biology, environmental science, or civil engineering [6]. No apparent connection exists in entry-level computer science courses, at least by the titles of courses taught in CS/CE. To address the problem, Buckley and Nordlinger et al. have introduced socially relevant computing as a new way to reinvigorate interest in computer science [7]. They believe that computing for a cause, or computing as a means to solve problems, rather than as an end in and of itself, is key to attracting this generation to the discipline.

Although solving real problems is a useful way for students to gain "hands-on" experience in college, it is still difficult to find a meaningful problem for first-year computer science students to work on. Most entry-level course sequences in CS consist of *CS1*, *CS2* and *Data Structure*, with the *CS1* and *CS2* being the first two courses taken by CS majors [8]. In both courses, students learn the basic programming elements. In teaching the entry-level courses, software life cycle is an important topic and algorithm design is essential to this cycle. The two-course sequence emphasizes a programming paradigm with a focus on problem solving and algorithm development. Still, they are programming-centered and unappealing to an increasingly diverse student groups.

In this paper, we develop a project using satellite images of the Deepwater Horizon oil spill to teach students problem solving using computers. The oil spill in the Gulf of Mexico between 21 April and 31 July 2010 was the largest offshore spill in the U.S. history. To deal with this unprecedented disaster, researchers and management agencies have used satellite images to track the spill. The objective of the student project is to design image processing algorithm(s) and implement computer software to delineate surface oil slicks on satellite images. This paper describes the project and how it was used in teaching entry-level programming classes.

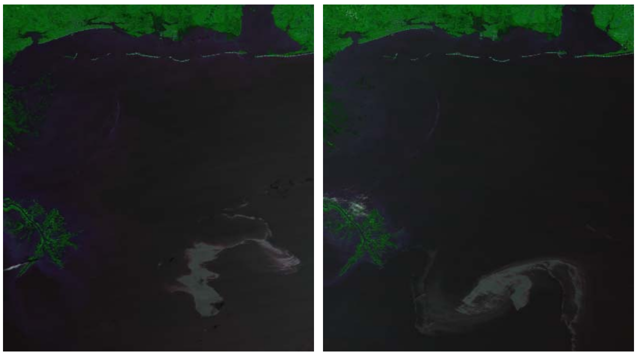

Fig. 1. MODIS images of oil slicks from the Deepwater Horizon oil spill in the Gulf of Mexico. To the left is the Mississippi River bird-foot delta, and the top right shows Mobile Bay. The oil slicks appear whitish in these images.

TABLE I. THE LINEUP OF SPECTRAL BANDS OF MODIS IMAGERY.

Band	Wavelength (nm)	Included?	Assigned Color
8	405 – 420		
9	438 – 448	Yes	
10	483 – 493		
11	526 – 536	Yes	
12	546 – 556		
13	662 – 672	Yes	
14	673 – 683		
15	743 – 753		
16	862 – 877		

A. *Deepwater Horizon oil spill*

The Deepwater Horizon oil spill was captured by several earth-observing satellites. Satellite images are used in a wide-range of civilian applications, including mapping, agricultural monitoring, environmental monitoring, disaster response, etc. MODIS (Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra and Aqua satellites (http://modis.gsfc.nasa.gov/). The MODIS instruments provide images of the entire Earth's surface once every 1 to 2 days.

MODIS data covering the Gulf of Mexico were originally downloaded from the U.S. NASA Goddard Space Flight Center, and then processed using customized algorithms and software by the Optical Oceanography Laboratory at the University of South Florida [10, 11]. The processed MODIS data contained geo-referenced (or map projected) reflectance at 9 spectral bands (Table 1). Three of nine spectral bands (9, 11 and 13) were used to create Red-Green-Blue color images in BMP format. Examples of the MODIS sub-images covering the spill area in the Gulf of Mexico are shown in Fig. 1, while Table 1 lists the wavelength and the color assigned to each spectral band.

II. HANDS-ON PROJECT

Computer software development life cycle consists of five main phases, requirement analysis, program design, coding, testing and program maintenance [9]. As a user-oriented cycle, it evolves around user's requirements for the software. Though it is introduced in *CS1*, students usually work on specific problems and seldom experience the full cycle of it. As a result, many students view it as abstract and boring.

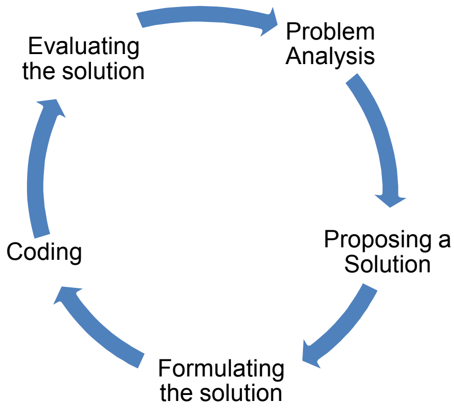

Fig. 2. Cycle of problem-solving process used in the project.

A. *Problem Driven Approach*

To bring real-world problem solving into *CS1* and *CS2*, we revised a generic problem solving process for use. The process evolves in fives phases of analyzing problem, proposing, formulating, implementing, and evaluating a solution (Fig. 2). In adapting the project, the instructor first introduces the problem, fundamentals of color image interpretation and how to display images in Java. Then, students are asked to develop a Java program to visualize ocean color satellite images during phase I of the project.

Displaying satellite images often creates excitement among students, but it does not present a direct solution to the problem. To move forward toward a solution, the instructor may ask students to suggest software functions useful for distinguishing oil from water. We would like students to consider algorithm design and software development as a problem-driven process, not just for students' self-satisfaction or as they are told to. In phase II, the instructor asks students to implement an image "sampler" to allow a user to move the cursor over an image and to click and display the color values of a pixel. Students are asked to use the implemented "sampler" to collect data for further investigation.

The phase III of the project starts with data analysis in Microsoft Excel. Students create scatter plot(s) with the data they previously collected, and develop linear function(s) to separate oil pixels. Instructor gives a lecture on the implementation of a thresholding algorithm with decision-making and repetition statements. Students will implement their algorithms and apply to the satellite images.

At the time this project is introduced, students should have learned array, decision, and repetition structures, and they should start to learn event handling and user interface in Java.

Typically, array, decision, and repetition are taught in *CS1*, and event handling and user interface are introduced in the beginning of *CS2*. For many Computer Science and Computer Engineering programs using Java in teaching an entry-sequence class, this project would be started late in the first semester or in the beginning of the second semester. If the students are not capable of developing a user interface from scratch, the instructor may provide students an initial user interface to use.

Fig. 3. MODIS image with oil spills outlined.

B. A Simple User Interface

The project is introduced to students with breaking news on the Deepwater Horizon oil spill, as there is extensive news coverage on the internet about this disaster. Instructor then introduces the problem of mapping oil slicks on satellite images, and presents a problem-solving process. Apparently, images of oil slicks need to be displayed before a solution could be found. So, the first task is to develop a Java program with user interface to visualize MODIS images.

Fundamentals of interpreting color images and how they are displayed with Java are discussed in class. The computer application has a menu bar and an area for image display (Fig. 3). A File menu consists of Open menu item which reads in an image in BMP format and Exit menu item. The primitive user interface has minimum features but is still flexible enough to allow students to add in more functions later.

- The main class will extend *java.swing.JFrame*. Its content pane, a *JPanel* object, consists of a *JMenuBar* object and an *ImagePanel* object. A *JMenu* on the menu bar has multiple instances of *JMenuItem* with each instance registered as an action listener.
- The use of *JFileChooser* allows user to browse folders to locate an image to read.
- The *javax.imageio* package has classes supporting different image formats including JPEG, PNG and BMP. Students can use *ImageIO* to read an image into a *BufferedImage* for future processing.

In phase I, students will experiment with basic user interface design and file I/O. They are provided with six MODIS images in BMP format.

C. Visualizing Oil Slick Patterns

Displaying satellite images does not present a direct solution to the problem. A solution relies on the visualization of differences between pixels contaminated by oil slicks and the rest of image pixels. Oil slicks appear "brighter" than the surrounding water on the selected images because they were collected under strong sun glint [10]. In the beginning of the phase II of the project, instructor will display the image and raise questions such as *"What makes oil slicks different from water?"* and "*What are the software functions needed in order to catch the differences?*" As the perceived color of a pixel is formed by three values, namely red, green and blue (RGB), it's intuitive to collect the color values of oil pixels and inspect. If students can collect image samples on different subjects and examine their values, they may identify the differences.

A useful software function would allow a user to click on an image and display color values of a pixel. Students can use *MouseListener* class to return the location of cursor and, then, retrieve the color values of a pixel for that location.

- Students can make an image display panel to implement *MouseListener*. The *MouseEvent* has a *getPoint()* method which returns the location of a cursor.
- The location can be mapped to row and column indices of a *WritableRaster* object.

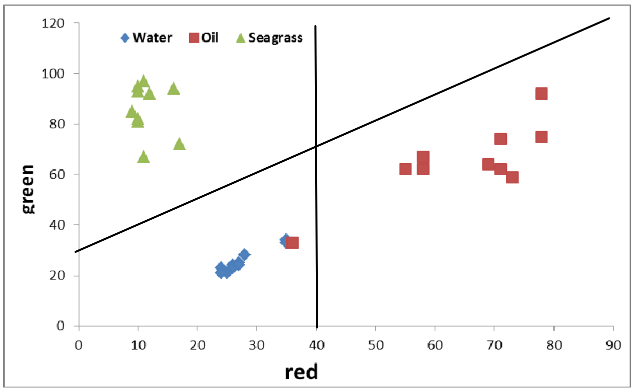

Fig. 4. Scatter plot of sample pixels over red and green colors.

By clicking on the image, students can display color values of a pixel on screen (Fig. 3). They can collect data for oil, land, water and vegetation on the image, record them in Microsoft Excel spreadsheet and create a scatter plot. A scatter plot is a mathematical graph which displays two variables for a set of data. It can suggest various kinds of correlation between variables. Scatter plot(s) of sample pixels is created using spectral bands (or colors) as variables in Microsoft Excel (Fig. 4).

With three spectral bands, students are able to create three scatter plots using different pairs of colors. Oil pixels tend to fall into a cluster, so do water and vegetation pixels. Threshold values or functions can be identified on scatter plots to separate oil pixels from other subjects. Students can create lines to separate oil, water, and vegetation (Fig. 4).

D. Outlining Oil Slicks

To outline oil slicks, students need to first formulate linear equations for the lines they have created on the scatter plots and design pseudocode to use these linear equations in their programs. The pseudocode consists of nested repetitions to iterate through each pixel on an image, and decision structures which uses image thresholding to label the pixels of targets. A sample pseudocode is given as,

```
for each row x
   for each column y
      get red color of a pixel as pixel_red
      get green color of a pixel as pixel_green
      get blue color of a pixel as pixel_blue
      if pixel_red>40 then
         //Oil
         set all color values to 255 for the pixel
      if pixel_green>pixel_red+30 then
         //Vegetation
         set green color to 255, other color values to 0
   end
end
```

Thresholding is the simplest method of image processing [10]. By thresholding, a pixel is converted into a labeling color or unchanged depending on whether the original color value is within the threshold range. The labeling color for oil pixels is white (255 for all RGB values), and green for vegetation. In Java, one can create a *WritableRaster* from the image using *getRaster()*, and modify the color of a pixel using *setSample()*.

```
WritableRaster raster = bfimage.getRaster();
raster.setSample(x, y, band, value);
```

A menu would be added to the menu bar for the algorithm. As the threshold values need to be adjusted in thresholding different images, a sliding bar seems a useful addition to the program.

The project is a good example to teach students computer algorithm design as a problem solving process. In solving a real-world problem, even a well-designed algorithm may not produce perfect result. On thresholded images, barrier islands and clouds could be mistakenly labeled as oil, and diluted oil-contaminated water are often identified as normal ocean water. Students are encouraged to do more research on the problem, research on a more robust algorithm for use. For instance, students may collect a set of mislabeled pixels, add them to the scatter plots, and redefine threshold functions.

E. Societal Impact of Computing Science

The summary lecture reviews the problem solving process, discusses societal impact of computing science and shows other potential problems that could be solved by adapting the project. Instructor may introduce several advanced methods for students to consider, where suggestions are given in the optional phase IV of the project. When the boundary of a cluster of oil pixels cannot be described precisely with a simple linear function, a higher order polynomial function is needed. Although the employment of such a function improves the accuracy of recognition, it also increases the computation time. Students should understand that there are alternative solutions to a given problem, and they should be aware of tradeoffs between different algorithms.

Computer technology is one of the greatest scientific achievements of the 20^{th} century. Its use has direct effect on our daily life as well as in our social life. Both CS and CE students need to understand the basic cultural, social, and ethical issues inherent in the discipline of computing [11]. They need to develop the ability to ask serious questions about the problems people are facing and to evaluate proposed answers to those problems. In the summary lecture, the instructor addresses the basic elements of ethical analysis and claims. Specifically, students need to learn to discuss their claims rationally based on the results of their analyses. The results of computer algorithms will not be perfect or completely accurate. Students should discuss the ad hoc of their approaches and know the limitations of computer algorithms. In concluding the project, a documentary video "Hindsight and Foresight, 20 Years after the Exxon Valdez Spill" [12] is played.

TABLE II. OUTLINE OF PROJECT WITH SUPPLEMENTARY

Course Material	Media Type
Java SE, Eclipse IDE to be downloaded	Software
MODIS images	BMP format
Lecture 1 – Introduction & News Coverage	Powerpoint & Video
Project phase I: Building a graphical user interface to display color image	Assignment & Java Solution
Lecture 2 – Event handling in graphical user interface	Powerpoint & Video
Project phase II: Sampling pixels on color images	Assignment & Java Solution
Lecture 3 – Algorithm design for problem solving	Powerpoint & Video
Project phase III: Image thresholding	Assignment & Java Solution
Lecture 4 – Summary & "20 Years After the Exxon Valdez Spill" by NOAA	Powerpoint & Video
Project phase IV: Advanced image thresholding (optional)	Assignment & Java Solution

III. ADAPTATIONS OF PROJECT

Instructional materials with software solutions in Java are available at IEEE Real World Engineering Projects program (http://www.realworldengineering.org/), and summarized in Table II. The portal is designed to disseminate high-quality, hands-on and team-based projects for the first-year electrical, computer engineering, computer science, biomedical engineering and electrical engineering classrooms.

A. Suggestions on the Use of Project

This project's target time frame is approximately eight hours. In a typical 3-credit hour freshmen class, the project will extend over 2-3 weeks. The activities of the project are following:

- 1 hour: Introduce Deepwater Horizon disaster and oil spill detection problem, explain the fundamentals of color image, review event handling and discuss image manipulations in Java. A 5-minute news report could be used in introductory.
- 2 hours: Students develop a Java program to open and display an image.
- ½ hour: Discuss *MouseListener* class, and explain how to create scatter plots in Excel.
- 2 hours: Students implement *MouseListener*, collect data and create scatter plots.
- ½ hour: Discuss how to formulate threshold functions and design pseudocode.
- 1½ hour: Students implement algorithm.
- 1 hour: Conclude the project. A documentary video may be played to the class.

The main software used in the project is Java, though solutions in MATLAB and Microsoft Visual Basic are also available. Solutions are exported as Eclipse projects (http://www.eclipse.org/downloads). The project is not to train students in digital image processing techniques. Rather, we seek to enhance our students' ability to solve problems by giving them access to the data and teaching them how to design algorithms to analyze. Pre-processed MODIS images are archived at many institutes, MODIS images of the Deepwater Horizon oil spill can be downloaded from http://optics.marine.usf.edu/ (under "Events => Deep Water Horizon Disaster"). If instructors and students are interested in images of different natural phenomena, they can download the software SEADAS (http://seadas.gsfc.nasa.gov/) and use it to process other MODIS images (http://modis.gsfc.nasa.gov/).

One can find extensive news coverage on this disaster and presents one news piece to introduce the project. We have found a documentary film titled "Hindsight and Foresight: 20 Years after the Exxon Valdez Spill" to be useful for this purpose. The documentary revisits the 1989's Exxon Valdez oil spill twenty years later to reveal lessons learned from coping with the disaster at the time. It is used to emphasize the project's societal impact and help students to understand how their own work might help others.

B. General Education Course

The project has been adapted in teaching Computer Science General Education class, *Problem Solving with Computer*, at Winona State University. This class is to introduce programming and problem solving for mathematics. It provides an overview of the principles of computer program design, and leads students through a complete cycle of problem solving using computers. Students develop programming projects to construct contemporary applications of mathematics. They learn to analyze the problem, formulate mathematical solution and actually implement it in Microsoft Visual Basic.

There were a total of 57 students who took the class in summer and fall 2012, with 48 students completing the project. Over 80% of students found "the project stimulating and intellectually challenging", 70% students agreed "their interests in the problem solving with computers has increased as a consequence of this project". Students consider the project "… very interesting…" and "… like the idea of the project and the end result …", they suggested "the project would be much more stimulating in a full semester term".

C. Digital Image Processing Courses

MATLAB is a programming language for building an interactive environment to carry out computationally intensive tasks. It is often used in teaching CS/CE/EE Digital Image Processing courses. The software has built-in functions for solving problems which require data analysis, signal processing, and several other types of scientific computations (http://www.mathworks.com/). MATLAB provides a Graphical User Interface (GUI) development environment which gives the user a simplified experience in running a program. Software solutions in MATLAB are also available per request. With MATLAB, students can build more advanced image segmentation and pattern recognition algorithms.

IV. Conclusion

We have developed a hands-on project to teach first-year undergraduate students in computer science, computer engineering, and electrical engineering in problem solving with computers. In developing a computer algorithm to outline oil slicks on satellite images, students learned to analyze the problem, propose a solution, and formulate the solution in mathematical forms and in pseudocode, and then implement and evaluate it. Students gained hands-on experience in several basic programming related concepts such as user interface, array, decision-making, and repetition. The project demonstrated how an algorithm would need to be designed rather than simply providing a solution. The project also showcased the societal impact of computing. We expect to continue and strengthen this type of project for beginning students in the coming years.

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"We Weren't Intentionally Excluding Them…Just Old Habits": Women, (Lack of) Interest and an Engineering Student Competition Team

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***Abstract*—Student, experiential-learning, engineering, competition teams (SELECT) provide an opportunity for engineering students to practice engineering technical and professional skills. The low representation of women in SELECT is often rationalized as a lack of interest by individual women rather than systemic processes that discourage or exclude women. We employ a qualitative-interpretive design and a cultural constructionist lens to bring into focus the interplay of individual interests, understandings of appropriate gender roles, and structural elements that contribute to a culture of inclusion or exclusion. Primary data consist of 90-minute semi-structured interviews of eight team members and one non-member. By interpreting the narrative portraits of two female students, we show the construction of a team culture where in general women are discouraged from participation based on stereotyped gender roles, by night campus attitudes, and by peers who challenge or ignore their skills, contributions, and interests. One woman persevered through the male-dominated culture because she received the encouragement and support of male peers who engaged as comrades and champions. This paper offers recommendations for institutions to demonstrate commitment to equitable access to experiential learning and to nurture student peer cultures that challenge historic gendered ideologies and rhetoric.**

Keywords— experiential-learning; interest; competition teams; gender; culture, diversity

I. INTRODUCTION

Student, experiential-learning, engineering competition teams (SELECT) provide an opportunity for engineering students to practice engineering technical and professional skills while engaged in competitive experiential learning design/build projects. Students form teams to design and build an engineering artifact, usually some kind of vehicle. These teams may be strictly extra-curricular, co-curricular, or constitute the main focus of a complete course within the degree curriculum, usually a design-focused or capstone course. Some teams operate under close supervision of a faculty advisor, while others more closely resemble any other student-run organization where members only engage their faculty or staff advisor when paperwork needs to be signed.

As the popularity of SELECT have increased over time, institutions are dedicating increasing resources to these teams. In a time when economic pressures and accountability demands require universities to do more with less, SELECT are a visible and promotable means to provide experience-based learning opportunities. Team photos, often highlighted in promotional materials for prospective donors and students, depict students engaged in authentic, hands-on, collaborative learning in a competitive environment. A sampling of materials featuring successful SELECT reveal the overwhelming preponderance of student images are white and male.

While these experiential learning opportunities are theoretically open to all engineering students, in practice, cultural and attitudinal norms limit who may participate [1]. Participation rates of under-represented population (URP) students in many competition teams are exceptionally low, even when normalized for engineering enrollment.

With the opening of our institution's engineering design and leadership facility, teams were brought into the public view. Moving the teams into this central, high-visibility facility revealed disturbing demographics and behaviors. The absence of women and racial/ethnic minorities was suddenly visible to the public (including donors and prospective students), and culturally sensitive faculty in the College.

The absence of females on one vehicle team (V Team) was not lost on a female who did join the team. In an interview for this project she explained, "*I talked to older guys on the team and I was like 'why aren't there older girls on the team?' The guys said they've always had one girl show up and get involved and then she kind of leaves.*" Male 6 corroborated that observation, *"there weren't any women on the team until two years ago. We would have some girl show up at the first couple of meetings, but we never had anyone stick around."*

The low representation of women in SELECT is often rationalized as a lack of interest from individual women rather than systemic processes that discourage or exclude all but the most assertive women. A male student interviewed for this project explained the attrition of females from V Team: "*If they have left, it's typically not been because they were shunned or anything like that, it's just they decided they aren't really that interested anymore.*" Another member echoed that opinion but added an additional stereotype: "*The more I realize it I think they* (females) *are just not interested in that type of engineering. They don't want to get their hands dirty, which might be a trait for girls.*"

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The male teammate quoted below brushed off language and cultural differences as an explanation for why two female international students would probably not continue on the team and grounded his explanation in lack of interest and commitment. Similarly, in his closing statement, he does not link the fact that "*engineering is male dominated*" to the absence of girls on the male dominated competition team.

Male 3: *We have two girls that are [international students], they speak [non-English]. They don't speak very much English. And we have a senior who speaks [non-English] with them. They're half way committed as much as I was last year. I don't see them sticking around or going to competitions. They show up like they are interested but I doubt for long; they won't* (keep coming). *Uhmm, just commitment, I guess also language barrier and they're just not as committed as we need them to be. You have to give up part of your life to be part of the V Team. We've never had any girls really. Not that I know of there hasn't been any consistent girls that were team members, like critical team members. Engineering is a male dominated degree I guess, and it's hard to get girls in (*engineering*). I know there are girls in my class that are engineers, (I guess) they are just not interested* (in V Team)...

Accounts like these reflect culturally normative explanations for the absence of women [2]. Explanations grounded in the rhetoric of lack of interest or stereotypes ignore the structural, ideological and social conditions that together construct learning spaces, such as SELECT, as open and welcoming or closed and unfriendly [3].

In the larger project, of which this study is a part, we seek to identify and explain what factors contribute to cultures of inclusion or exclusion among varied SELECT. This report will compare the experiences of two female students who acted upon equally strong interests in engineering and this SELECT to address the research questions: ***How do elements of gender ideology and the rhetoric of interest contribute to the peer culture for V Team? How does this peer culture create an environment that supports diversity or reinforces gendered exclusions?***

II. Research Methods

While qualitative methods have multiple traditions, contemporary qualitative methods emphasize that cultural understandings, experiences and structures are socially constituted [4]. We employ a qualitative-interpretive design and a cultural constructionist lens to bring into focus the interplay of individual interests, understandings of appropriate gender roles, and peer culture that contribute to a culture of inclusion or exclusion on one SELECT.

Interviews and observations constitute the preferred approach for studying cultural phenomenon [5]. The study we present here develops primarily from analysis of 10 semi-structured interviews of eight (majority male) V Team members lasting one to two hours, but also observations of team activities, examination of team documents, as well as web and social media sites. To provide an additional perspective on team culture, a female engineering student who had been a team member for one year and left was also interviewed.

The semi-structured interview protocol allowed the interviewer to augment standardized questions with additional probes as needed. Interviews were transcribed, reviewed for accuracy, and coarsely coded using N-Vivo qualitative data analysis software [6]. Quotations from student interviews are used extensively. Their understandings, perceptions, and language are the data for this paper, specifically their responses to questions on these topics:

- When did you first know you were interested in engineering? Who or what fueled that interest?
- Would you consider yourself a tinkerer?
- On a scale of one to ten, how would you rate your technical proficiency? What experiences inform that rating?
- Why did you join this particular team?
- What are your impressions of this team?
- How would you describe the culture of this team?

Student responses are generally preceded by a member designation assigned to that participant. Words or excerpts that appear in *italics* represent the actual language of the students. Words or phrases inside parentheses ( ) have been added by authors to add context or clarify participants response. Words or phrases inside square brackets [ ] replace or delete identifying information and are used to ensure anonymity of participants and other entities. A (L) indicates that the participant or interviewer is laughing.

III. Interest, Peer Culture, and Gender Ideology

Explanations for students' interests in particular majors and professions arise from many sources. Economists and some educators suggest that considerations of earnings potential and status attainment influence major interests [7]. Psychologists tend to focus on intrinsic factors and individual characteristics [8], [9]. Integrating elements from simplistic materialist and individual psychological explanations, Social Cognitive Career Theory (SCCT) also incorporates the notion that interest is socially constructed [10], [11]. Within this theory, interest is predicted by self-efficacy. Both self-efficacy and interest, along with outcome expectations and social influences, are directly linked to choice of pursuit and intention to persist. In other words, a student's choice of major/career path/extra-curricular activity (pursuit) derives from their interest in the activity, their confidence in performing the activity (self-efficacy), and their expectations of desired outcomes. The enabling or constraining characteristics of the social environment in which a student's choice is enacted will either support an intent to persist or lead to a decision to withdraw. SCCT defines that social environment as the choice-proximal environment and maintains that the comprising social and material supports and barriers play a crucial role in maintaining choice goals.

Experience-based activities, such as SELECT, are choice-proximal environments where interests encounter barriers and constraints. These environments are heavily influenced by peer culture, yet little is known about the processes and dynamics that make peer culture a powerful influence on student experience and desired (or undesired) outcomes. According to

Dalton and Crosby college peer culture “is the single most important influence on student learning, values and behavior in the college setting and yet remains one of the least studied and understood aspects of higher education” [12, pp.1]. Peer culture consists of the norms, language, values, practices, and beliefs that guide the behavior of members on a daily basis and serve as a frame of reference that group members use to interpret the meaning of events and actions, both on and off campus [5]. Across campuses, in the Greek system, athletic teams, student organizations, etc., peer cultures act as sites where gender, race and class stereotypes are often reproduced but sometimes challenged [13].

Many of the activities and interactions that shape student-defined culture occur during the evening and night hours when faculty and staff are not around [12]. Matthews named the resulting environment “night campus” [14]. “Night-campus” is not well-understood as this culture operates in parallel to the institutionally-defined culture in time and space that faculty rarely visit. Similarly, SELECT generally work in relative isolation with the only visible activity typically associated with special events to promote the competition or their sponsoring organizations or departments. Therefore, little is explicitly known about the team composition, interactions, and practices constructing their peer cultures. These peer cultures can be constructed in ways that promote positive outcomes and persistence (social supports) or in ways that are hostile and drive students away (social barriers).

Historically, the majority of SELECT have been male-dominated student organizations engaged in the design, construction and competition of culturally-understood-masculine technologies (race cars, airplanes, off-road cars). Female engineering students whose interests lead them to participate on male-dominated competitive teams must overcome barriers that arise from cultural notions of appropriate feminine behavior [15], [16]. Ideologies of race, gender, sexuality, etc. frame cultural understandings of appropriate behavior and label positions or actions as “right” or “wrong” and have a legitimizing function [17], [18]. Women who wish to act on interests and participate on most competitive, experiential-learning teams encounter a learning space whose peer culture is informed by masculine norms, language, values, practices and beliefs. One older male team member described the culture as a “*fraternity*”:

Male 6*: The friends I have on the team have really become my fraternity. … I’m sure some of it* (why there were no women on the team) *was that it was difficult to be in our group, just because we were so tight knit and, I don't know, we probably came off as an intimidating group, even though every year we said, 'we got to get a girl this year.' (L) Just because you see other teams every year at competition and alot of teams will have one or two.*

The fraternity-like peer culture acts as a gate-keeper – rewarding those who understand and are comfortable with the language and practices and excluding those who are not. This was the culture Female A encountered when she acted on her interests and attended an organizational meeting for V Team.

Female A*: When I walked in* (first organizational meeting) *I wasn’t really sure; it was a bunch of older guys, most of them were seniors, it was awkward, strange…I was a freshman girl, I didn’t know what to do.*

IV. Parallel Portraits of Interest in the V Team

In this section we provide excerpts from the narratives of two female students with very different outcomes as illustrative data for the peer culture they encountered within the V Team environment. These data arise from responses to questions related to the elements of SCCT. Interpretative comparisons of their experiences will follow in the next section.

Female A (member): Female A began participating on this SELECT first semester of her freshman year. As a sophomore, she served as the design lead for one of the vehicle’s sub-system. Interviewed the first semester of her junior year, Female A had ascended to an over-all leadership position with logistic and external relations responsibilities.

Female B (non-member): Female B began participating on this SELECT the first semester of her freshman year (Female A’s sophomore year). She participated for one academic year (fall and spring), but did not continue. She was interviewed first semester of her sophomore year.

A. Engineering Spark (interest):

Female A: *My grandfather was Vice-President of Manufacturing at* [aerospace company]. *So I grew up with a lot of history and background. Aerospace engineering just always seemed so interesting and innovative. Also, I was always good in math and science like my dad. Coming in, I wanted to be a designer, to design planes. Growing up my older brother did a lot with Legos and stuff and everyone thought he would be an engineer. I was more of a team-oriented person in high school; I like to be around people.*

Female B: *I decided I wanted to be an engineer during my sophomore year in high school when I went and visited my sister at her place of employment. All of the people she worked with were engineers. I got to play on a flight simulator. It was the coolest thing in the world. I was like, 'okay, how do I get to play with these toys for a living?' Then from there I kind of went and looked into engineering more, because I had never really heard about it. I knew it existed but I didn't really know what it was. I did a lot of research. I decided I wanted to be a* [major deleted] *engineer.*

B. Technical Proficiency (self-efficacy):

Female A: *Prior to joining the team I hadn't done any mechanics, other than the little my dad showed me with my car. I've never like torn apart a car or anything like that. All this* (technology) *was new to me. I never used tools around the house. I would honestly say on a scale of one to ten my technical proficiency is about a six. I do have technical experience but I don't feel like it is a strength of mine. I wasn't much of a tom-boy, I was a girly-girl.*

Female B: *What appealed to me about engineering was the technical aspect; I've always loved playing with the new toys. It's always kind of had a fascination for me. One of my favorite toys growing up was the chemistry models. I would mix those with Legos and build these ridiculous things (L). I* *would pretend that I had built something really cool though it probably looked really dumb (L). I liked the hands-on activity. I really liked the actual building of it and seeing it transform in front of my eyes from a pile of blocks to a ten story tower or whatever. Now I am really comfortable using tools around the house. Overall, on a scale of one to ten I would rate my technical proficiency at a seven…over the past few years I've picked up welding. My brother-in-law taught me and every break I get I go and weld with him on projects. I also put in wood floors for a living so I use lots of saws and stuff. I haven't got it yet, but I am working on my pilot's license.*

C. Join Team (choice):

***Female A**: I joined the team because I was really interested in the engineering aspect of it. I thought it was really cool how you could build a* [vehicle]. *That to me just sounded really cool. A lot of people join because they are interested in racing. I had no interest in that at all, I'm scared of that (L). The day I set foot on campus I never imagined myself being a leader on the Team? No, no way at all. (L). That probably is the last thing I thought I would do. No one ever believes this is what I am doing.*

***Female B**: When I came to campus for a tour, I think it was my junior year of high school, the first thing you see when you walk in the facility is this* [vehicle]. *I was like 'okay, what is this* [vehicle] *about?' And they told me and I was like, 'okay, I have to join in that.' Then, first week of school comes around and they had all this information out and I was like 'okay, I want to join.' And I did.*

D. Hope to Gain (outcome expectations):

***Female A**: I am hoping it will help my career when I get out of college. It has helped me very much know what industry I want to go into or type of job I want. I just hope when I get into industry things will be more, I'll be able to pick things up more because I have this background and experience working with people and different types of programs and software that maybe others weren't exposed to.*

Female B: (I wanted) *to learn a lot about* [vehicles] *because that was something I didn't know a whole lot about and I would like to know something about. I am very curious.*

E. Perception and Experience of Team Culture (peer culture-choice-proximal environment):

***Female A:** The thing about the team, if you are new and you want to get involved you have to push yourself to get involved. You have to be like 'hey, I want to get involved.' They don't reach out. You really have to push yourself to get involved or ask for stuff to do and if you need help you have to not be scared to ask for help.*

***Female B:** There was never anything to bring in new people. You really had to swim upstream to be able to get into it. There wasn't any training on building things. I went into it not knowing anything about* [this technology], *nothing at all. I really wanted to learn this stuff but then there was no way to jump in. It was very difficult. I was always like waiting for something to happen and then nothing ever happened. The atmosphere was kind of like 'we know how to do this and it will be faster if you aren't here.'*

***Female A:** I got close to some of the older guys and they really encouraged me to stay and they didn't see me as a girl, they saw me as a team member. I mean it could be so easy to be 'I am the only girl on the team.' But if you're treated as everyone else, what's the difference. Like the two grad students, they're not really on the team, but they are still around and they have both always encouraged me. They have always pushed me even when I felt like I didn't know anything. They always told me 'believe in yourself.' The hard time is with yourself, like 'do I want to commit all this time and am I even valued on the team'. Everyone has been at that point, whether you are a boy or a girl. I am friends with them all and I feel welcomed and comfortable. I've always been encouraged to stay and sometimes I think that is what it takes.*

***Female B:** I told them that I wanted to work in that area (*welding frame*) and they were like 'okay show up at this time' and I did and no one was there. It was just so hard to get involved in it. They had Saturday work days. We would all come in and we would just sit around. One Saturday, I went in to learn how to do CAD because we were supposed to be having a little session on CAD101, a weekend workshop. I go in and they're like 'okay, I want you to build this in CAD.' I've never used CAD, never built anything in CAD before and so 'I was like I don't know what any of these things mean,' and they just kind of left. They just handed me something and said 'build this' and left. I was like, 'I don't know how to build this (L).' I guess it was a trial by fire and I failed.*

F. Role of Faculty Advisor (choice-proximal environment):

Female A: [Advisor] *he's really good...he's someone who most of the leaders on the team are really close to.*

***Female B:** I met him twice and I don't really know much about him.*

V. How the Flames of Interest are Fanned or Suffocated Within the Choice-Proximal Environment of V Team

"Under the proper educational conditions, a spark of intrinsic interest can be nurtured into a flame of committed life purpose" (Dewey, 1897)

In these narrative portraits, Female B expressed greater pre-conceived interest in the particular design project and goals of V Team and even had a relevant skill that she assumed would be valued between the time that she first was exposed to the team during a pre-college campus visit and her matriculation to the college. She expressed stronger expectations and goals within her reasons for joining V Team. Using the rhetoric of interest, one might predict that Female B would be integrated into the team culture and become a valued member. However, the social supports and barriers comprising the choice-proximal environments encountered by these two students led to Female A persisting and Female B retreating.

Male team members recognized that the culture of V Team posed challenges for females. *Male 6 explained, "it's not that they* (older male members) *are really cold but they're not as* *open unless people really step up and so I can see where being a female and maybe feeling intimidated or just unsure, that that would come off as a 'we don't want you type thing.'"* Both Female A and B perceived entry into the team as difficult. They both recognized that the peer culture active in V Team was masculine and required new members to be pro-active or even aggressive in claiming a role or space within the team structure.

However, the team composition changed significantly between the times Female A joined and Female B attempted to join. Female A joined the team as a freshman when there was strong and competent senior leadership. Most team members had participated continuously for four years. The team had just come off an exceptionally successful competition season. Morale and confidence among senior core leaders was strong. However, membership ranks did not include many juniors. As a result, the freshman cohort of which Female A was a member had to assume the team leadership roles the following year as sophomores. The iteration of the team that Female B faced the following year was short on established members, leadership experience, technical skills and confidence.

The findings of Kvande and Rasmussen offer one explanation for the different peer cultures produced by the changing team composition [19]. In their examination of male and female professional engineers in different organizations, they found that different types of men react to the presence of women differently, resulting in either good or poor opportunities for the women. Comrades, men who have reached a certain position and confidence generally embrace the presence of women and form alliances that prove beneficial to women. Cavaliers and competitors tended to hold views that place themselves in a dominant position or in direct competition with women for status attainment. Alliances are not formed and relationships can be either patronizing or combative. Female A was able to form supportive alliances with older, technically proficient and confident, "comrades" like the following male:

Male 4: *We kept Female A around… like we tried to involve* [her] *more, tried to keep her on the team. We didn't make sacrifices but we attempted to remember her name and get her involved and we didn't treat her as a freshman who was not going to be around after the first semester. I think we all recognize that the team is all white, Caucasian males. We just go with it. But we are not closed minded to the idea of new people, minorities or sexes or anything like that.*

Female B joined V Team at a time when there were few older leaders. Younger male members were sorting themselves out and not confident in their status. With this void of team leadership, the less-confident members did not reach out in support of her interest and skills. Also, the team was short staffed in general which made it difficult to engage new participants and learn about individual skills.

Female B**:** *I never took it as malicious. It was never that 'we don't want you here', it was just 'we are not going to put out any effort to keep you here.' I think it was more the group culture, like it wasn't expected of them to do this* (reach out) *so they didn't feel it was necessary. …they were never taught how to teach or mentor. They would come up with with these ways to have us learn things, but then it was an epic fail. It was awful, it was not happening. It was just very frustrating because coming into it it was something that I was just very excited about and it was just a huge let down.*

Although Female B was not sufficiently integrated into the choice-proximal environment of the team to fully experience the gender ideologies influencing the peer culture, Female A and the male members clearly describe an environment informed by traditional gender schemas and roles. Given the masculine nature of engineering and the V Team technology in general, these ideologies make it even more difficult for female students to have their interests fanned and nourished.

Gender schemas, implicit, non-conscious hypotheses about sex differences in behaviors and preferences (interests), play a fundamental role in shaping men's and women's educational and professional lives [17]. Gender roles refer to our notions about how men and women are expected to behave [17]. Vehicle/competition-based engineering student teams operate at the intersection of two historically masculine domains: engineering and vehicles. A double-bind exists for women whose interests lead them to participate on SELECT. Current gender ideologies continue to conflate engineering, technologies, and masculinity [15]. Participation by women on vehicle-based SELECT, including V Team, challenges cultural socialization; a woman interested in V Team, according to one male team member, "*goes against the norms*".

These cultural norms create an expectation of a team devoid of female involvement. The following member is surprised by the number of females interested in V Team; yet, 80% attrition is expected and does not warrant comment.

Male 4: [Female A] *is the only involved female. Yeah,* [Female A] *is it. We had more girls sign up this year than last year. I don't know why. I remember seeing about ten sign up and I was surprised. I think there are like two still around.*

As an explanation for the dearth of females on V team, the following male team member describes a perceived conflict between female and engineers' schemas and roles. He claims that a female student's expected behavior as a girl subsumes behavior expected of an engineer and therefore she is more interested in what girls do, than what engineers do.

Male 3: *It* [V Team's project] *is different than your common perception of what a girl would want to do, I guess. Even though I know girls that are engineers, they're more girls than* [they are] *engineers I guess in that aspect they are more interested in what they were before becoming an engineer*.

Female A has persevered on the team in spite of challenges based on cultural ideology of appropriate gender behavior:

Female A: *People have looked at me and asked, 'a girl like you, why are you interested in* [the vehicle]*, why would you do that? You're not a tom-boy, you don't like* [vehicles].*' I've had people say that to me before and it's like well 'why not do it, if I'm not the person you expected, why not do it?'*

While her interest in the particular technology of V Team is seen as transgressive, Female A's assignment at competition reflects the prevailing gender schema and does not challenge appropriate female work roles [17].

Female A: *I went to competition, I did the business presentation as a freshman…I got to do it probably just because I was a girl. They wanted a girl to do it…probably to make us look…I don't know why, maybe more diverse, maybe we're better communicators? I got to do it again this year and will probably do it next year. I know the big, top teams have two girls doing it.*

Additionally, the night campus or fraternity-like aspects of V Team culture contribute to an uncomfortable or hostile environment for female team members. As this team member states, "*A lot of what the team does isn't really oriented to girls, like, you know, a group of guys are going to say jokes about your mom or things that are offensive to girls. Most girls that join the team disappear within a couple of months because they are alone.*"

VI. CONCLUSIONS

How do elements of gender ideology and the rhetoric of interest contribute to the peer culture for V Team? How does this peer culture create an environment that supports diversity or reinforces gendered exclusions?

The undergraduate engineering students' experiences revealed in our data demonstrate that these females possessed both the interest and the self-efficacy to pursue joining a competitive, experiential learning, engineering design team. They expressed and acted on this interest even though the team was engaged in the construction of technology in conflict with stereotyped notions of femininity. The choice-proximal environment or peer culture each student encountered was the most important factor influencing persistence on the team. The welcoming comradeship of the senior, secure male students supported Female A's choice to join the team and encouraged an intent to persist. With their support, Female A could ignore or forgive a fraternity-like atmosphere and communicated ideologies of appropriate gender behavior. In contrast, Female B's choice to join V team was not supported by existing team members. While not overtly hostile, the less-established, male team members did not encourage her involvement and therefore did not recognize Female B's crucial skills. Although rare among young women, her welding skills could have benefited the team and made her a valued member.

Although Female A found some acceptance on the team, she did not escape gendered work schemas. Our data reveal that gender schemas still exist in engineering, on this and other SELECT, as evidenced by the assignment of females to perform the business presentations at competitions.

These parallel portraits demonstrate how peer culture can counter messages of inclusion and inhibit access to opportunities for experiential learning. The lack of women on this SELECT is not due to a lack of interest but to structural and cultural factors that are far from inclusive.

VII. RECOMMENDATIONS

How can engineering educators and administrators demonstrate institutional commitment to equitable access to experiential learning and nurture student peer cultures that challenge historic gendered ideologies and rhetoric?

1) Understand the peer group cultures at your institution. Because of the potential for exclusionary or hostile environments within SELECT that counter institutional goals, efforts must be made to understand and monitor in-group dynamics. Institutional representatives must be particularly vigilant to identify roles and actions reflective of gender schemas, discriminatory attitudes, or the presence of cliques.

2) Interact in informal face to face ways to recognize and correct any negative manifestations of peer culture. Institutional interfaces (faculty, staff, and administrators) need to model and require a welcoming and empowering environment for diverse student team members. Supportive, approachable faculty who show interest in individual students boost student self-efficacy and confidence, which are known to lead to persistence. These factors are especially important for females and other underrepresented populations [20]. Formal (e.g. structured meetings, reports from leaders) and electronic interactions keep hidden any night campus dynamics within a team.

3) Provide appropriate and effective mentoring to develop team leaders and teachers. SELECT are promoted as experiential learning spaces; however, as student-led organizations, student-peers are responsible for leading the group to accomplish its mission and goals, as well as for teaching younger members. These dual, and potentially conflicting, roles are complicated further because both the leadership and membership change annually (at best). Essentially, these undergraduate students are fundraisers, engineers, teachers, managers, spokes persons for the group and the College, all without prior training, and successful full time college students too. As leaders, these students should be provided instruction and guidance to acquire the cultural competency to ensure a choice-proximal environment where all interested students can flourish.

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Convergence of Evolutionary Biology and Software Engineering: Putting Practice in Action

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***Abstract*— This paper presents a project in experiential learning where students put knowledge of software engineering processes into action in a multidisciplinary project combining computer science and biology. Visualization serves as a primary element to bind the concepts of the two disciplines. Students seeking to further their experience and strengthen their skills in software engineering may choose to complete their senior capstone course working on an ongoing project to construct a toolkit for visualization of phylogenies generated from Avida experimental data. Avida provides a complex computational environment in which the evolution of digital organisms is tracked and analyzed to help find answers to a wide range of research questions. Student projects involve extensions of existing analytic and visualization techniques, as well as the addition of new, often novel, techniques. Importantly, to be successful a visualization technique must be appropriate for the domain in which it is to be used, requiring students to also understand elements of biology. It is our premise that exposing computer science students to the convergence of these two disciplines will strengthen their ability to work at different levels of abstraction and develop new conceptual frameworks to address current and future challenges in hardware and software.**

Keywords—experiential learning; software engineering; visualization; Avida

I. Introduction

A successful software engineer must possess a core body of knowledge in software engineering. This body of knowledge has been defined through projects such as the Software Engineering Body of Knowledge (SWEBOK) [1] and SE2004 Software Engineering Education Knowledge (SEEK) [2]. Both projects assert that software engineering education should cultivate a range of capabilities, including engineering and professional practice, problem-solving and project management ability, professional ethics and relevant legal knowledge, international exchange ability, organizational and management skills, discipline and teamwork, initiative and creativity, and the ability to study independently and actively. SE2004 presents curriculum guidelines for the design and adaptation of educational programs. Even with this guidance, there are still challenges for educators, including how to prepare students as software engineers, as well as how to teach enduring principles in the context of current practice, so that students are prepared to adapt to rapid change in computing environments.

To capture the context of current practice in industry, a number of courses have incorporated projects that emulate real-world experiences, sometimes involving real clients [3-13]. The introduction of formal software engineering knowledge together with concurrent technique and skill development, can bring valuable experience to both students and faculty [5]. While it is critical that software engineering students leave the university with the technical and soft skills expected by employers [14], a single semester or two of course work may not prepare them to move into the workplace as a software engineer.

Our solution to this challenge has been to design a capstone experience that brings students into an ongoing multi-disciplinary research project as a software engineer. The role the student plays depends on the state of the project when they become involved, their previous coursework, and their individual strengths. In this paper we present information about our curriculum, the research project, which extends the Avida Toolkit with special emphasis on visualizing phylogenetic trees, and how we use this ongoing project to develop students' skills. Skills are developed in software engineering, computer science, and in a domain outside the student's expertise with the goals of expanding students' ability to think abstractly, as well as develop a library of software tools for the visualization of data generated by the Avida platform.

II. Project Context

A. Bioinformatics and Phylogeniies

In the bioinformatics domain, the amount of data continues to grow exponentially, formats change often, and complexity of results continues to increase. Researchers need tools that will assist them to effectively link, match, cleanse, transform, analyze and understand the huge volume of data (Big Data). Tools that are currently available to work with Big Data are often complex and hard to use or require resources beyond those readily available [15]. Innovation in phylogenetics and evolutionary biology has been accompanied by a proliferation of software tools, data formats, analytical techniques and web services, and creates a challenge when integrating phylogenetic and other related biological data. This creates the need for reusable software that can read, manipulate and transform this information into the various forms required to build computational pipelines[16].

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B. Visualization

The goal of visualization is to provide insights from masses of data through visual representations [17]. Visualizations are powerful and often elegant abstractions that provide mechanisms for the discovery of potentially valuable relationships in data. Techniques for visualizing commonalities between hierarchically structured data sets have a long history in visualization, and new graph visualization techniques have been introduced to display multi-category graphs, i.e., graphs that show both connectivity and category [18,19,20,21].

C. Visualization in Bioinformatics

The use of visualization in bioinformatics is not new, and a number of successful systems have been developed. However, challenges remain in developing readily available and easy to use visualization tools that can be used with large heterogeneous datasets. Many of the current techniques for bioinformatics visualization of phylogenetic data employ node-link graphs to represent data as trees. Finding the best tree for the dataset can be a computationally intensive problem. Most of the favored approaches provide approximations for NP-hard optimization problems [22]. Though some software packages can handle the massive amount of data generated in bioinformatics work, reconstructions of phylogenies have typically been limited, primarily by running time, to sets of some dozens or hundreds of organisms [22]. As data continues to grow in size and complexity, algorithms will have to be scaled up in terms of speed and accuracy, and bioinformatics visualization tools will have to improve their ability to layout extremely large graphs, as well as label, annotate, navigate, and compare multiple trees simultaneously [22].

In spite of the fact that there are already many software systems for biological computing, active research drives unforeseen change in requirements that may arise at any moment. This creates a continuing need for tools and modular software kits that can be integrated into bioinformatics analysis workflows independent of data storage formats [16], volume, and complexity. An immediacy of the need for results often leads to the development of analysis and visualization programs by scientists whose principle education is in fields other than Computer Science or Software Engineering [22,23]. The increasing body of nontrivial software being developed by end users can be a very costly practice [22] and often a distractor of the original research initiative.

D. The Avida Platform

Avida is a software platform for digital evolution, used for studying evolutionary processes relevant to both natural and artificial systems [24]. Avida is free, opensource software written in C++, and can be easily extended to add new features and system capabilities. Avida is the most widely used digital evolution software in the world, and its users encompass a wide range of backgrounds and expertise, including biology, computer science, engineering, and philosophy. Avida places a population of self-replicating computer programs, called *digital organisms* or *Avidians*, in a user-defined computational environment. Avida is not a simulation of natural evolution, but a separate instance of evolution in its own right: the digital organisms compete, replicate, and mutate, thus satisfying the fundamental requirements of evolution [25].

Due to the extensibility of the platform and the flexibility of system configurations, Avida experiments produce vast amounts of data that need to be processed. Avida contains some limited analysis tools, but individual researchers have to write most of their own analysis tools outside of Avida itself. The computer scientists and engineers who use Avida do not generally find this situation particularly burdensome, except that writing such custom tools is time-consuming. The situation is a larger problem for researchers who are not trained or experienced programmers, such as the biologists who use Avida. Learning the tools and programming skills required to write software for basic analysis is time consuming, and presents a significant barrier for non-programmer users of Avida. Exacerbating this issue is the fact that most of the software tools used at this time to produce analysis programs are heavily command-line based. Most non-programmer users are unaccustomed to working with command line interfaces, and the added complexity of learning a new interface scheme along with programming skills makes the task even more daunting. Another difficulty in Avida experiment analysis is that, in the past, most existing Avida data analysis software was written using Matlab, an expensive propriety software product. More recently, Avida researchers have turned to Python and other freely available software to write analysis tools. Although this solution eliminates the need for high cost tools such as Matlab, it still fails to address the lack of tools available to non-programmers, or the potentially complex tool chains and configurations that may be required in order to use non-propriety software.

III. Existing Software Engineering Curriculum

The University of Texas-Pan American (UTPA) offers ABET accredited degrees in Computer Science and in Computer Engineering. The first degree is housed in the department of Computer Science, while the second is jointly housed in Computer Science and Electrical Engineering. In addition to a core body of knowledge in the domain, the educational objectives for both degree programs include providing graduates with an understanding of social, professional and ethical considerations related to their respective disciplines

Each degree requires a course in Software Engineering that may be taken after students have completed courses in advanced algorithms and data structures and in systems programming. Students in the software track of Computer Engineering are also required to take a second course in Software Engineering and may also choose an elective in software verification, validation and quality assurance. Each major requires a capstone senior project.

The majority of CS majors opt to take other advanced electives after they have completed a single semester of Software Engineering. At the same time, the majority of the CE majors opt for the hardware track, leaving very few students graduating with two or more semesters of courses in software engineering.

The first course in software engineering (Software Engineering 1) provides a formal approach to the state-of-the-art techniques in software design and development with focused discussion on project planning, requirements, specification, system design, testing and implementation, integrating the knowledge that the students have learned in their other classes. The course uses teamwork in small groups on a substantial project for a real client to provide some experience in real world environments similar to those they will be working in after graduation. The nature of the projects requires that students learn to not only apply software engineering principles, but, more importantly, develop collaborative and project management skills and expand their written and oral communication proficiency.

Projects vary by semester, but typically are real problems or challenges identified by students. Often these are challenges that they or someone they know face on a daily basis and involve concepts outside of CS and CE students' domains of expertise. Thus, projects force students to expand their existing knowledge base beyond the principles of their discipline and software engineering. Addressing a real problem adds value and motivation to the learning experience: the project becomes a challenge with multiple options for a solution, not just an exercise. Students take ownership, and the process to a solution results in identifiable learning outcomes [3,4,13]. Examples of projects include a real-time collection, reporting and analysis system for county health inspection data, a tracking and awards system for student participation, a teacher performance evaluation and student learning outcomes analysis system, and an auto tracking system for controlling and monitoring driver access to a vehicle.

The products of the first class' projects are often used as starting points in subsequent Software Engineering courses. Software Engineering II focuses on the analysis of requirements and software architecture with an emphasis on object design, and adds implementation, testing and validation, maintenance and software re-engineering. Just as in the first Software Engineering course, students work on large projects in a group situation. A third course, Software Verification, Validation and Quality Assurance, covers methods for evaluating software for correctness and reliability, including code inspections and their role in software verification, program proofs and testing methodologies, formal and informal proofs of correctness, unit and system testing techniques, testing tools and limitations of testing, statistical testing, and reliability models.

The curriculum includes a capstone senior project in which students construct a software product, following it through the stages from initial specification to the final completed project. This paper discusses the use of the capstone course for experiential learning that is designed to deepen students' comprehension of the application of the fundamental principles of software engineering while strengthening their skill in communication and collaboration through the incorporation of students into an ongoing interdisciplinary software development project focused on a research initiative [14].

The capstone course we discuss is experiential learning in the context of an ongoing software development project, Avida Toolkit. This capstone course project involves the visualization of phylogenies generated from Avida experiment data. Avida is a digital evolution research platform, with the current version developed in the Digital Evolution Lab and the BEACON Center for the Study of Evolution in Action at Michigan State University. While mathematical modeling serves as an underpinning for simulation in evolutionary biology, Avida was not designed to serve solely as an evolution simulator. Rather, Avida provides a complex computational environment in which the evolution of digital organisms is tracked and analyzed to help find answers to multiple research questions. The transparency of the Avida platform means that any experiment may result in a very large data set. A set of tools exists to work with Avida data, but the tool library is continually under revision as new research questions arise. The approach taken in the capstone course is to use a software development process model to develop a tool library that can serve as the basis for students' innovation, differentiation and growth in understanding and supplying tools for answering questions that researchers ask, so that knowledge can be gained in phylogenies and, more broadly, bioinformatics.

IV. The Avida Toolkit Project

The Avida Toolkit Project originally started to provide data analysis and visualization tools for researchers working on the Avida platform., This would allow researchers to focus their attention on the science, and so discover complex relationships in the data that would provide new insights in their domain, rather than programming and tool development. Like many software projects, new technologies, applications, and participants resulted in project evolution. Both changes in technology and environmental circumstances allowed for the addition of a second purpose for the project. The project would provide an experiential learning opportunity in which students apply the knowledge they have gained through the software engineering, computer science, and computer engineering curriculum to an ongoing software engineering project.

The Avida Toolkit project started a little over two years ago. It originated with one faculty member, whose research involves analysis of Avida data. She began working with a undergraduate student to determine the feasibility of working with the Avida data files in the existing environment using resources available at UTPA. Given acceptable results, she introduced the development of an Avida toolkit as the project for a graduate level course in software engineering to provide a real-world experience and to support the research needs of Avida platform users. At the end of the course, she had three distinct project plans, requirements, requirements analysis, design, and design analysis documents. While each set of documents contained valuable insights into the development of a toolkit, it was her original problem description and a compilation of the student documents that created an actual requirements document, along with three tool prototypes.

The next event in the evolution of this project involved the faculty member receiving a call from a colleague using Avida, currently working in China. As an evolutionary biologist, the colleague had challenges with the extension of existing Avida tools to enhance his visualization of Avida experiment data that might provide insights leading to new questions. With little formal training in software development, coming up to speed quickly on other software platforms was not a reasonable option. He was interested in working with someone more familiar in the domain of programming in computationally complex environments. Casual academic conversations and back of the napkin sketches lead to forming a team including additional faculty members with knowledge and interest in biology, evolution, artificial intelligence, information management, and visualization, a collaboration that bridged two continents and multiple domains of expertise.

As the team expanded and collaboration solidified, the project requirements began to expand. As we see in our project based classes in software engineering, each participant brought his or her own perspective and understanding of the problem, here, including visualizing phylogenies, visualizing big data sets, analyzing big data sets, evolution, and biology. It swiftly became apparent that to be successful in creating an Avida toolkit, we would have to be deliberate in our actions. We decided to practice what we teach.

Gaining insight from the experience of Schaetter, Koeglmayr, Blankenbach, and Nippa [12], we use a slightly modified incremental development process based on Boehm's spiral model [26]. Using the model, we combine the advantages of top-down and bottom-up concepts, integrating prototypes in the design process. Incremental refinement as we move through the spiral allows us to better manage the risk and keep the software development process under control. Because this is an ongoing research project with a clearly defined software development process, students in CS and CE can join the project as their capstone course. Students' specific goals, tasks and products for their capstone course are driven by the current state of the software development process for the Avida Toolkit project.

The Spiral Model is an ideal model for this project. We have the flexibility to incorporate a variety of requirements, design techniques, and implementation styles, e.g. on one cycle we may use Agile programming or XP and on another cycle we may use a version of commercial off the shelf (COTS) products to incorporate new or repurposed source code. Each iteration of the cycle allows us to refine or extend the Avida Toolkit. Fig. 1 provides a snapshot of the model as used in the project.

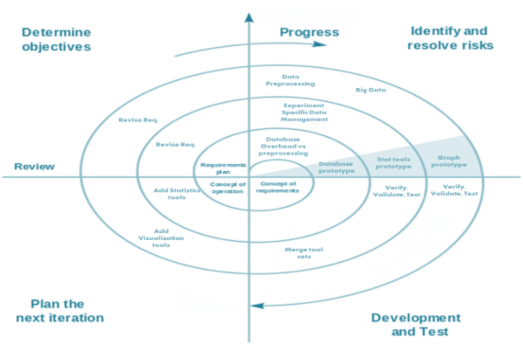

Fig. 1. Spiral model for Avida Toolkit Project

Students and faculty work together closely using this interdisciplinary approach. Students experience different roles and learn to communicate within the project team, as well as with specific stakeholders. Teamwork and efficient group communication establishes a basis for a learning community that includes both students and faculty. Most recently, two seniors in computer science joined the team. Their work involved refining requirements for Avida data management to facilitate the use of open source software libraries, including the Ape package and Biopython, to derive and display phylogenetic trees. In addition to requirements, one student focused on a comparison of software libraries, while the other prepared a prototype tool to display and manipulate phylogenetic tress in 2 and 3-D.

We are moving into the fourth iteration of the process. Using an existing toolkit for graph construction, we demonstrate the functionality available for generating visualizations of large data sets and expand our perspective on the visualization of phylogenies. We are taking advantage of our previous research in document set visualization and software developed at UTPA, InfoViz [27, 28,29]. The current functionality in InfoViz visualizations augment traditional text based search mechanisms and provide a means to make the overall data collection visualizable. InfoViz's visual representation has facilities to generate an overview of a complete document set, filter, add, and delete documents. The system also uses 2 and 3-D visualization tools to identify groups of useful documents and gain access to relevant clusters and individual documents as seen in Fig. 2. Given the obvious analogy to the size and complexity of data generated during Avida experiments, we are evaluating the potential redesign and repurposing of the InfoVIz software.

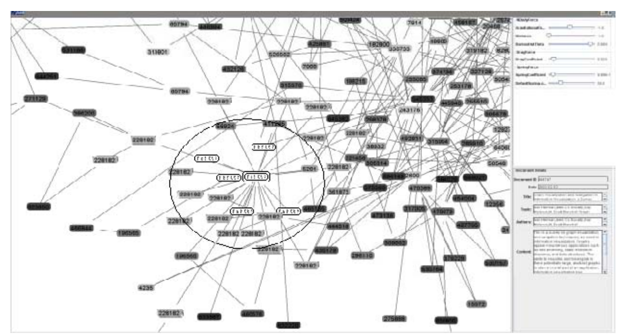

Fig. 2. An example of selective document filtering in InfoVIz.

Requirements definition will begin shortly for a new preprocessing module which allows us to complete syntactic analysis of data generated by the Avida program. Using the existing code graph layout we will develop prototypes that generate neontological time-scaled views, phylogenetic depth views, and pseudo-paleontological views of the Avida data. We will maintain the current ability to move through, refocus, zoom in, zoom out and carve out portions of the graphs. Other revisions under review include enhanced manipulation of actual node data.

This project is a real-world software development environment in an academic environment. New team members are on-boarded and off-boarded as if they were working in industry. They have to familiarize themselves with the Avida platform and quickly grasp the current state of the Avida Toolkit project. They may need to familiarize themselves with statistical analysis and visualization concepts used in the project, as well as the terminology and basic ideas involved in deriving phylogenies. They need to understand what they required to contribute and determine what they will have to learn to be successful, truly an example of experiential learning.

V. Discussion

An interdisciplinary approach and a learning method that uses the state of the project to drive the definition of the individual learning experience is not common in Software Engineering Education. Brugge and Gluhow [3] discuss the importance of finding an innovative way to facilitate the knowledge transfer process. They looked for a way to ensure that knowledge outlasted the end of the semester. They suggest that enhancing the written documentation is not enough, rather, they suggest involvement beyond the project course is important.

Given our own experience and that of others, as well as a project based course in software engineering that emphasizes learning and application of principles of software engineering together with a senior capstone project where students demonstrate their ability to complete a software project, we were able to create a framework where students extend their skills in software engineering, expand their understanding of complex computational environments and exhibit actual transfer of knowledge in computing sciences and software engineering to the solution of problems in evolutionary biology. Using a real world, faculty-driven research project, students work in a multidisciplinary team including faculty with specializations in visualization, information and knowledge management, artificial intelligence, and evolutionary biology. The project uses visualization as a primary element to bind the concepts of the disciplines through the management and display of the datasets of biology in the computing environments employed in the project. To promote deeper understanding and experience in knowledge transfer, we have designed a project plan that includes deliberate, effortful abstraction together with time to search for connections [12,30].

In this approach students are given more control over their learning than in a traditional approach and, most importantly, acquire new knowledge only as a necessary step in solving authentic and cross-disciplinary problems representative of professional practice. Students link prior knowledge with new knowledge and gain a more balanced understanding of complex situations. Furthermore, affective learning serves as a critical link between cognitive and behavioral learning that motivates students and enhances educational outcomes, learning that results in behavioral change and not just conceptual mastery [12].

The purpose of creating a real-world software development project using the spiral model is to improve the students' learning experience, while reinforcing the soft skills required in software engineering and computer science courses. It provides students with the experience of understanding and solving real-world challenges and the opportunity to understand the software development process. Students achieve defined learning outcomes and soft skills that will be important to them in their software engineering careers. In addition, students gain experience in a real, on-going research project.

VI. Conclusions

It is our premise that a single experience, even in an in-depth project based course, is not adequate for students to transfer all required software engineering knowledge and skills to other situations. The project we described allows us to instill an engineering attitude in the curriculum and the academic computing environment. Through flexibility and responsiveness to change, this approach prepares students to adapt to rapid change in the field by teaching enduring principles in the context of current practice. Exposing computer science students to the convergence of multiple disciplines strengthens a student's ability to manipulate and automate different levels of abstraction simultaneously and develop new conceptual frameworks to address current and future challenges in hardware and software engineering.

Finally, we suggest that this approach hones soft skills and reflects the reality of large development projects as seen in the workplace; team members come and go throughout the life of the project. Fortunately, this project has the advantage of a stable core of faculty whose research interests continue to drive the project forward. Future plans include using biologically inspired techniques, such as flock based clustering, to computationally based automation and computationally inspired techniques from 2 and 3-D visualization that have been shown successful in other domains, to biological problems. Using an analogy of the corporate world and their approach to visualization and data analytics may also provide additional insight to manage, understand, and take advantage of the bioinformatics data's full value.

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Using Different Methodologies and Technologies to Training Spatial Skill in Engineering Graphic Subjects

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***Abstract*— Most papers about spatial skills and their components refer to the fact that engineering, architectural and scientific jobs require a good level of spatial ability. Spatial ability has an impact on every scientific and technical field, so it's still undergoing strong development when it comes to engineering, technology, art and many other aspects of life. In the academic environment, Graphic Design teachers usually see students who have difficulties solving tasks requiring spatial reasoning and viewing abilities. The main aim of this work is the development of didactic material based on several virtual and augmented reality formats, knowing how students behave while using them, and checking if they are useful materials to improve their spatial abilities. This work present Three different technologies: virtual reality, augmented reality and portable document format to find out if they are suitable technologies together suitable methodologies to improve spatial ability and from the student's perspective, their opinion of the tool and their motivation to learn more about the aspects of 3D reality. We present a pilot study that compared the results of improvement in spatial ability acquired by freshman engineering students also a survey of satisfaction and motivation of the methodology and technology used.**

Keywords—engineering education; spatial skills; training courses; augmented reality; virtual reality.

I. INTRODUCTION

In the academic environment, Graphic Design teachers usually see students who have difficulties solving tasks requiring spatial reasoning and viewing abilities. In the curriculums of degrees where Graphic Design appears (previous to the *European Space* for *Higher Education* change), no reference is made to providing development for a student's spatial ability. As the time available for exploring the contents of the subject is quite short, teachers do not consider how a student may be able to develop their mental abilities relating to object rotation, spatial reasoning etc.

There is a void in the curriculums of Graphic Design programmes of not helping students improve their spatial ability. If that issue could be solved, we may help the students that have greater difficulties in understanding the sketching systems overcome that handicap.

Now in the curriculums of engineering field degrees in the framework of the European Space for Higher Education (ESHE), the spatial vision capability is present as a competence that should be developed by students as a foundation of all engineering degrees.

The use of technologies applied through a suitable methodology may be included in the curriculums of Engineering Graphic subjects to provide to the students a better level of spatial ability.

The main aim of this work is the development of didactic material based on several virtual and augmented reality formats, knowing how students behave while using them, and checking if they are useful materials to improve their spatial abilities.

The didactic material will always be designed under the principle of improving spatial vision abilities, learning of Graphic Design contents, and better adaptation of each technology according to the engineering field where it should be applied. This implies designing learning activities that follow the philosophies of each one of those three technologies and implementing them in the classroom to three different groups of students that belong to the same level. One of these technologies would be applied to every group and then studied to discover their spatial ability progress, inferring the influence of the tool used in the acquisition of Graphic Design knowledge.

For establishing the possible differences between these technologies, the learning between groups will be compared against a fourth (control) group which will use a traditional methodology. The control group will not use any of the three technologies that are being studied.

II. TRAINING OF SPATIAL ABILITY

Without any doubt, spatial ability is an important component of human intelligence, but there is no agreement about the sub-factors that compose this component of intelligence [1]. Some of the most accepted theories come from researchers[2, 3] that have proposed three major sub-factors for categorising spatial skills: spatial relations, spatial visualisation and spatial orientation, although some researchers don't recognise spatial orientation as a separate factor. Following

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classification proposed by researchers from both psychology [4] and engineering [5], it has been reduced to just two sub-factors:

- Spatial relations, defined as the ability to imagine rotations in both two and three dimensions. Authors indicate that this skill includes mental rotation and spatial perception factors.
- Spatial visualisation, which is the ability to recognise 3D objects through the folding and unfolding of their sides. Visualisation is defined as the ability to mentally manage complex shapes.

To measure these components we use the Mental Rotation Test (MRT) [6] and the Differential Aptitude Test (DAT-5: SR) [7], as they are highly validated tools for measuring spatial skills. Spatial ability is something that cannot be taught, but rather trained and that training is the only way to develop and improve it. Some studies demonstrate that spatial abilities can improve by means of specific training. These abilities in engineering can improve with multimedia exercises, 3D software and other technologies used in graphic engineering [8,9,10,11,12].

Researchers like P. Connolly [13] suggested a need to develop spatial abilities in Graphic Engineering subjects. Barr [14] analysed future academic engineering plans with modern trends in mind and highlighted that the most important subject that should be included in a programme should be the development of spatial skills. Historically there has been a great deal of interest in the methods of instruction and technologies that could potentially increase the spatial skills of its users [15,16,17]. Currently, the rise of virtual reality (be it augmented, desktop or immersive) has fuelled the renewed research about the development of spatial ability.

Over the last few years we have performed several studies about fast remedial courses that try to improve the spatial abilities of engineering students in the University of La Laguna in Spain. In these courses, different tools have been tried out: classic exercises (views) using pen and paper; online multimedia web-based exercises; sketch-based modelling through a calligraphic interface [18]; use of Dynamic 3D apps [19]; and videogames as a work tool [10]. The aim is that students who take part in these courses will improve their spatial abilities and help them to have a better understanding of the contents of the subject of ‘Engineering Graphics’.

Recently there has been an important evolution in the teaching of Graphic Design in technical degrees. New incoming technologies have been essential in this evolution, determining to a great extent both the teaching and learning processes of this subject. Besides this, the steep rise in the number of students in engineering degrees is starting to make traditional strategies look outdated, such as using physical models, where students can manipulate these with their hands, turning it until they understand them and are able to develop plans to sketch them. This made us plan methodologies to reduce physical models and seek new methods aimed at students who can learn through new computer technologies that they are already used to.

III. Proposed Technologies and Didactic Materials

We have performed an experiment with three different technologies: virtual reality (VR), augmented reality (AR) and portable document format (PDF3D) to find out if they are suitable technologies to improve spatial ability, and from the student’s perspective, their opinion of the tool and their motivation to learn more about the aspects of 3D reality.

A. *Virtual reality (VR)*

Virtual reality is a set of technologies and interfaces that allow one or more users to interact in real time with a computer-generated 3D environment or dynamic world. These 3D elements and interactive environments are built through VRML language that has evolved through different versions since its inception in 1994.

The continuous improvement of tools allowing the creation of virtual reality applications, as well as the better performance of the technological equipment needed to execute them, has allowed VR to become standard in spatial ability training. For building scenes and worlds through VRML, we use resources such as low-level programming can be used, as well as the syntax and semantics of the language where an ISO spec, as well as a large bibliography. In our case, to develop this virtual world we have used 3D design programs and their VRML export abilities.

The didactic material is made up of forty exercises that were created and distributed in three levels of increasing difficulty, which are quite similar to those used in pre-university education (Fig. 1).

The exercises, based on VR, are uploaded to a web platform called Draw Help System (DHS). When an exercise is selected, the application shows a piece in the virtual environment that allows its manipulation (movement, rotation or change of position etc.) so the user can become aware of all its details.

Fig. 1. DHS main window

B. *Augmented reality (AR)*

Augmented reality uses either direct or indirect vision of a physical environment from the real world, where real elements combine with virtual elements to create a real-time mixed reality. It uses a set of devices that add virtual information to the physical information that already exists. This is the main

difference with VR, as it doesn't replace the physical reality but superimposes the computer data onto the real world.
An augmented reality scenario we have proposed for this work consists of the elements shown in Fig. 2:

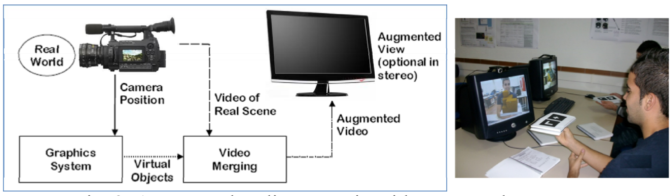

Fig. 2. Augmented reality scenario with a personal computer.

All exercises and pieces were adapted to the format used by the BuildAR Pro augmented reality application [20], which allows the creation of scenes made up of a set of images or marks that codify a 3D model. When a scene is executed, a webcam connected to the PC recognises an image that is related to the 3D model and shows it integrated into the real world. A 'marks book' is also created, where the mark is composed by a frame and the exercise's image inside (Fig. 3).

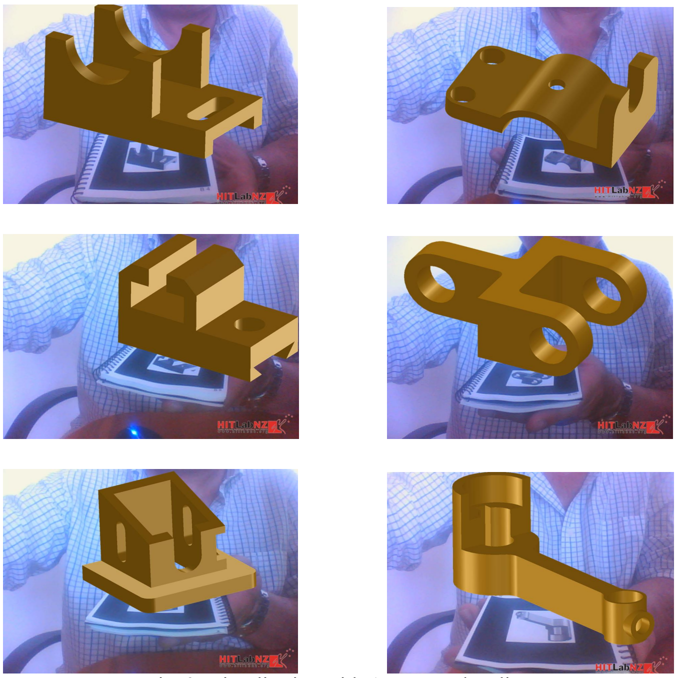
Fig. 3. Visualisation with Augmented reality.

C. *Portable Document Format 3D (PDF3D)*

The PDF format has incorporated 3D object vision capability inside its multimedia characteristics through the Universal 3D (U3D) format included in the PRO X version [21]. The portable document format (PDF) developed by Adobe Systems has become the information exchange standard for any application or computer system. It has the following characteristics:

- Open standard: the PDF format is an open standard developed under the ISO 32000 norm.
- Multiplatform: PDF files may be visualised on every platform available, including Windows®, Mac OS and mobile platforms such as Android™.
- Extendable: Many providers offer PDF-based solutions including creation, plug-ins, consultancies and technical support tools.
- Reliable and secure: the fact that there are over 150 million PDF documents available for public use online, together with the huge number of PDF files available in both public and business administrations, proves that enterprises trust this format for information transmission.
- Sophistication for information integrity: PDF files have the same aspect and show the same information as the original files, such as text, drawings, multimedia content, videos, 3D content, maps, color graphics and pictures, regardless of the application used to create them, or if they are compiled in a unique PDF folder from several formats.
- Search capability: the text search tools on documents and metadata ease searching in PDF files.
- Accessibility: PDF files use support technologies to increase access to information for people with disabilities.
- Interactive: Its new 3D manipulation capability (U3D) has helped it to become one of the best systems to distribute and share graphic information.

The same exercises and pieces were transformed into U3D format used by PDF3D, allowing them to be manipulated in an independent environment (Fig. 4).

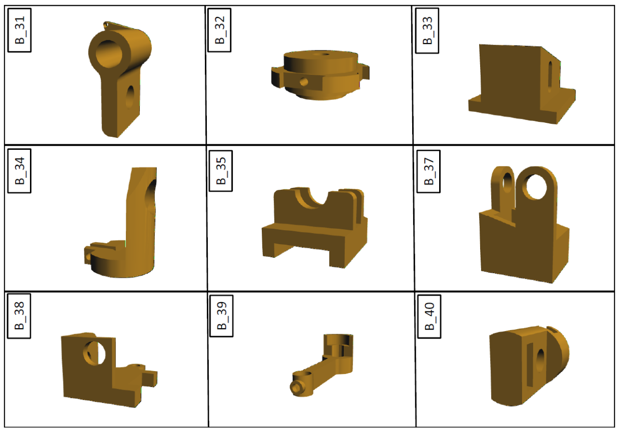

Fig. 4. PDF3D interface

The three methodologies have the same aim: the student gets to know the piece, without needing the real model in their own hands, and has all the information needed to sketch the piece and create a workshop contour plan.

The previous tools allow as a student may work on the questions stated in the exercise notebook and practice their sketching abilities.

IV. Experimental Study

A. Participants

A study was undertaken by 57 freshmen studying Graphic Design from the first course in the Industrial Technology degree in the Civil and Industrial Engineering School from the University of Las Palmas de Gran Canarias at Spain. All students completed the training phase using the same exercises using three different technologies (VR, AR and PDF3D) and three methodologies accordingly. An overall of 18 students used the VR-based tool, 20 students used AR, and 19 used the PDF material available. There was a control group of 20 students who didn't undertake any kind of training.

B. Methodology

The training was performed in the Graphic Design laboratory. The aim was to obtain data about the improvement of spatial ability in the groups using the three methodologies and to find out from the feedback of students their motivation and satisfaction.

The study was performed at the beginning of the 2011/12 academic year, so when they undertook this task these students had not attended any kind of Engineering Graphics classes previously.

The spatial abilities of engineering students were measured before and after training using both the Mental Rotation Test (MRT) and the Differential Aptitude Test (DAT-5:SR). Besides, upon completion of training, the students completed two surveys about their satisfaction with the training and their motivation while performing this experiment.

Only a standard PC and a webcam (for AR) were needed for this training. The students visualised the virtual elements on the monitor. The training had six hour duration, so they worked on it for two hours per week. The students performed it on their own, although the teacher could help them when needed.

The didactic material was composed of three difficulty levels as shown, so each student performed a level weekly.

C. Results and analysis of spatial abilities

The mean values of the MRT and DAT-5:SR tests of the three experimental groups and the control group, prior to undergoing the training (pre-test), were very similar (Table I). The analysis of variance (ANOVA) for MRT and DAT-5:SR, measured in the four groups (AR group, VR group, PDF3D group and Control group), showed that there were no significant differences between groups prior to spatial training ($F_{3,74}$=0,654, p=0.583 on MRT and $F_{3,74}$=1,055, p=0,374 on DAT-5:SR). So, all groups were statistically equivalent in spatial visualisation and spatial relation at the start of this study.

After completing the courses, spatial abilities were measured again. Table I shows the results of the pre and post-tests scores, as well as the gain for each group.

TABLE I. VALUES PRE/POST TEST AND GAIN

	Pre-test		Post-test		Gain MRT	Gain DAT 5:SR
	MRT	DAT 5:SR	MRT	DAT 5:SR		
VR Group n=18	19.00 (6.40)	30.22 (9.13)	25.33 (7.18)	38.39 (7.85)	6.33 (4.58)	8.17 (6.42)
AR Group n = 20	18.94 (9.79)	24.94 (8.78)	25.67 (10.97)	32.33 (8.76)	6.72 (4.91)	7.39 (3.82)
PDF3D Group n=19	15.47 (7.10)	27.06 (8.33)	23.53 (8.06)	37.65 (7.67)	8.06 (7.59)	10.59 (4,64)
Control Group n=20	17.44 (9.80)	28.40 (10.17)	19.22 (9.91)	33.52 (11.77)	1.78 (4.36)	5.12 (7.13)

We compared the mean values obtained pre- and post-test using the Student's paired series t-test:

- VR: MRT [t=5.872, p-value=0.00]; DAT-5: SR [t=5.398, p-value=0.00].
- AR: MRT [t=5.81, p-value=0.00]; DAT-5:SR [t=8.20, p-value=0.00].
- PDF3D: MRT [t=4.38, p-value=0.00]; DAT-5:SR [t=9.41, p-value=0.00].

In the MRT test, the Control Group obtained t=1.88, p-value=0.066; in the DAT-5:SR t=1.718, p-value=0.092.

The groups that underwent training showed a statistically-significant improvement in spatial ability levels. P-values are around 5% for statistical significance, which indicates that the students have a probability of over 95% of improving their levels of spatial ability when performing the proposed training. Besides this, results show there is no improvement in control group levels. To compare and check if there is any difference in spatial ability levels obtained by groups that underwent training, a LSD Fisher post-hoc contrast analysis was performed. This allows multiple comparisons between the three groups with a different number of individuals in each group, as seen in the results in Table II and Table III.

The results confirms that there is a significant difference in the gain between each type of training and control groups, but that there is no difference between the training groups, which underlines the fact that improvement was similar in all groups.

TABLE II. COMPARISON BETWEEN GROUPS FOR GAIN IN MRT

(I) group	(J) group	Difference between averages (I-J)	Typical error	Sig.	Confidence interval at 95%	
		Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
1,00	2,00	1.33660	1.73613	.444	-2.1317	4.8049
	3,00	1.72549	1.73613	.324	-1.7428	5.1938
	4,00	8.05882(*)	1.81851	.000	4.4259	11.6917
2,00	1,00	-1.33660	1.73613	.444	-4.8049	2.1317
	3,00	.38889	1.71115	.821	-3.0295	3.8073
	4,00	6.72222(*)	1.79467	.000	3.1370	10.3075
3,00	1,00	-1.72549	1.73613	.324	-5.1938	1.7428
	2,00	-.38889	1.71115	.821	-3.8073	3.0295
	4,00	6.33333(*)	1.79467	.001	2.7481	9.9186
4,00	1,00	-8.0588(*)	1.81851	.000	-11.691	-4.4259
	2,00	-6.7222(*)	1.79467	.000	-10.307	-3.1370
	3,00	-6.3333(*)	1.79467	.001	-9.9186	-2.7481

1 (VR Group), 2 (AR Group), 3 (PDF3D Group). 4 (Control Group)
* Difference between averages is significant at .05 level.

TABLE III. COMPARISON BETWEEN GROUPS FOR GAIN IN DAT-5:SR

(I) group	(J) group	Difference between averages (I-J)	Typical error	Sig.	Confidence interval at 95%	
		Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
1,00	**2,00**	3.19935	1.71456	.067	-.2259	6.6246
	3,00	2.42157	1.71456	.163	-1.0037	5.8468
	4,00	8.58824(*)	1.79591	.000	5.0005	12.1760
2,00	**1,00**	-3.19935	1.71456	.067	-6.6246	.2259
	3,00	-.77778	1.68989	.647	-4.1537	2.5982
	4,00	5.38889(*)	1.77237	.003	1.8482	8.9296
3,00	**1,00**	-2.42157	1.71456	.163	-5.8468	1.0037
	2,00	.77778	1.68989	.647	-2.5982	4.1537
	4,00	6.16667(*)	1.77237	.001	2.6260	9.7074
4,00	**1,00**	-8.58824(*)	1.79591	.000	-12.176	-5.0005
	2,00	-5.38889(*)	1.77237	.003	-8.9296	-1.8482
	3,00	-6.16667(*)	1.77237	.001	-9.7074	-2.6260

1 (VR Group), 2 (AR Group), 3 (PDF3D Group). 4 (Control Group)
* Difference between averages is significant at .05 level.

D. Students´ satisfaction

Bevan [22] mentions that in order to make reliable estimations of satisfaction results, 8 to 10 participants are necessary as larger samples offer a more significant value for the success rate. In our study, the evaluation of the material and the software was done by all students (57) who undertook the training.

Once the experiment was finished, they were provided with a survey to find out the level of satisfaction of each group regarding the methodology of the training used. The user's satisfaction was measured using an adapted version of the QUIS Questionnaire [23] using a 9 point Likert scale, from 1 to 9. A selection of these questions is shown in Table IV.

TABLE IV. USERS' SATISFACTION RESULTS AND QUESTIONS

	Group		
Question	**VR**	**AR**	**PDF3D**
Terrible-Wonderful	6.2	8.6	6.1
Frustrating-Satisfying	6.0	8.7	7.4
Dizziness-Natural environment	7.3	8.8	6.0
Uncomfortable-Comfortable	5.7	7.1	6.0
Not interesting-Very interesting	6.2	8.6	5.5
Difficult-Easy	8.0	8.5	8.4
Rigid-Flexible	7.1	7.4	6.9
Operation learning: Difficult-Easy	6.1	8.4	7.6
System speed: Too slow-Fast enough	8.1	8.5	8.4
Intuitive system: Not at all-Very much	7.7	8.7	7.0
Overall satisfaction: Low-High	6.9	8.7	6.7
Mean Values	**6.8**	**8.4**	**6.9**

This table shows (for each group) the mean values for each item satisfaction survey. We can see the satisfaction in the use of each of the technologies. Students using augmented reality technology show greater satisfaction on all items.PDF3D technology is perceived as more comfortable, easy to use, easy to learn that virtual reality. By contrast, VR is considered more wonderful, interesting, flexible and intuitive than PDF3D technology.

V. MEASURING MOTIVATION OF STUDENTS

In this research work, we regarded the use of a scientifically-validated tool as quite interesting to find out the motivation of students towards the training performed. The learning questionnaire **Motivated Strategies for Learning Questionnaire (MSLQ)** [24] was designed to evaluate university students' motivational orientations and learning strategies.

There are three proposed motivational dimensions related to the learning strategies:

- Expectations component: Regarding the student's skill for performing a task.
- Value component: Importance given to the performance and interest in the undertaken task.
- Affective component: Related to the student's emotional reaction to the task.

Regarding the learning strategies, the MSLQ authors regard three aspects as essential:

- Metacognitive tasks: for planning, addressing and modifying the cognitive operation in itself.
- Control of resources: Time and location, effort and help from others.
- Cognitive strategies: used by students to learn, remember and understand the studied subject.

The latest MSLQ version [25] establishes subscales for every dimension previously described, aiming to analyse in depth the factors that can influence motivation. This version is composed of 81 items, where 31 of them belong to motivational aspects and the other 50 to strategic factors. Each item is answered using a likert scale of seven levels, where one means no/never and seven means yes/always. Every item is sorted into six motivational and seven strategic scales, as shown on Table V.

TABLE V. DISTRIBUTION OF MSLQ SCALES, DIMENSIONS AND SUBSCALES.

Scales	**Dimensions**	**Subscales**
MOTIVATION	Expectations components	Control beliefs Self-effectiveness
	Value components	Intrinsic aims Extrinsic aims Task value
	Affective component	Anxiety
LEARNING STRATEGIES	Cognitive and metacognitive	Elaboration Organisation Critical thought Metacognition
	Resources management	Study time and location Perseverance/Effort regulation Seeking help and learning with others

For more information about the MSLQ theoretical approach, several previous studies can be read [26,27,28].

Table VI shows the results obtained for motivational and strategic factors. The study of motivation is carried out on total of students to determine if the use of 3D visual technologies influence the motivation of students.

Students are mainly guided through their study by aiming toward intrinsic goals as they trust their own learning skills and value the importance, their interest and the usefulness of training. They also realise that any improvement they attain through training depends on their own efforts and that they know they will be able to reach high levels of spatial ability.

Overall, they have reached a satisfactory motivation level. There is positive performance, which is reflected in motivational factors, concretely over the learning strategies scale. It is remarkable that the highest level is in anxiety, possibly as a consequence of insecurity caused by the lack of explanatory material for the proposed activities. The training is made so students can acquire basic knowledge about orthogonal views through their own finds and intuition.

TABLE VI. MOTIVATION FACTORS (SUBSCALES) –

Motivational factors	**Mean**	**SD**
Control beliefs and learning self-effectiveness	3.73	1.79
Self-effectiveness performance	3.53	1.40
Orientation towards intrinsic aims	3.98	1.82
Orientation towards extrinsic aims	3.20	1.60
Value of task	3.31	1.98
Anxiety	4.60	1.58
MOTIVATION SCALE	**3.72**	**1.69**
Strategic factors	**Mean**	**SD**
Elaboration	3.31	1.98
Organisation	4.87	1.22
Critical thought	3.42	1.72
Metacognition	3.31	1.98
Use of time and concentration	4.55	1.42
Perseverance/Effort regulation	4.88	1.37
Seeking help and learning with others	5.57	1.26
LEARNING STRATEGIES SCALE	**4.22**	**1.56**

From the data we can see in the table, it follows that students reached a good level of development in the learning strategies, but they usually made inappropriate use of them, as can be seen in the values for the strategic factors about learning approaches. Another aspect that should be pointed out is that the most developed strategic factor is help, as a consequence of the collective group work. The value obtained for making the most of the available time was also outstanding, as well as focus, which indicates the need to strengthen orientation towards self-sufficient study.

The metacognition and self-questioning scales show that students have not reached the suitable level over the control of their own study, which shows the need of a teacher's support to develop critical thought, as well as the link to other contents learned from other areas.

VI. CONCLUSIONS

The evolution of technology and the appearance of new teaching techniques have made some methodologies obsolete as they are not properly adapted to modern trends. Teaching methods must evolve and adapt to the new technologies that students are used to, and learning will clearly benefit from this.

The students are digital natives as they are used to all kinds of electronic devices and handling information in many digital platforms. Traditional teaching methodologies can cause boredom and a lack of motivation during the teaching activities.

The use of objects and physical models for working in the classroom are not enough for the volume of students who are currently attending these classes. The computer tools that allow virtual modeling and the handling of 3D objects ease teaching tasks as any piece or figure is available without needing to obtain physical models that can be quite expensive and take longer to create. The modeled object may be implemented in every format, such as virtual, augmented, PDF3D or any other.

We have introduced into the classes of an engineering degree three methodologies based on technological tools and 3D models. Overall, the students were quite satisfied with the tools used to learn. The users enjoyed the simplicity of the apps and pointed out the powerful control of tri-dimensional models. Specifically, those students using AR were more satisfied than those using VR and PDF showing the same values. According to the data observed on site, we note that students who trained using AR felt quite impressed and motivated by the use of a new technology, of which they had no previous contact as they were not aware of it. Therefore, the difference is due to the technology's novelty. The teachers observed that students showed more participation and motivation than those from groups where physical models are used, as passivity and a lack of motivation during learning was quite noticeable.

The students who used multimedia didactic material showed confidence in their own capabilities in developing tasks and showed interest while performing them. The students adopted strategies for planning, learning and understanding the upcoming subject, which denotes a high level of motivation about the work that is being developed.

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Enhancing Engineering Mechanics Statics Instruction Using Manipulative Truss Models

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***Abstract*—Enhancing a student's ability to mentally visualize and intuitively assess foundational concepts in engineering mechanics - statics can create a significant advantage for students in their pre-professional engineering courses. Concepts such as forces and moments often prove to be challenging for students lacking hands-on mechanical experience or those who are visual and kinesthetic learners. Showing students these "intangible" mechanics principles is not an easy task and usually requires proactive measures to improve learning. In an effort to improve visualization and tactile learning in a college mechanics – statics course, hands-on and visual truss models were developed based on the concept of physical manipulatives. Mathematics instructors use manipulative models to help students identify different mathematical concepts. These models not only allow the students to see and feel different objects but also to manipulate the objects to form a concrete representation of the concept. Furthermore, manipulative models help students visualize, feel, and analyze the behavior of the material being manipulated. This study examines the relationship between the use of a physical model of a truss and the students' framing of information during task interpretation to successfully attain conceptual understanding about truss analysis.**

Keywords—manipulatives; statics; task interpretation; constant comparative analysis

I. Introduction

Statics is the branch of mechanics that is concerned with the analysis of loads and forces on stationary structures and machines. It is a fundamental course that prepares students for subsequent courses such as dynamics and mechanics of materials. Studies have shown that students tend to have different conceptual understanding misconceptions in statics. Students "fail to account for the mutual nature of forces between connected bodies that are separated for analysis" [1]. One example that illustrates this difficult concept for students in engineering statics is the internal and external force analysis in a truss problem. Trusses are structures comprised of units, also called members, connected to one another through joints. These structures provide stability and shape to different larger structures and machines such as crates, cranes, buildings, and bridges. Simple mathematical analysis often leads to a solution that may not have a true intuitive meaning for the student. Manipulatives can be used as a tool tying together students' analytical capabilities and their engineering intuition. Research has indicated that the manipulatives are most effective when students' exploration is somewhat guided, either by their instructor in lecture or by homework, lab, or recitation activities using guided-inquiry approach to learning [2]. For example, mathematics instructors use manipulative models to help students identify different mathematical concepts [3]. The advantage of using physical manipulatives is the fact that manipulatives enhance spatial visualization for engineering students [4]. Nonetheless, there is a gap between how the students understand the problem and how they plan and execute solutions for the problem. Therefore, investigating the students' task interpretation during the analysis of the truss is important in order to incorporate the three layers of information construction: explicit, implicit, and socio-contextual information about tasks [5]. These three factors influence how the student creates a strategy for task understanding and execution. The framing of the information gathered through task interpretation, in terms of underlying concepts, helps students decode the requirements of a particular task [6], which, along with other aspects of self–regulated learning, help develop work habits in their learning activities. This also helps create empowering pedagogies where students can use their task interpretation in new productive and meaningful ways.

II. Analysis of Literature

A. *Physical and Virtual Manipulatives*

The challenges college students face when learning statics was investigated using learning activities [7]. The study addressed different misconceptions and problems for students in statics, including the forces between rigid bodies, moments, and forces on inanimate objects. The study described different techniques that could be used in the classroom to improve learning, especially the use of physical manipulatives to demonstrate the "invisible" and help develop mechanical intuition for the students. Instruction with these physical manipulatives was accompanied by a series of group discussions, collaborations, and feedback activities in the classroom. The authors described two core ideas: 1) students have difficulty perceiving forces between inanimate objects but physical manipulatives can help students see and feel what is "invisible" and abstract, and 2) the necessary assessment and feedback required in the statics course. The authors argued that learning modules that use physical manipulatives and other activities could be applicable to a wide variety of engineering

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subjects and help students understand, observe, and feel concepts that are somewhat abstract [7].

Other studies have investigated the use of both physical and virtual manipulatives in a variety of STEM areas. These studies investigated different frameworks that would describe the best way to integrate, sequence, or "blend" the use of both physical and virtual manipulatives to understand abstract concepts. For example, the use of hands-on (physical) malipulatives helped engineering students in modeling and engineering problem solving [10]. The results from this study showed that students increased their understanding of engineering concepts when they used manipulatives and were able to see and feel reactions created by the manipulative. Another study, involving physical and virtual manipulatives, indicated that manipulatives affected not only learning but also engagement and knowledge transfer [3]. The results from this study showed that the learning of all groups in the study in all conditions increased as the result of the use of manipulatives. Students developed skills to correctly identify variables based on word problems. It was observed that students with concrete materials, or manipulatives, led to better procedural use and therefore a reduced cognitive load.

In another study, three characteristics were observed: instruction, type of knowledge gained, and the use of physical and virtual materials [11]. For this study, the researchers used "mousetrap cars" as the physical manipulative and a digital mousetrap car from a computer program as the virtual manipulative. The analysis focused on open-ended discovery, confidence, and gender effects (male vs. female). The study showed that students learned equally with either medium regardless of constraints. Students were able to increase their knowledge equally using both methods even when time spent on a task was different [11]. However, students using the physical manipulative were able to observe several mistakes with their design while students using the digital manipulative did not experience such observations due to the lack of those features in the computer simulation.

In addition, another study investigated the use of manipulatives and the ability of students to follow specific hand manipulative tasks using instructional animations [12]. The purpose of the study was to show that animated presentations are more effective than static presentations, especially if these depict human movement. The results showed that instructional animations are more effective and lead to better learning and understanding. The study indicated that participants could not imitate actions showed on static images and generated cognitive overload, thus negatively affecting learning.

B. Task Interpretation

Task interpretation is a key theoretical component in students understanding, academic performance, and appropriate and effective task engagement [6]. Task interpretation theorizes that there are three layers of information construction: explicit, implicit, and socio-contextual information about tasks [5]. Explicit features of a task are overtly presented descriptions and are often described in assignments and are the aspects of the task that give it structure and some type of cohesiveness across students [13]. Implicit features of a task include information that students might be expected to extrapolate beyond assignment descriptions such as connection to learning concepts or resources to completing the task [13]. Finally, socio-contextual features include information about the broader course, such as beliefs about knowledge and expertise or beliefs about ability [13]. The importance of task interpretation, or task understanding, when working with a manipulative is that understanding problems is influenced by implicit and explicit aspects that may or may not be accurate. Task understanding is also affected by a social or cultural context that may help the student base a strategy to understand and solve the task. Therefore, it is important to investigate how these three layers of information construction are incorporated when using the manipulative during truss analysis in order to determine if the manipulative can be used in meaningful pedagogical ways.

III. Research Goals

The use of manipulatives can help the learning outcomes of engineering students, particularly in the context of ill-structured problems while relating concepts to their own background and prior knowledge. However, not enough studies have been done related to the use of manipulatives and their relationship to task interpretation and students' problem solving approaches. Therefore, it is important to consider the inclusion of manipulatives in the engineering statics courses and evaluate their relationship to academic achievement in engineering students. The intent of the project is to improve conceptual understanding of the forces involved in truss design and to assess students' task interpretation (explicit, implicit and socio-contextual) of a truss analysis engineering problem. The fundamental research questions are: (1) Would a physical manipulative help students improve task understanding in an engineering statics course? and (2) How do these students reconcile their initial understanding and interpretation about internal forces in a truss after the use of the physical manipulative?

IV. The Study

The study involves a mixed methods approach comprised of different intervention sessions with selected students. Participants include six engineering students randomly selected from a statics course at a public university. The students are presented with a problem involving a truss analysis. The objective of the task is to predict what is happening on the system followed by a specific explanation or reasoning behind such prediction. The task given to the students involves answering different questions related to the analysis of forces in a truss, such as identifying two force members, zero force members, etc. This problem has posed different challenges for students in the current course due to the students' unfamiliarity with engineering concepts in statics. Students are asked to solve the problem during a think-aloud process where students identify the information necessary to solve the problem. The think-aloud process helps identify the explicit, implicit and socio-contextual aspects of the task as they work toward understanding the design that solves or explains the engineering problem [13]. Knowledge may be in the form of social context (beliefs about understanding and expertise from their relationships and discourse practices), explicit resources (terminology and specific instructions), or implicit resources (different concept connections or extrapolations). Data collection involves think-aloud tasks that elicit students' task interpretations and perceptions [13]. Broadly speaking, the collection of a protocol involves the recording of a research participant's verbalization while working to solve a problem, usually one specified by the researcher. This verbal thought process, as well as follow-up interviews and observations, are recorded and transcribed. The purpose is to generate a verbal text that a researcher can analyze to provide an account of cognitive processes [14]. Implicit and explicit layers of information from the students' verbalizations may or may not be correct, and this allows the researcher to identify how many of their implicit and explicit layers of information are accurate in order to create a coding system for analysis.

Once the prediction, solution, and subsequent explanation have been made, the students have the opportunity to work with the manipulative. Two types of data are collected during the process: *concurrent*, in which a participant thinks aloud during the process of completing the task, and *retrospective*, in which a participant completes components of the task or the whole task and then is prompted to reconstruct the process from memory [14]. Once they have worked with the manipulative, a final interview is conducted to determine if the students concur with the predictions made and determine any assimilation problems and possible elimination of misconceptions. The prediction and final interview may consist of descriptions of design load calculations, reactions and free body diagrams, presentation of engineering calculations, and determination of zero force members. All questions are open-ended questions and help describe the kind of thinking and kind of knowledge the students emphasize during the task assignment. In this process, student may connect different stories that they can relate to the type of assignment being investigated.

Constant comparative analysis is used to critically draw important information about the participants. The constant comparative method consists of identifying a phenomenon, object, or event, then comparing incidents applicable to each category, and finally integrating such categories and their properties [15]. Thus, this method combines category coding with simultaneous comparison of all incidents observed as well as simultaneous comparison across categories. The constant comparative analysis would create a coding system used to compare, contrast and determine frequencies of different sets of beliefs, ideas or perceptions.

V. IMPLICATIONS

This project is intended to promote an instructional technique that is relevant to students in engineering. Providing engineering students with opportunities to communicate science and engineering through physical manipulatives, drawings, charts, tables, graphs, and computer-developed simulations increases participation and promotes more focus on communication for understanding. It provides the students with the time to build context, common experiences, thinking skills, cooperative learning, comfort level and a positive attitude toward learning. The results obtained from this study will be used to modify and expand further research regarding engineering physical and virtual manipulatives, curriculum materials, and practices to help the linguistically and culturally diverse classrooms. At the time of the FIE 2013 Conference, results from this research will be presented.

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The City as a Learning Gamified Platform

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***Abstract*— The area of mobile city guides has grown really fast in the last years based on new mobile capabilities. This growth has been fostered by the evolution of ubiquitous systems and the great penetration of smartphones in the society. In this paper we propose a generic model to support a new way of visiting the city: instead of as a place for tourism, we see it as a place for learning in which located educational resources are available for end users. The model has been conceived as a way to encourage them to create their own educational tours, in which Learning Points Of Interest are set up to be discovered. Two main use cases are supported by the model: formal (conducted by a teacher) and informal (no educator is related to the learning experience) outdoor mobile learning. Details about the impact of the conjunction of tourism, learning and gamification dimensions in the model design, as well as about the model itself are provided. Finally, a mobile application prototype developed in the context of the FI-CONTENT European project is presented as a proof of concept of the model.**

Keywords—Mobile Learning; Gamification; Educational Tours; Learning Object

I. INTRODUCTION

The area of mobile city guides has grown really fast in the last years based on new mobile capabilities such as connectivity or location context. This growth has been fostered by the evolution of ubiquitous systems and the great penetration of smartphones in the society. Mobile city guides are changing the way people experience tourism, plan their travels and share these experiences. Many mobile city guides exist nowadays such as Stay [1], Tourist Eye [2], or Lonely Planet [3] providing guides for travelling worldwide. Moreover, a lot of cities offer also their own mobile city guide. The main aim of these guides is to provide basic information about locations that are useful or interesting. These locations are formally known as Points Of Interest (POIs). Other common features are personalized recommendations, customized travel guides, sharing travelling information, offline access and augmented reality functionalities. In addition, new features can be added to these mobile tourist applications in order to provide new services. For instance, [4] proposed a mobile tourist service built by integrating mobile guide services with other services such as notifications and payments. In the same way, these mobile applications can be expanded further to include mobile learning. So, they can be repurposed in the education domain. Bearing in mind this idea, we propose a new way of visiting the city: instead of a place for tourism we see it as a place for learning in which located educational resources are available for end users interested in discovering history, legends or curiosities about the cities they live in or visit. Furthermore, in order to provide engaging and motivating learning experiences a gamified dimension is also considered together with the tourism and learning dimensions.

The idea of enriching and gamifying traditional tourist tours is not new. For instance, the “Matera Tales of a City” project [5] provides a web platform and a gamified mobile application to allow tourists to access to cultural contents (e.g. 3D reconstructions or audio guides) while attending places.

Using a real city (or the world) as a gamified scenario is not new either. The stage used to play MEECO [6] is a real city, where citizens can virtually register their real ecological actions such as recycle or biking using their mobile devices.

Nevertheless, no learning approaches have been defined to take advantage of mobile city guides benefits in the educational field. Bearing this in mind, we present in this paper a generic model that defines a new learning approach based on the use of the city as a learning gamified platform considering three dimensions: tourism, learning and gamification. This new learning approach arises from the combination of the areas of mobile city guides, mobile learning and gamification according to Fig. 1.

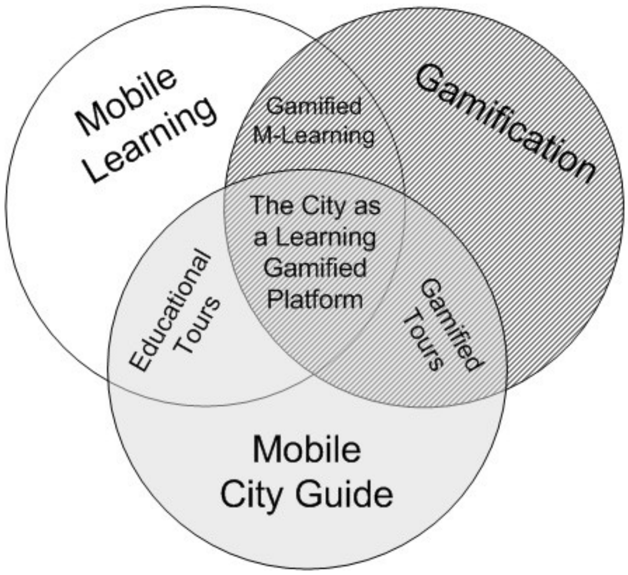


Fig. 1. The City as a Learning Gamified Platform research field.

The model has been defined based on a scenario designed in the context of the FI-CONTENT (http://www.fi-content.eu) European project. One of the aims of this project is to validate and evaluate the service infrastructure provided by the FI-WARE (http://www.fi-ware.eu) European project. For this reason, a scenario based on the city as a gamified platform was proposed and selected to test specific components and technologies developed as part of the FI-WARE project. The main use cases and requirements of this scenario were identified and used as a basis for the model definition. Lastly, as a proof of concept, an application prototype has been developed using FI-WARE elements.

The rest of the paper is organized as follows. The next section reviews related work of mobile learning, adventure in education and gamification. Section 3 introduces the FI-CONTENT and FI-WARE projects and illustrates the main use cases. Section 4 explains the model in detail. Section 5 presents the application prototype. Then, section 6 provides some discussion. The last section finishes with some concluding remarks together with an outlook on future work.

II. Related Work

As technology evolves, faster wireless and mobile networks and more powerful handheld devices are available at lower cost. These technological advancements are creating the ideal conditions for Mobile Learning (M-Learning). There are several definitions of the term M-Learning. A commonly accepted one can be found in [7] which defines M-Learning as "any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies". This definition can be completed by adding that M-Learning also aims to allow learners to assimilate learning anywhere and at any time [7], [8]. Another common goal of M-Learning applications is to allow learners to accomplish learning activities by taking all contextual elements into consideration [9]. This brings the concept of context. According to [10] context is "any information that can be used to characterize the situation of an entity", where an entity is defined as "a person, place or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves". Some studies have already showed that learning can be effectively extended to handheld devices and that M-Learning applications can be used to complement classroom or distance learning [11]. This type of learning opens up new opportunities for educators because the learning activity is not limited to the classroom; it can also be completed anywhere and anytime, without requiring strict supervision by the teacher [12]. Novel learning opportunities can also arise by introducing collaboration [13]. These new chances are especially relevant for informal learning, where the learning activities usually take place outside educational establishments and formal curricula of schools.

On the other hand, new opportunities in formal and informal learning can also be achieved by incorporating adventure into education. Some approaches aim to achieve this goal in a pedagogically meaningful way. The first one was Adventure Education (AE), which is a form of experiential learning typically associated with cooperative games, problem-solving tasks and high adventure activities [14]. Despite AE not necessarily occurs out of the classroom, it is sometimes used wrongly as synonymous of outdoor learning, which is precisely characterized by experiencing learning activities in the outdoors. Another approach called Adventure Learning (AL) was defined by Doering in 2006 [15]. It can be defined as a hybrid distance education approach that provides students with opportunities to explore real-world issues through authentic, field-based narratives within an online learning environment. Lastly, one more approach exists based on the novel concept of User-Drive Adventure Learning Environments (UDALE) allowing learners to create and share self-initiated AL projects. UDALE merges components of AE and AL. It aims to engage learners in their own physical adventure while concurrently teaching others about a real-world issue, sharing authentic data and employing technology for data collection and collaboration [16]. Due to UDALE tools, mobile learning is being explored as a mean to introduce adventure into education and engage learners in AL.

Finally, educators can also provide new learning experiences by applying gamification in education. Although gamification lacks a universal definition an appropriate one can be found in [17], which defines gamification as "the use of game design elements in non-game contexts". In education, gamification can be used to promote learning because many of the elements of gamification are based on educational psychology and are techniques that designers of instruction, teachers, and professors have been using for years [18]. Examples of common elements used in gamified applications are, among others, badges, leaderboards and scoring systems. A typical example of a gamified application is Foursquare (http://www.foursquare.com), in which users can collect badges for accomplishing activities such as check-in a certain number of times to specific POIs (e.g. 20 different pizza places). Hence, gamification can be applied to M-Learning to provide more engaging learning experiences, especially beyond the classroom walls.

III. Scenario

A. FI-CONTENT and FI-WARE projects

FI-WARE is a European project which main goal is to advance the global competitiveness of the European Union economy by introducing an innovative infrastructure for cost-effective creation and delivery of versatile digital services, providing high QoS (Quality of Service) and security guarantees. The project also intends to demonstrate how this infrastructure can support novel Future Internet (FI) services in multiple sectors such as healthcare, telecommunications or education in a more productive, reliable and efficient way. The service infrastructure is built upon building blocks called Generic Enablers (GEs). A GE can be defined as a component that offers at least one reusable and commonly shared functionality and can serve a multiplicity of usage areas. The identification and specification of GEs are key goals of the FI-WARE project together with the development of reference implementations of them.

The FI-CONTENT European project aims to shape the next generation Internet providing a framework to allow transformations of novel and inventive scenarios into technical outputs and demonstrating usage beyond current state of the art. FI-CONTENT is focused on several content areas such as virtual environments, games, educational entertainment and culture and user created content. The scenarios are proposed by a consortium formed mostly by major content providers, game companies, broadcasters, research institutes and academic institutions. One of the foremost aims of FI-CONTENT is to validate and evaluate the existing GEs provided by FI-WARE in different scenarios for their future implementation by using working prototypes.

B. Use cases

A scenario grounded on the city as a gamified platform can provide several novel learning experiences. These experiences are very diverse but all of them share the mobility component. Learners are moving across the city visiting different places, i.e. the learning activities are undertaken outdoors. All of these activities will interact in some respects with different elements of the city such as citizens or locations. On the one hand, learning can be produced by visiting POIs and gamification can be used to encourage participants to do that. On the other hand, people can interact in different ways collaborating, competing, teaching or leading. Taken into account that the presence of an instructor influences significantly the learning experiences in this scenario, two main use cases were identified related to formal and informal outdoor learning, respectively.

1) Formal Outdoor Learning

This use case describes a scenario in which a teacher creates an educational tour targeted for his/her students related to the current subject that is being studied in class. First off, the teacher creates the educational tour selecting the different POIs and learning materials. Besides adding existing materials, the teacher can create new specific contents or adapt the existing ones. Then, the teacher has to explain the rules of the learning experience in the classroom. Students can use their own smartphones to access to the educational tour and perform all the activities available. The tour starts leaving the classroom and adopting the entire city as the learning environment. Since this moment, students are involved in an adventure in which they have to achieve a set of goals. The achievement of the goals is based on the discovery of selected city locations and the realization of learning activities related to these places. These activities will be triggered when the students arrive to the associated location. A learning activity can be, for instance, watching a video about the place, a quiz that asks questions that require the student to explore physically the place to answer or a puzzle game that challenges the student´s intelligence. Moreover, several elements may be involved in an activity. For instance, a learning activity may consist of a video and a quiz that ask a question about it. This way, students have to overcome diverse challenges based on the realization of learning activities through their mobile devices. As a consequence of performing successfully a learning activity, new goals or missions can be offered to the student and new elements can come into play. Finally, other actions can be carried out by the students during the tour such as take geo-located photos about specific topics and share them through an online environment.

2) Informal Outdoor Learning

This use case describes a learning scenario which lacks the presence of an instructor and where anyone can create his/her own educational tour and offer it to the community. The learning experience is based on the same principles than the previous use case. Each participant has to achieve a set of goals, whose achievement depends on the discovery of POIs and the realization of specific activities. However, this use case is focused on providing more joyful and engaging learning experiences in the process of discovering POIs. First off, each participant or player assumes the role of a character like in a role playing game. Optionally, the adventure can be set in a fictional or historical setting, explaining the backstory and the motivation. Each character has its own mission composed by a set of goals. In this scenario, Virtual Objects (VOs) are scattered around the city. Players can find VOs in some POIs, and they can watch and collect them via their mobile devices using augmented reality. Players can also trade with VOs. New goals are defined around VOs. For instance, the mission of a player may be to collect all of the pieces of the Philosopher's Stone and bring them to a specific spot. Some goals may also require collaboration to be achieved. This way, players are involved in an adventure which tests their ingenuity and their problem-solving and teamwork skills. Finally, two game elements are included in the scenario to encourage competition: leaderboards and badges. The leaderboard is built based on scores that can be earned by achieving goals or finding VOs, while badges can be collected undertaking different actions.

C. Requirements

Based on these use cases, several requirements were identified and numbered from *Requirement 1* to *Requirement 7*.

1. The learning experiences must be provided by educational tours, which should be available for mobile devices since the learning occurs outdoors. Furthermore, they should be able to be created and designed by anyone.
2. Learning activities (e.g. videos, quizzes, mini games) are very diverse and can be combined to build more complex ones. Therefore a logical choice is to build them as Learning Objects (LOs) [19], [20].
3. The learning activities are tied to locations and hence the LOs must be associated with POIs.
4. Virtual Objects (VOs) are tied to POIs and participants can obtain them using their mobile phones.
5. Each participant may have a character associated with a specific mission and/or goals to achieve. Some goals may require teamwork to be achieved.
6. Several actions performed by participants or triggered by the occurrence of certain events have to be considered (e.g. reveal new POIs or goals, take a picture, etc.).

7. Certain events (e.g. activity completion or POI discovery) should allow participants to achieve badges or earn a certain amount of score points. A leaderboard based on these scores ought to be provided.

IV. Model

Based on the requirements derived from the use cases analysis, we define a model for the educational tour entity considering three dimensions: tourism, learning and gamification. This means that any educational tour can be represented by three components or vectors, each of them related to one dimension. The magnitude of these components relies on diverse factors of the educational tour such as LOs, POIs or VOs quantity, academic load or the role played by game mechanics in the learning experience. Therefore, educational tours tailored for different use cases will lead to different representations. To illustrate this idea, Fig. 2 shows the representation of the educational tours corresponding to the above mentioned use cases.

In the first case the learning component is the strongest one, since the educational tour has been created by a teacher with a strict educational purpose. Gamification is limited to provide a set of goals and maybe by including puzzle-like LOs. On the other hand, the second case has a very strong gamification component due to the preparation of the tour as a role playing game. In this case the LOs will be in most cases riddles, mini games, jigsaws and ability tests, which sometimes can offer less educational contents for the sake of entertainment and thus the learning component can be weaker. The tourism component mainly relies on the quantity of POIs. However, the more time participants spent consuming LOs, less time they will have to visit new locations.

A. Educational Tour Structure

In order to allow people to easily create educational tours regardless of their technical knowledge, they should use an e-Learning authoring tool. For this reason, the educational tours must follow a standardized structure that can be easily represented. This way, they can be implemented as web contents accessible through mobile devices and exported to standard e-Learning formats like SCORM (Sharable Content Object Reference Model) [21]. As a consequence we achieve the *Requirement 1*.

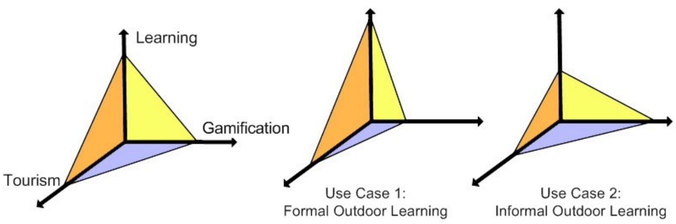


Fig. 2. Educational Tour Representation.

This model defines the structure of the educational tours including the description of the different components, their properties and how they relate among themselves. Fig. 3 summarizes this structure.

The learning activities are the building blocks of the tour. Providing them as LOs allows people to easily create and customize them conforming to e-Learning standards by using e-Learning authoring tools. Furthermore, it allows the reuse of a big amount of existing learning materials. *Requirement 2* is met thanks to this strategy.

To associate the LOs with POIs (i.e. *Requirement 3*), we have created the concept of Learning Point of Interest (LPOI). A LPOI can be defined as a POI that has a LO associated, or in other words, a LO that is tied to a location. Since a LPOI is nothing more than a particular LO, it can be formed by aggregating other LOs. The set of all LPOIs is called scenario.

In an educational tour, a LPOI can also be associated with Virtual Objects (VOs). *Requirement 4* is fulfilled as consequence of this linkage. In addition, VOs can be used by participants to touch off specific events in the tour (e.g. by bringing one to a specific POI).

An educational tour has a set of characters or roles. Each role has one mission with a uniquely associated goal and optionally a set of initial VOs. Goals are always related to LPOIs, VOs or both. The model considers three types of goals: go to a LPOI and accomplish the learning activities (i.e. consuming the LOs), bring a VO to a LPOI, and a combination of any of them. For instance, a collaborative goal can be defined by linking two simple goals: bring a VO to one location and bring another VO to a different location. Since a participant cannot be in two locations at the same time he/she will have to look for a partner. Since all of the goals are defined objectively based on existing entities, it is easy for a mobile application to manage them. Moreover, missions can also be split into activities. An activity is like a mission, but its associated goal is a "partial goal". This structure allows the achievement of the *Requirement 5*.

The accomplishment of an activity may result in the execution of an action. Actions cause effects over different entities of the tour. The main actions are: "Reveal a hidden LPOI", "Show a new activity" and "Give one VO to a certain participant". Actions can be performed as a response to a particular event (hence defined by the author of the tour), or because of a participant decision. For example, a VO can be given to a participant for discovering a LPOI or because of a barter deal between players. This modeling of the action entity covers the *Requirement 6*.

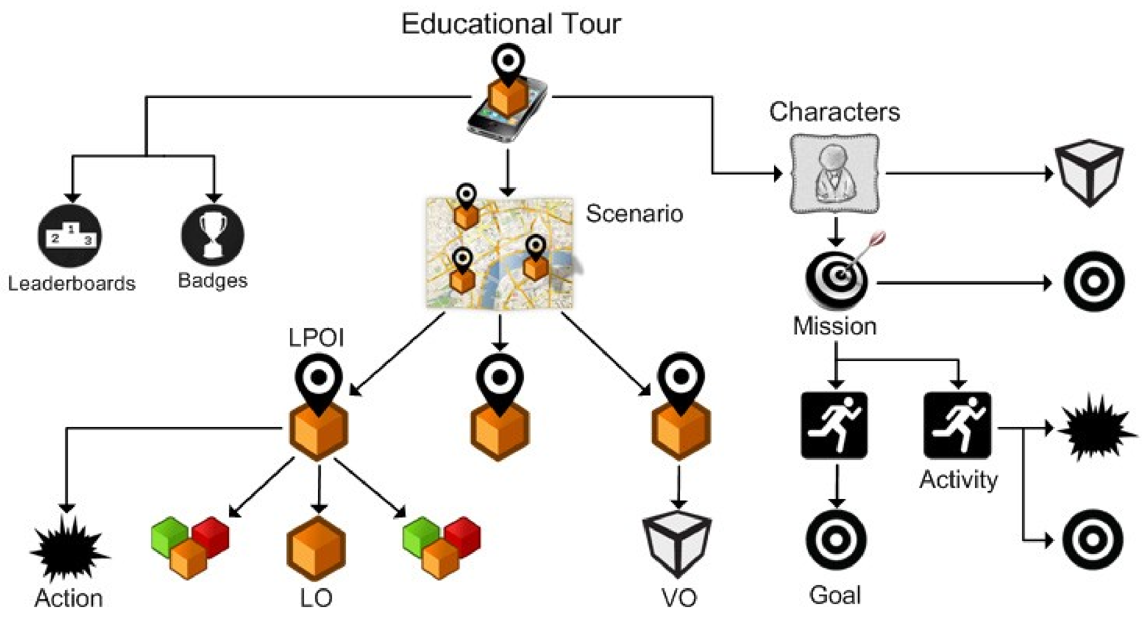


Fig. 3. Educational Tour Structure.

Lastly, in order to satisfy the *Requirement 7*, two more elements are considered in an educational tour: a leaderboard and a set of badges. There are two actions related to this: "Give a badge to a specific participant" and "Add score to a specific participant". Thereby, a participant can earn score points or achieving a badge by discovering and/or realizing the learning activities of a LPOI or by accomplishing a goal.

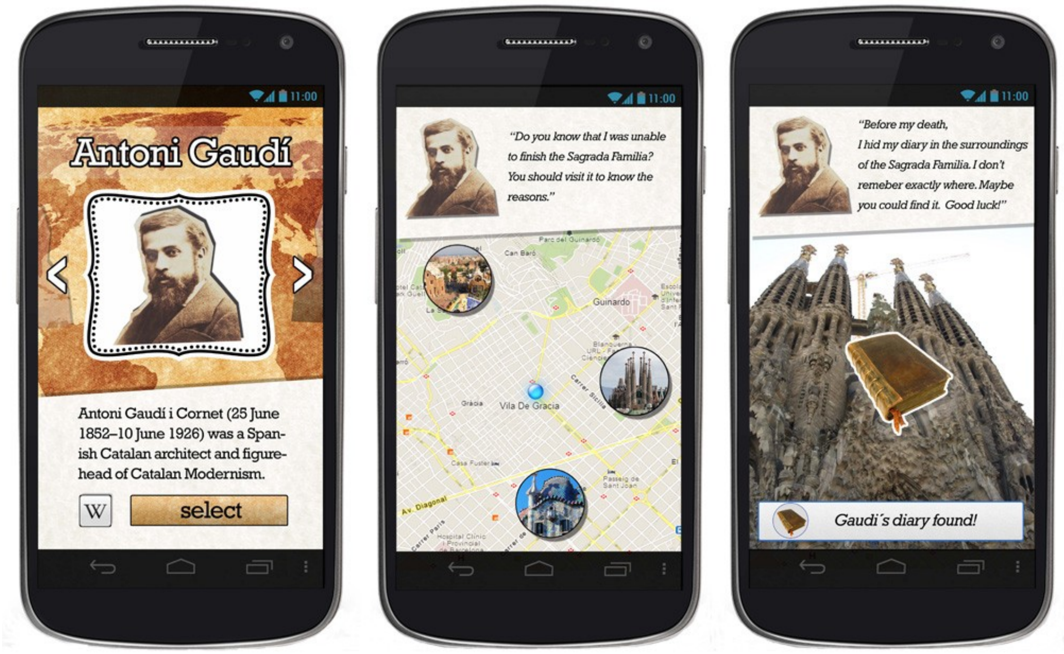
V. PROTOTYPE

As a proof of concept, an application prototype (Fig. 4) has been developed on top of the cloud services provided by the following GEs of the FI-WARE platform.

- *Location* to retrieve the users' location and notify the system when a user arrives to a LPOI.
- *Publish/Subscribe Context Broker* to notify users about certain news or events.
- *Identity Management* to provide authentication and authorization.

The application provides a set of educational tours of the city of Barcelona. Each tour is grounded on an historical character who will guide the user around the city. These characters explain different stories and curiosities related to their experiences throughout the tour. Characters can also propose different activities to accomplish. Fig. 4a shows the initial screen where a historical character from Barcelona can be chosen between Antoni Gaudi, Joan Miró or Pablo Picasso among others. After the selection of a character (in the Fig. 4 Antoni Gaudi) the educational tour starts. Then several LPOIs are revealed in a map as well as the current user's location. Fig. 4b represents this situation, where three LPOIs are showed: one in the Güell Park, other in the Sagrada Familia and another one in the Casa Batlló. Moreover, the user receives an initial advice from the virtual fellow traveller, recommending him/her to visit one LPOI. As we can see in Fig. 4b Antoni Gaudi is recommending the user to visit the Sagrada Familia. If the user follows this advice, a clue to perform activities related to the LPOI will be given upon his/her arrival. In the case illustrated, Gaudi confesses that he lost his diary in somewhere in the surroundings of the Sagrada Familia, encouraging the user to look for it. Fig. 4c shows the result of finding the VO representing the diary using augmented reality capabilities.

This application meets the two above mentioned use cases. This was achieved by providing several educational tours, each of them tailored for a different use case. On the one hand, it provides educational tours that could have been created by teachers with strong learning objectives related to the current subject studied in their classroom (e.g. an art history class). On the other hand, it also provides educational tours with weaker educational purposes, focusing more in the tourism and gamified dimensions. This kind of tours could have been created, for instance, by the tourism office of Barcelona or by a group of friends.



a) b) c)

Fig. 4. Prototype screenshots.

VI. Discussion

The model presented in this paper satisfies several use cases of outdoor M-Learning. Learning approaches focused on incorporating adventure into education such as AE and AL usually involves the realization of learning activities outdoors. Hence, in these cases, the model can be very useful providing more engaging learning experiences. Furthermore, the learning experiences can be tailored to be adapted to the desired use case by strengthening the correspondent component (tourism, learning or gamification). Another application of this model can be found in the emerging UDALE environments, since one of the challenges in its implementation is to provide an optimal structure and scaffolding for teachers and learners to allow them to create their own learning experiences [16].

However, some limitations exist when the model is put into practice. Learning experiences rely on mobile devices and hence they are limited by the technology capabilities of these devices. For example, if the mobile device is unable to determine the current location of the user for a prolonged time, they would not detect if the user arrives to a new LPOI. This fact can ruin the whole learning experience. Therefore, this technological issue limits the scope where the model can be applied. We designed the model for a city scenario, but it can fail or being unable to be applied to rural areas, where the connectivity is worse, or even to indoor scenarios where the geo-location is really complicated.

Finally, bearing in mind the tourism, learning and gamification components in which an educational tour can be decomposed, it is worth questioning if educational tours with a strongest learning component are the most effective or if it is better to include game elements to increase motivation at the expense of a weaker learning component.

VII. Conclusions and Future Work

We have presented a generic model which allows creating educational tours covering the main use cases of a scenario grounded on the city as a learning gamified platform. This model was created with the main aim of taking advantage of the benefits of linking the areas of Mobile City Guide, M-Learning and Gamification. As a consequence, the created educational tours can be represented by three dimensions: tourism, learning and gamification. Lastly, as a proof of concept, a mobile application prototype has been developed in the context of the FI-CONTENT European project to guarantee the achievement of the use cases and to ensure that the model is ready to be applied in real scenarios.

We have showed that the city can be effectively used as a place for learning. Several novel learning opportunities can be achieved in formal and informal outdoor M-Learning by using the city as a learning platform in combination with gamification. Also, this approach can enhance the experiences in existing learning approaches such as Adventure Education or Adventure Learning. Although these learning experiences can be limited by technological constraints, these limitations will be overcome since the technological advancements are creating the ideal conditions to use the city as a gamified learning platform.

Open challenges after this research consists of refining the mobile application prototype into a final product ready to be delivered to the public as well as the different components used in the service. Also, we plan to develop an authoring tool capable of creating the educational tours according to our model. This will allow us to test completely this new learning approach in the real world with teachers, learners and citizens as end users.

Since this is a novel research field, it opens several new research lines towards the exploitation of the city as a learning environment. In the considered scenario, places are passive elements. Learners can interact with the Learning Objects associated with them but not with the places themselves. Thereby, an interesting research line to investigate would be to consider in the model that different places and urban elements may be intelligent entities that interact with the participants. For example, an intelligent recycle container could give a badge or score points to a participant (or citizen) for recycling appropriately a certain amount of trash. Bearing all this in mind, we believe that Smart Educational Cities can become a next frontier in education.

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A Contribution to the Quality Evaluation of Mobile Learning Environments

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***Abstract* – In recent years, issues related to teaching and learning have been more and more discussed and investigated by the scientific community. Mobile learning (m-learning) environments, despite the benefits provided, are still considered as new and incipient products. Among the limitations observed in the construction and adoption of such environments, we highlight the lack of specific quality guidelines to allow an adequate evaluation of them. In short, the planning and execution of a systematic evaluation among m-learning environments can ease their selection and adoption by apprentices, tutors and educational organizations. Motivated by this scenario, in this paper we propose a process for the quality evaluation of mobile learning environments. To validate our ideas, we have applied the proposed process in the quality evaluation of a set of m-learning environments. The promising results achieved suggest the feasibility of adopting the process for quality evaluation purposes in the m-learning domain.**

Keywords – quality evaluation process, mobile learning environments, quality model

I. INTRODUCTION

In recent years, learning environments have shown an increasing importance, playing a fundamental role in teaching and training activities, both in academic and industrial settings [1,2]. Together with the advent of ubiquitous computing, learning environments have also provided a new modality of education – the mobile learning (m-learning) [3, 4, 5, 6].

Mobile learning is characterized by the ability to promote a strong interaction among apprentices and tutors, enabling them to contribute, participate and access the learning materials through mobile devices (e.g., mobile phones, tablets, laptops, among others) at anytime and anywhere. So, the main goal is to provide greater motivation, convenience and flexibility to the learning processes in general.

Despite the benefits of m-learning, it is still considered a new and incipient concept, having some limitations in its construction and use [5, 6]: (1) reduced processing power; (2) variable screen size; (3) limited energy (battery dependent); (4) transmission rates generally smaller than those of the fixed network; (5) adequacy to usability aspects; (6) lack of architectural patterns; and (7) lack of requirements and quality guidelines for the educational practices.

Quality aspects, in particular, represent an important issue to be addressed, mainly because of the growing popularity of mobile applications in different sectors of the society. In this emerging scenario, quality is not only related to technical aspects. There is also a need for dealing with intrinsic issues (e.g., educational, socio-cultural and economic) related to the daily activities of apprentices and tutors [7].

Few studies regarding quality guidelines for mobile applications have been found in the literature. As a consequence, there is no well-defined and widely used mechanism to support the quality evaluation of mobile educational environments. In this paper we propose a process for quality evaluation of mobile learning environments. In short, the process establishes a set of quality metrics as well as the levels of punctuation and the judgment criteria. A quality model for mobile learning environments, defined in a previous work [18], is also used as part of the process. To validate our ideas, the process is applied in the quality evaluation of three mobile learning environments.

This paper is organized as follows. In Section II, we provide an overview of the main topics on which this paper relies: m-learning and quality evaluation processes. In Section III, we briefly describe a quality model for m-learning environments. In Section IV, we present the quality evaluation process we have worked on. In Section V, we illustrate the application of the proposed process for evaluating three different m-learning environments. Finally, in Section VI, we summarize our conclusions and perspectives for further work.

II. BACKGROUND

A. *Mobile Learning*

The rapid growth of information technologies along with the increasing flexibility in communications among users have provided new modalities of learning as well as innovative ways to deal with the limitations of traditional learning. For instance, due to the advent and evolution of technology, allied to the ubiquitous computing, a new modality of education based in mobile computing, referred to as mobile learning (m-learning), has emerged [8].

Several attempts to define m-learning can be found in the literature. Rachid and Ishitani [9] define m-learning as any type of teaching/learning that occurs when the apprentice is not in some fixed place, or when the individual is taking advantage of learning opportunities offered by mobile technologies. Ozdamli and Cavus [10] consider m-learning as an activity that enables individuals to be more productive when they consume/create or interact with the information, mediated by mobile devices.

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Whatever the definition adopted, the use of learning environments through mobile devices brings benefits that go beyond affordability, convenience and communication [11, 12]. For example, with mobile devices apprentices can use the most different types of applications (e.g., text processors, photos, games), specific environments for learning, Web access, collaboration tools, social networks, among others.

Despite the benefits provided, and even with the increasingly demand for flexible, reliable and high-quality mobile learning applications, there are few studies dealing with quality aspects in the particular context of m-learning development. Furthermore, the existing studies generally focus on some quality characteristics in separate (e.g., accessibility) [8, 12, 13]. On the other hand, considering mobile applications in general, some proposals on how the quality should be assessed can be found. For instance, Spriestersbach and Springer [21] identified the major challenges in the development of mobile applications, relating such challenges into the quality characteristics described by the ISO/IEC 9126 standard. Mantoro [22], in turn, suggests some adjustments to this quality model in order to assure the quality of context-aware applications.

The identification and understanding of quality criteria, requirements and metrics for m-learning environments is a complex task [7, 12]. Different factors are involved in the development and adoption of such environments. Additionally to technical aspects, educational components, attributes of ubiquitous computing, criteria of mobile usability, among others, should also be taken into consideration. Besides that, there is a need for the establishment of specific processes for quality evaluation in the context of mobile learning. The idea is to ensure that evaluations can be effective and capable of being replicated in different organizations, for a wide range of m-learning environments.

B. *Evaluation Process for Software Quality*

Several processes for the evaluation of software quality can be identified in the literature. Most of them, however, are specific for a particular type of software products, hindering their application to different domains.

In order to define an adequate quality evaluation process for m-learning environments, we were based on ISO/IEC 14598 standard [14]. Shortly, ISO/IEC 14598 is a guide for quality evaluation in software products, which allows the definition of evaluation requirements in terms of quality characteristics as stated in ISO 9126 standard [15]. The defined process can be used to evaluate products in development as well as products already finished. It comprises five stages [14]:

- A*nalysis of Evaluation Requirements*: the objectives of the evaluation are described, and the requirements to be evaluated are established. Different points of view can be considered, depending on the users of the product;
- *Specification of the Evaluation*: the goal is to define the scope of the evaluation, and the measurements to be performed in the product. Constraints, methods to be used and responsibilities of all people involved in the evaluation process are defined as well;
- *Design of the Evaluation*: the procedures to be followed to perform the measurements previously specified are documented. The evaluator must produce a plan that describes the resources required to conduct the evaluation (e.g., deadlines, evaluation team, associated risks and all the activities involved);
- *Execution of the Evaluation*: the evaluation is performed and the results achieved are summarized in a report;
- C*onclusion of the Evaluation*: the evaluation report is reviewed and delivered.

The adoption of an evaluation process based on ISO/IEC 14598 standard is relevant in order to establish a process that is repeatable, reproducible, impartial and objective. Actually, the aim is to have a practical and non-bureaucratic process, easy to be adopted by companies and organizations [16, 17].

III. A QUALITY MODEL FOR M-LEARNING ENVIRONMENTS

According to Guerra [17], to effectively perform a quality evaluation, it is necessary the use of a quality model specifically defined for the domain of the software under evaluation. In this work, we have adopted a requirements catalog for mobile learning environments, defined by Duarte Filho and Barbosa [18], as the basis for our quality model.

The catalog comprises three levels of hierarchy [18]: (i) *Criteria for Evaluation (Level 1):* responsible for determining the specific criteria that must be considered during the evaluation of the m-learning environment; (ii) *Requirements (Level 2):* composed of development and quality requirements, this level provides relevant guidelines regarding both the development and the quality evaluation of m-learning environments; and (iii) *Descriptions:* corresponds to the textual descriptions of the requirements defined in the previous level.

Figure 1 illustrates the general structure of the catalog. A brief description of the proposed criteria and requirements is presented next. In total, 44 requirements, organized into nine criteria, were defined.

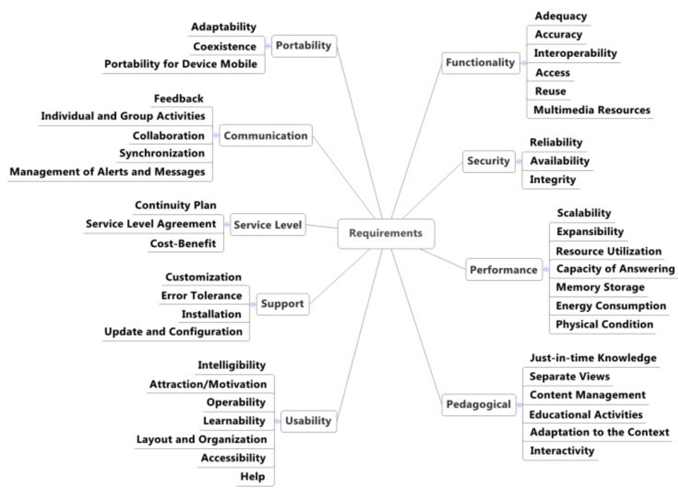

Fig. 1. Catalog of requirements for mobile learning environments [18].

The *technical criteria* deal with assumptions and constraints regarding functionality, security and performance.

- *Functionality:* Mobile learning environments, as any other software product, have to provide functions that meet the explicit and implicit users' needs. Regarding *functionality*, six requirements were defined: *adequacy*; *accuracy*; *interoperability*; *access*; *reuse*; and *multimedia resources*.
- *Security:* Since m-learning environments are mostly used via remote access (web), security is an important issue to be addressed in the development of such systems. Regarding *security*, three basic requirements were identified: *reliability*; *availability*; and *integrity*.
- *Performance:* In the scope of m-learning environments, performance is mainly related to the response time, expansibility and scalability, processing power, memory storage capacity and battery consumption. Thus, seven requirements were defined: *scalability*; *expansibility*; *resource utilization*; *capacity of answering*; *memory storage*; *energy consumption*; and *physical conditions*.

The *educational criteria* aim at providing greater competence and adaptation to the educational practices, taking into account pedagogical and usability aspects.

- *Pedagogical:* Additionally to the basic functional requirements, m-learning environments must address educational and pedagogical requirements in order to ease and support teaching and learning activities. Six requirements were defined regarding *pedagogical* issues: *just-in-time knowledge*; *separate views*; *content management*; *educational activities*; *adaptation to the context*; and *interactivity*.
- *Usability:* Interface is one of the strong points for software acceptance by the users. In the context of learning environments, especially for mobile devices, the interface should be easy to learn and to be recognized and remembered. Seven basic requirements on *usability* were defined: *intelligibility*; *attraction/motivation*; *operability*; *learnability*; *layout/organization*; *accessibility*; and *help*.

Regarding *economic criteria*, it is necessary to have a balance between the costs and the benefits involved in the m-learning environment application, taking in consideration aspects such as support and service level.

- *Support:* Support can be considered as a quality differential for m-learning environments. Every service provided must have an efficient support to its users in order to enable questions. Regarding *support*, four main requirements were identified: *customization*; *error tolerance*; *installation*; and *update/configuration*.
- *Service Level:* The establishment of service levels in the context of m-learning environments aims at improving the security in the use of such applications while guaranteeing the continuity of the services. Three main requirements were defined regarding *service level*: *continuity plan*; *service level agreement* (SLA); and *cost-benefit*.

Finally, the *socio-cultural criteria* assure the adequacy to issues relate to a particular social group and to the cultural level of the user of the mobile learning environment, taking into account communication and portability aspects.

- *Communication:* Communication is an essential characteristic for e-learning and m-learning environments. Regarding *communication*, five requirements were identified: *feedback*; *individual and group activities*; *collaboration*; *synchronization*; and *management of alerts and messages*.
- *Portability:* The apprentice must be able to interact with the objects of m-learning anytime and anywhere, ensuring convenience and flexibility during the learning process. Three man requirements were defined: *adaptability*; *coexistence*; and *portability for mobile devices*.

IV. Proposal of a Quality Evaluation Process for M-Learning Environments

To effectively evaluate and compare a mobile learning environment, it is important to follow a systematic and well-defined evaluation process. Besides that, the process should be capable of being followed by different organizations. Our proposal of a process to evaluate the quality of m-learning environments is described next.

Initially, it is necessary to define the actors and their roles with respect to the activities of the evaluation process. In the case of m-learning environments, there are three main actors that can participate in the evaluation process: (i) *Requester*: person/entity who asks for an evaluation, specifying what are the main purpose and objectives; (ii) *Evaluator*: person who knows the quality guidelines and knows how to apply the evaluation process, serving as a guide and primary contact between the process and its participants; and (iii) *Specialist*: person who has full knowledge regarding the application context of the mobile learning environment.

The evaluation process is illustrated in Figure 2. It is based on the best practices and knowledge prescribed in the ISO/IEC 14598 standard [14], being composed of six main steps. It is important to notice, however, that such steps were simplified and specifically adapted to the context of m-learning.

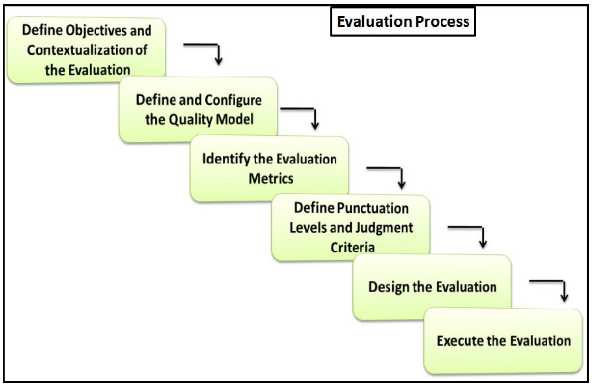

Fig. 2. Steps of the quality evaluation process for m-learning environments.

Define Objectives and Contextualization of the Evaluation: The objective of the evaluation is to analyze and compare mobile learning environments in relation to technical, educational, economic and socio-cultural aspects, identifying strengths and weaknesses of each environment considered. The idea is to perform the evaluations through quality guidelines specifically defined for this kind of software product, thereby ensuring the effectiveness in the assessments.

Define and Configure the Quality Model: The quality model adopted in the evaluation process is based on the Duarte Filho and Barbosa's model [18]. This model was chosen since it establishes a well-defined set of quality criteria and requirements for mobile learning environments, which has been prioritized and evaluated by specialists in the area.

Identify the Evaluation Metrics: In this step, the quality requirements should be mapped into attributes that can be measured and scored. In short, the measurable attributes are set up based on the knowledge of specialists, by creating simple and straight questions that are evaluated and scored by means of a checklist. In total, 90 questions were created and classified into nine distinct groups, according to the criteria defined in the quality model. Table I summarizes the main objectives of the questions that compose the checklist.

TABLE I. *MAIN OBJECTIVES OF THE QUESTIONS IN THE CHECKLIST.*

Quality Criterion	Objective of the Questions
Functionality	Questions in this group aim at evaluating aspects of functionality, such as cohesion and accuracy in performing the tasks. They allow checking if the m-learning environment works correctly according to the apprentices' and tutors' needs.
Usability	Questions in this group aim at evaluating if the users are able to easily employ the system options, and verify their level of satisfaction in relation to ergonomics, interface, among other characteristics of usability.
Security	Questions in this group aim at evaluating items regarding the access of users, reliability, integrity and availability of the mobile learning environment.
Performance	Questions in this group are concerned with the operation of the m-learning environment during the access of several users, in different organizations. The type of data transmitted is also considered in the evaluation.
Pedagogical	Questions in this group aim at evaluating educational and learning requirements. Issues of interactivity, motivation, and adjustments to the context of the apprentices are considered as well.
Support	Questions in this group aim at assessing the system behavior after occurring changes in their functions. Treatments of incidents and problems as well as corrections of bugs and defects are also considered.
Service Level	Questions in this group aim at evaluating the process of planning, control and definition of service level agreements (SLA), ensuring transparency in legal issues.
Portability	Questions in this group aim at verifying the system behavior with respect to different mobile devices, browsers and even with different operating systems.
Communication	Questions in this group aim at evaluating the effectiveness of the communication among users. Communication can be done in several ways (asynchronous or synchronous) through mobile devices.

For the sake of space, the proposed checklist for m-learning environments is not presented herein. The complete list of questions is available in Duarte Filho and Barbosa's work [19]. It is important to highlight that the checklist was elaborated as a template in order to facilitate its application by the evaluator.

Define Punctuation Levels and Judgment Criteria: To define the punctuation levels for the questions in the checklist, firstly we have to specify the type of nominal answers that can be applied in these questions.

For each one of the 90 questions created, the punctuation level is defined as follows: (i) maximum value: "1" (highest score); (ii) minimum value: "0" (lowest score); and (iii) intermediate values with the interval of "0.25". The score for each quality criterion is obtained by the sum of the scores achieved by its respective questions. This process is applied for the nine criteria established in the quality model. In the end, a final score for the m-learning environment under evaluation is obtained. Notice that by knowing each score separately, the requestor of the evaluation is able to prioritize adjustments and improvements on the criteria that did not achieve the required level of quality.

The judgment criteria are defined from the Martinez's work [20], in which three levels for judgment are established: *Superior*, *Medium* and *Lower*. To achieve the *Superior Level*, the m-learning environment must be in accordance with at least 80% of the quality requirements specified, i.e., the final score can vary from 80 to 100, on a scale of 0-100. To get the *Medium Level*, the system must be in accordance with at least 50% of the requirements, i.e., the final score can vary from 50 to 80. In the *Lower Level*, less than 50% of the requirements are achieved, i.e., the final score varies from 0 to 50.

Design the Evaluation: The evaluation must be designed according to specific guidelines for the system domain. In the case of mobile learning environments, for instance, the evaluation must be based on educational activities (e.g., exchange of information among tutors and apprentices, use of forums/wikis, application of tests, among others). Manuals of the environment should also be considered.

Execute the Evaluation: At the final stage, the evaluator has to execute three main tasks: (i) collect the quality measures; (2) compare the measures with respect to the quality criteria predefined; and (iii) judge the data obtained during the evaluation.

V. APPLYING THE QUALITY EVALUATION PROCESS: A CASE STUDY IN THE M-LEARNING ENVIRONMENTS DOMAIN

In order to conduct a preliminary validation of the proposed evaluation process, it was applied in the analysis of three mobile learning environments (Figure 3): *Blackboard Mobile*[1], *Desire2Learn Mobile* [2] and *Mobl21* [3]. Due to space limitations, we have detailed focus on the quality evaluation of *Desire2Learn*, and then we provide an overview of the obtained results to the other environments.

A. *Quality Evaluation of Desire2Learn*

Initially, the questions of the checklist were answered by the evaluator through the use of *Desire2Learn*. Consider, for instance, the quality criterion of "Usability". The first column

[1] www.blackboard.com/platforms/mobile/overview.aspx
[2] www.desire2learn.com/products/mobile/
[3] www.mobl21.com

of Table II corresponds to the number of each question in the checklist related to this criterion; the second column shows the scores given by the evaluator for each question. The sum of these scores represents the level of quality achieved by *Desire2Learn* with respect to “Usability”. This process was repeated for each criterion of the quality model. The scores achieved for all criteria are summarized in Figure 4.

According to Figure 4, “Functionality” and “Security” obtained the highest scores, being the only criteria in the *Superior Level* of quality. All the other criteria were at the *Medium Level*. It is important to notice that these criteria deal with general aspects of a traditional learning environment, i.e., they do not address specific characteristics of a mobile system.

a-) Blackboard Mobile b-) Desire2Learn c-) Mobl21

Fig. 3. Mobile learning environments

TABLE II. SCORE OF EACH QUESTION RELATED TO “USABILITY”

Question	Score
1	1
2	0
3	1
4	0
5	1
6	0.5
7	1
8	0.5
9	1
10	1
Total	**7.0**

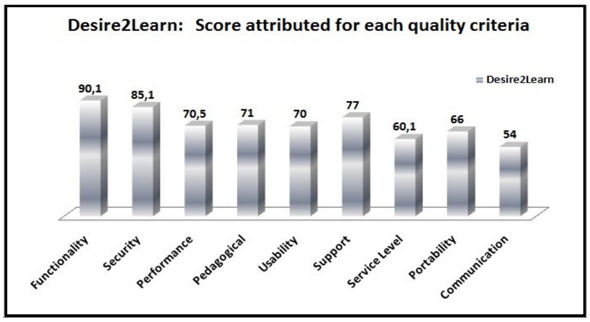

Fig. 4. *Desire2Learn*: Scores achieved for each quality criterion.

On the other hand, “Communication” and “Level of Service” obtained the worst scores among the quality criteria evaluated. Considering that these criteria deal with issues directly related to mobile systems, this result suggests a weak aspect regarding the quality of the environment under evaluation. Therefore, planning the evolution of *Desire2Learn*, specific improvements with respect to communication and level of service should be prioritized.

Then, the scores of each criterion were added and the arithmetic average was calculated. The final score for *Desire2Learn* was 71.5. According to the judgment criteria previously defined, the m-learning environment shows a *Medium Level* of quality.

B. Summary of Evaluation Results

Next we discuss the overall results obtained to the three mobile learning environments evaluated. Figure 5 summarizes the scores for each quality criterion in relation to the environments evaluated.

From Figure 5 we can notice that, in general, the m-learning environments have shown good scores in relation to the criteria of “Functionality”, “Security”, “Performance” and “Pedagogical”. These criteria correspond to the technical and educational/pedagogical areas, as defined by Duarte Filho and Barbosa [18] and by Economides [7]. On the other hand, we also may notice a decrease in the scores related to “Usability”, “Level of Service”, “Portability” and “Communication”, which are closely related to economic and socio-cultural aspects.

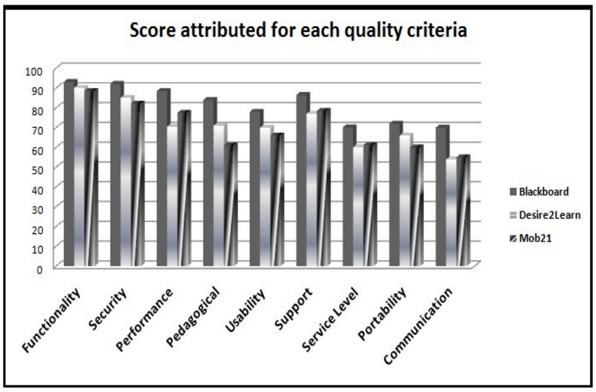

Fig. 5. Overall scores achieved for each quality criterion.

Adding all the scores achieved for each criterion and then computing the arithmetical average, it is possible to verify the final score for each one of the evaluated environments. Figure 6 shows the comparison among the final scores obtained.

From the evaluation performed, it was also possible to identify some strengths and weaknesses that the m-learning environments had in common (Table III). Such analysis is helpful in providing additional information to the requestor, suggesting potential aspects for future adjustments and changes in the products evaluated.

TABLE III. MOBILE LEARNING ENVIRONMENTS: SUMMARY OF COMMON POSITIVE AND NEGATIVE ASPECTS IDENTIFIED.

Criteria	Positive Points	Negative Points
Functionality	Most of the functions presented in the environments were capable of satisfying in an accurate and efficient manner both the users' needs and the educational practices.	During the evaluation, limitations related to the reuse of learning objects were identified, mainly due to the lack of using a standard reuse technique.
Security	The environments showed several technical mechanisms to ensure a greater security, assuring reliability and integrity to the users' information.	No mechanism to verify the number of times the users try to login using a wrong password was identified in the evaluated environments.
Performance	The environments showed to be effective in relation to the scalability of new users, using multi-tenant (use of the system by different users at the same time). Its use can also be performed by different organizations, ensuring confidentiality to the data.	The environments presented limitations regarding the inclusion of new services (scalability). In general, they do not provide a well-defined interface contract, hindering the inclusion of new services and components.
Pedagogical	The environments were well-evaluated in terms of content and educational activities management, allowing the use of information and knowledge transfer by means of texts, images, graphics, multimedia, games, audio, among others elements.	The environments do not provide an adequate separation of visions among tutors and apprentices, having problems in relation to the management of permissions and specific features.
Usability	The environments showed a variety of well-defined buttons and menus, organized together with adequate tabs of services and functions.	A weakness observed was the lack of help systems, demonstrations and tutorials, hindering the use of the environment, mainly by inexperienced users.
Support	The environments provided an efficient process for installation, update and configuration, ensuring that these tasks be treated in an easy, fast and automatic way, thus avoiding errors by the users.	Customizations, personal changes and actions in the environment were not well-adapted for the end user.
Service Level	The environments showed a good cost-benefit relation regarding purchase and maintenance, being economically viable to reach a specific group of apprentices, enabling the use and distribution of the system.	The environments provided an SLA. However, it was not well-defined, presenting ambiguities and not clarifying the legal implications with respect to non-compliance of essential clauses to the system operation.
Portability	The environments showed an adequate behavior while in use in different mobile devices, preserving all the functions and educational characteristics.	Some problems in relation to the hardware configuration were observed.
Communication	The environments presented a set of efficient tools for collaboration, such as wikis, games, micro-blogs and discussion groups.	Problems with respect to the management of warnings and messages were identified, hindering the correct receiving of SMS/MMS by users.

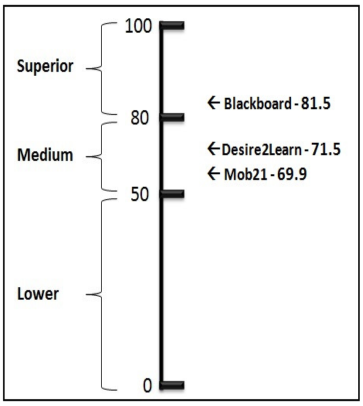

Fig. 6. Final scores achieved by each mobile learning environment

As a complement to the results already discussed, each environment was analyzed in separate. In general, the advantages and disadvantages identified are more related with functional and educational aspects.

<u>*Blackboard Mobile*</u>

The analysis performed in *Blackboard Mobile* pointed out the following advantages: (1) compatibility between different operating systems; (2) good interaction with users; (3) content grouped according to tasks and interactive forms; and (4) configuration facilities in the mobile device hardware.

As the main disadvantages we highlight: (1) proprietary software; (2) synchronization defective; (3) lack of support to previous versions of operating systems; and (4) versions conflict, requiring product verification and update.

<u>*Desire2Learn Mobile*</u>

Desire2Learn has characteristics that point out advantages, such as: (1) optimized access to content for apprentices/tutors; (2) communication and direct connection of interactive resources; (3) compatibility with several different operational systems; and (4) product customization.

On the other hand, some aspects can be considered as disadvantages: (1) low security; (2) inefficient control access; (3) it does not have content filter and optimization of broadband connection; (4) proprietary software; and (5) limitations on customization due to versions conflict.

<u>*Mobl21*</u>

During the evaluation of *Mobl21* the following advantages were identified: (1) free software via GNU-GPL; (2) portability among operating systems and databases; (3) interaction with the learner in real time, via SMS; (4) levels of perception of the m-learning environment in different colors (depending of context); (5) simultaneous access of users; and (6) information content arranged in several groups.

The main disadvantages are: (1) no control of bandwidth network; (2) latency in relation to web services; (3) it requires high computational power of the mobile device; and (4) difficulties to adapt the interface to different mobile devices.

As a final remark, it is also worth to notice that only minor problems were found during the execution of the case study. Furthermore, the evaluation process demonstrated to be effective and feasible to be applied together with the quality model previously established [18]. As a good practice, all results must be summarized and recorded in a final report.

VI. Conclusions and Further Work

In this work we proposed a systematic process for the quality evaluation of mobile learning environments. The aim is to help users (apprentices/tutors/administrators) in evaluating, comparing and selecting mobile learning environments. These environments should be compatible with pedagogical, socio-cultural, functional and economic criteria, ensuring higher quality and standardization to the educational practices.

The proposed process was based on a quality model [18], specifically defined to the m-learning domain. The ISO/IEC 14598 standard [14] was considered as well. The practical evaluation is performed by means of a checklist that, through a set of evaluation metrics, addresses all the criteria established by the quality model.

Furthermore, the process comprises a set of well-defined stages, enabling the evaluation be applied and reused by different evaluators, in various organizations and for different m-learning environments.

In order to validate our ideas, the process was applied in the quality evaluation of three mobile learning environments. The obtained results suggest the process is effective and feasible to be adopted in the quality evaluation of mobile learning environments.

Despite of the promising results achieved, we highlight the need for a more formal validation. Thus, systematic and controlled experiments, considering a wider set of mobile learning environments, have been planned and should be performed in short term.

Acknowledgment

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A model for integrating learning object repository resources into web videoconference services

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***Abstract*— Reusing Learning Objects saves time and reduces development costs. Hence, achieving their interoperability in multiple contexts is essential when creating a Learning Object Repository. On the other hand, novel web videoconference services are available due to technological advancements. Several benefits can be gained by integrating Learning Objects into these services. For instance, they can allow sharing, co-viewing and synchronized co-browsing of these resources at the same time that provide real time communication. However, several efforts need to be undertaken to achieve the interoperability with these systems. In this paper, we propose a model to integrate the resources of the Learning Object Repositories into web videoconference services. The experience of applying this model in a real e-Learning scenario achieving interoperability with a web videoconference service is also described.**

Keywords— online learning; videoconference; learning objects; interoperability; repository

I. INTRODUCTION

Digital Learning Objects are the building blocks of e-Learning activities. A Digital Learning Object (hereafter just LO) may be as simple as a paragraph of text or an image, or can be a more complex object like a quiz or an educational game. Due to the immensity of learning resources on the Internet, Learning Object Repositories (LORs) play a key role by facilitating their discovery and reuse. The repurposing of LOs in multiple contexts is essential to enable cost-effective development and foster collaboration between organizations. Hence, achieving their interoperability is one of the main challenges when creating a LOR.

On the other hand, the adoption of novel HTML5 [1] technologies and the growth of cloud computing services are enabling the development of innovative web videoconference services. These new technology solutions provide high quality services at low cost as well as unprecedented easy access since users just need a web browser to establish a real time communication.

These new services can offer huge benefits for distance and blended learning. They allow the sharing, co-viewing and synchronized co-browsing of educational resources at the same time that provide real time communication. However, to take advantage of these benefits, the LOs have to be integrated with the videoconference services.

Basic LOs like a simple image are very easy to integrate, but more complex ones, which can have a high degree of interactivity, need more sophisticated solutions. There are several interoperability standards for LORs, but they are usually more focused on achieving interoperability among them than on increasing the ability of their resources to be reused. On the other hand, some standards have been defined to integrate LOs in external environments such as Learning Management Systems (LMSs), but they were not designed with web videoconference services in mind. Therefore it is not possible to take full advantage of the power of these tools using existing standard solutions.

In this paper we propose a novel model to integrate the LOs of a LOR into web videoconference services. We also present the experience of implementing this model in a real e-Learning scenario, in which we achieve the interoperability with a web videoconference service called MashMeTV (http://mashme.tv).

The rest of the paper is organized as follows. The next section reviews related work of LORs focused on interoperability. Section 3 explains the model. Section 4 presents the scenario in which it has been applied as well as the use case. The last section finishes with some concluding remarks together with an outlook on future work.

II. RELATED WORK

The Learning Object Metadata (LOM) standard [2] defines a Learning Object as "any entity, digital or non digital that may be used for learning, education or training". However, in e-Learning this term usually covers only digital entities. The main aim of providing educational resources as LOs is to facilitate reuse [3]. Reusing LOs instead of repeatedly authoring them can lead to several benefits such as savings in time, reducing development cost and even enhancing the quality [4]. A key factor in improving reusability and interoperability of LOs is metadata, where their information is specified including their structure, properties and educational characteristics.

Usually, LOs are created using e-Learning authoring tools and stored, searched and accessed using LORs. A LOR stores both LOs and their metadata, either by storing them physically together or by presenting a combined repository to the outside world [5]. LORs also allow users to search and retrieve LOs. To provide the most possible resources, they take LOs from other LORs using different methods such as federated searches or harvesting. Metadata plays an important role in facilitating the retrieval process since LORs typically support advanced searches based on LOM properties (e.g. subject, target age). The most widespread standard to define the metadata scheme is LOM, although some LORs have implemented their own scheme. LORs also provide several services to users beyond searching and storing such as favorites, recommendations of LOs based on user's history and private repositories.

Some different interpretations exist for the term interoperability. It is often considered as the capability of one system to communicate and interact with others. But in this context, interoperability can be also defined as the ability of "enabling information that originates in one context to be used in another in ways that are as highly automated as possible" [6]. In this paper we always refer to interoperability according to this second definition. Then, a crucial factor of a LOR is to provide interoperable LOs. Or in other words, to provide LOs that can be integrated automatically with LMSs and third party websites. Several approaches exist to achieve interoperability with different systems. First off, most e-Learning authoring tools build LOs conforming to some e-Learning standard such as SCORM (Sharable Content Object Reference Model) [7] or AICC (Aviation Industry Computer-Based Training Committee) allowing their reuse in LMSs. Furthermore, many LORs offer the possibility of exporting their resources to some of these standards.

Lastly, we must take into account that not all integrations are equally strong. Some approaches (e.g. SCORM) allow communication between the LOs and the context in which they are running while others do not. In the context of videoconference services, regarding the achieved degree of interoperability, the LOs can be *shared* (i.e. each participant sees his/her own isolated instance of the LO), *co-viewed* (i.e. all participants see the same LO) or *co-browsed* (i.e. all participants can also realize actions over the co-viewed LO synchronously). For instance, the Bridgit videoconferencing tool [8] achieves LO interoperability by using computer desktop sharing. Therefore the LO can be co-viewed since all participants can see the same LO at the same time, but co-browsing is not possible since the only participant who can interact with the LO is the one who is sharing the computer desktop. Some other videoconference services offer computer desktop sharing (e.g. Google Hangouts) but all of them have this limitation.

III. MODEL

This model has been designed with Web Videoconference Services (hereafter WVSs) in mind. Its main aim is to satisfy the main use cases of a scenario where a WVS is used for distance and blended learning: sharing, co-viewing and synchronized co-browsing of LOs.

The designed solution is based on the idea that if a LOR can export its resources to e-Learning standards to integrate them in LMSs, then it also would be possible to export these resources using certain conventions to allow their integration into WVSs.

According to this model, all LOs are delivered as web resources including a lightweight component that provides an API (Application Programming Interface), which enables the communication between the context in which LOs will be used and themselves. Fig. 1 illustrates this idea that will be explained in detail along the next sections.

A. Delivering interoperable Learning Objects

The LOR provides a main function: Request/Deliver LO. This function is in charge of attending the requests of LOs and delivering them enabling their reuse in the way that the interoperability can be achieved as highly automated as possible. Several steps are carried out to attend a LO request:

1. If the LO is not in a web-ready format it should be adapted. This adaption can be done when the LO is stored in the LOR or on the fly in a less efficient way. Hence, if an image is requested, the LOR will deliver a simple HTML page with the image embedded in it.

2. Besides the LO, a lightweight JavaScript API (hereafter LO API) will be attached to the HTML page in order to detect the events triggered as a response of the user's actions. This API also provides functions to replicate these actions. This step makes no sense for non-interactive resources (e.g. an image) and then in those cases can be skipped. However, if an interactive LO is requested like an HTML5 video, the API allows to detect when a user plays or stops the video as well as to replicate any of these actions.

3. Finally, the HTML page will be delivered to the application or website that requested the LO. This application will integrate the LO using an HTML element called *iframe*.

B. Introducing the iframe element

Before continuing with the explanation of the model, we present in this section a brief summary of the iframe element. An iframe is an HTML element that is used to insert or integrate other HTML documents or resources inside a website. For instance, a YouTube video can be embedded in a website using an iframe. The iframe element was standardized by the W3C (World Wide Web Consortium) and is supported in all modern browsers. Other kind of HTML elements can be used to embed web content in a website (e.g. embed or object), but the iframe is the only one that allows bidirectional communication between the website and the embedded object in a standardized way. Following with the previous example, using the YouTube API it is possible to detect when the user clicks on the play button or to play the video automatically without the user intervention.

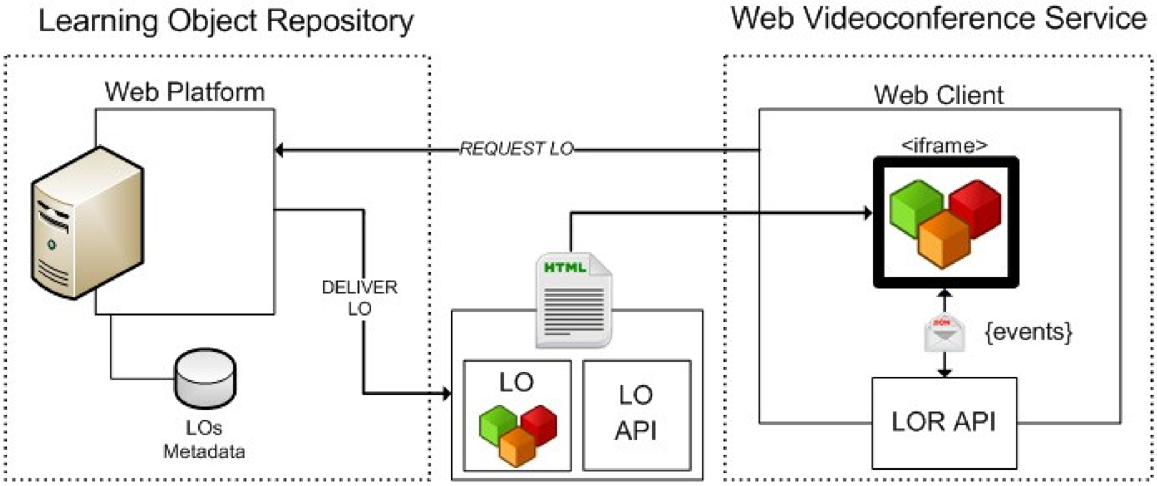

Fig. 1. LOR model to achieve interoperability with web videoconference services

C. Delivering particular LOs

In section 3A we saw that using a common API it is possible to automatically detect and replicate the events of standardized web elements such as an HTML5 video. However, this approach is not valid for particular LOs since they have their own specific actions. For example, the actions that users can perform in a slideshow (e.g. advance slides) are quite different that the actions they can do in an educational game (e.g. jump or shoot). Then, each kind of particular LO needs to provide its own LO API. As an example, Slideshare (http://www.slideshare.net) provides an API to interact with its presentations that specifies six actions: *jumpTo*, *next*, *previous*, *first*, *last* and *getCurrentSlide*.

Taken into account that these resources are usually created through authoring tools, the model specifies a convention that can be followed by these tools in order to create LOs that can be automatically integrated into WVSs. This way, teachers can create their own LOs (or adapt their existing ones) and share and co-browse them in a videoconference session.

Our solution requires the authoring tool to define each action that can be performed in the LO together with its corresponding triggered event. It needs to be able to replicate the different actions and detect their corresponding events. Therefore, in this case authoring tools will be in charge of providing the LO API. Furthermore, it is advisable that they include the possible events in the LO metadata or at least use the "Interactivity Level" parameter specified by LOM which describes the degree of interactivity of the LO.

For example, if a slideshow authoring tool wants to integrate their presentations into WVSs following this model, it may provide a LO API considering one action *jumpTo* to go to a specific slide, and its corresponding event *onSlideEnter* triggered when the user enters in a new slide. This way, if a user goes to slide 5, the *onSlideEnter* event will be triggered with the parameter 5. On the other hand, if the *jumpTo* method is invoked with the parameter 5 the slideshow will advance to slide 5. The key idea relies on the fact that in both cases, the final state of the slideshow is the same.

D. Delivering Learning Object events

In the previous sections we have explained how to detect the user actions for standard web resources and particular LOs as well as how to replicate these actions based on the events triggered. In this section, we are going to explain how these actions are delivered in a WVS environment. First off, the WVS should include the API of the LOR (hereafter LOR API) the same way as it includes third party APIs from external services like YouTube or Slideshare to integrate their resources (i.e. videos and slideshows). Fig. 1 also illustrates this fact. This API includes two functions: *onMessage* to receive the messages from the LO API and *sendMessage* to send them. These methods enable communication between the LOR API and the iframe in which the LO is inserted. This way, a bidirectional communication channel is built between the LO and the web videoconference client (hereafter just client) through the LOR API.

Fig. 2 represents through an example the different actions that are carried out to deliver the LO events. In this example, Alice and Bob are participating in a videoconference session talking and co-browsing a slideshow presentation. They are commenting the sixth slide. In a certain moment, Alice clicks on a button to go to the seventh slide.

1. The Alice's slideshow (i.e. the slideshow that Alice is seeing) advances to slide 7. As a consequence an event is triggered and handled by the LO API. Then, it composes a message including all relevant information about the event, in other words, all the information needed to replicate the event. Finally, the LO API notifies the LOR API.

2. The LOR API receives the message and delivers it to the client, which will send it to the Messaging Server of the WVS.

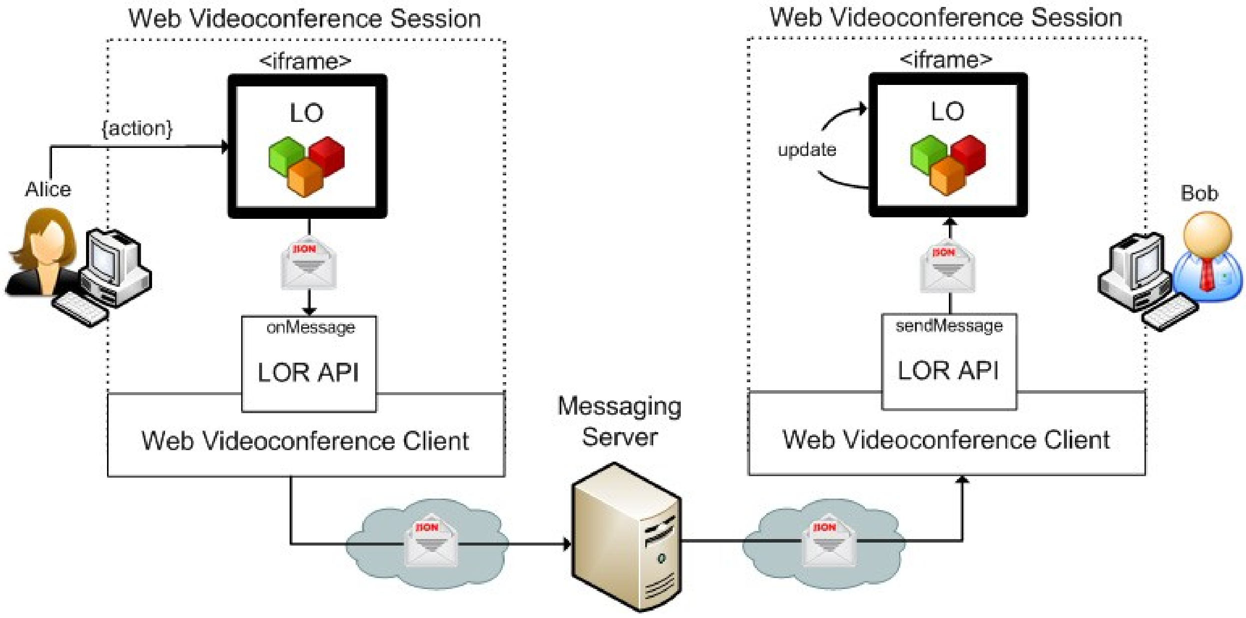

Fig. 2. Delivering Learning Object events

3. The Messaging Server do not have to read or understand the message generated by the LO, it just have to broadcast the message to the rest of the participants (in this case just Bob) through the network using its usual data channel.

4. After the broadcasting, Bob's client receives the message and sends it to the LO API.

5. When Bob's LO receives the message, it composes the original event and replicates the action. Therefore, Bob's slideshow also advances to slide 7. Hence, the final state of Alice's and Bob's slideshows is the same.

This is an example of co-viewing, but considering that Bob can also perform actions in the slideshow in the same way Alice does, co-browsing is also provided.

E. Achieving synchronized co-browsing

Previous section shows an example of co-browsing, but it is not synchronous. Considering again the initial situation of the previous example where the slideshow is in the sixth slide. If Alice clicks on the next button and at the same time Bob clicks on the previous button, Alice notifies that she advances to slide 7 while Bob notifies the he advances to slide 5. As a consequence, the final state will be different: Alice will be in the slide 5 since she receives Bob's notification, while Bob will be in the slide 7 due to Alice's notification. This problem is called "state synchronization" and is one of the biggest concerns in the development of distributed real time applications that requires synchronization (such as online multiplayer games). In the field of games, it has been defined as "the problem of maintaining the same game state information on each of the players' instance of the game and generating the actions of each player belonging to the same game instance" [9]. This definition is perfectly valid in our context, replacing game for LO and players for participants. After all, a LO can be an educational game.

Due to this problem, achieving synchronized co-browsing requires to use some distributed synchronization mechanism to order the events produced by the different LO instances. Several synchronization mechanisms and algorithms can be used to deal with this problem such as the logical clocks mechanism, which can be provided by different algorithms like the Lamport timestamps [10] or the vector clock [11]. Any synchronization mechanism that guarantees the ordering of the events is valid to apply the proposed model. However, some mechanisms do not operate completely in the client and need to implement logic in the Messaging Server, and therefore they may be unviable in common scenarios where access to the Messaging Server is not possible.

Another concern that should be taken into account is latency (i.e. time delay experienced), since it is the most critical network aspect related to the user experience of online distributed real time applications (e.g. multiplayer games) [12]. Fortunately, several latency avoidance mechanisms exist to alleviate the latency problem such as dead reckoning [12] and lockstep synchronization [13] that can be useful in this context.

Finally, to illustrate all these concepts, we give below a straightforward example of a solution to achieve synchronized co-browsing. In this solution a new operation mode is provided by the LO API. In this mode each time a user tries to perform an action, instead of allowing him/her to do the action and then notify it to the rest of the participants, the action will be prevented but the notification will be sent. Then, the WVS has to broadcast the event not only to the rest of the participants, but also to the user who originates the broadcasted event. This way, all participants will receive the event approximately at the same time depending on their latencies.

After that, a simple implementation of a lockstep event-locking mechanism is used to achieve synchronized co-browsing. In this mechanism the server distributes the events periodically. During each period or time slot, the clients can send their events to the server to be broadcasted, but the messages that arrive too late will be considered lost. Hence the state is updated every period. Consequently, the server just has to deal with the "event collisions": when two incompatible events are received in the same time slot. In this example we use a straightforward approach that consists of allowing just one event per time slot and in case of collision choosing one randomly and discard the rest.

This implementation has some limitations. For example, new participants (i.e. those that enter in the videoconference session when several actions have been performed over the LO) will not be able to compose the full LO state. So, a last improvement can also be made. The server can store all actions performed over the LO, and deliver them to the new participants that join later.

Finally, back again to the example where Alice and Bob click a button at the same time but considering now the solution described above, the process will occur in the following way:

1. After the clicks, Alice's and Bob's slideshows remain static but one notification per event is sent.
2. The two messages are delivered to their corresponding clients and sent to the Messaging Server.
3. As the two messages will arrive in the same time slot, the Messaging Server choose one randomly, for example, the Alice's message, and broadcast it to all participants (Alice and Bob).
4. When the message arrives, each client sends it to its corresponding LO.
5. The Alice's action is performed in both slideshows. As a consequence, the final state of Alice´s and Bob's slideshows is the same again.

F. The Iframe Gateway Method

In previous sections we have seen how to integrate LOs into WVSs. However, in those examples, a little effort from the WVS was always required to achieve interoperability. It needs to include the LOR API and provides message broadcasting. In some occasions, a WVS may be interested in performing other actions like encrypting messages, but these actions are not mandatory.

In some cases a WVS (e.g. Google Hangouts) may have its own API to provide third party web applications with functionalities like messaging (allowing communication between application instances) or access to users' information. This model takes advantage of this fact to make possible to achieve interoperability with a WVS without requiring its cooperation when it provides its own API (WVS API). This way it is not necessary for the WVS to include the LOR API and the integration process can be completely done by the LOR.

To add this improvement, an extra step is introduced in the Request/Deliver LO function described in Section 3A. Instead of directly delivering the web page with the embedded LO, the LOR inserts it in an iframe and delivers a new HTML page that includes this iframe and that will act as a gateway between the WVS and the LO. We call this method the "Iframe Gateway". Its operation is represented in Fig. 3. The LO still communicates with the LOR API. But in this occasion, the LOR API will deliver the messages to the *iframeGateway*, which will communicate with the web videoconference client through the public API of the WVS. This is a good strategy since it keeps intact both WVS and LOR APIs and can be implemented with little effort.

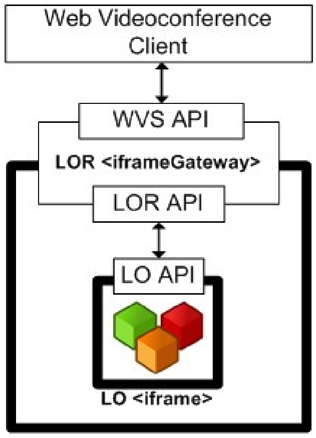

Fig. 3. Iframe Gateway Method

IV. VISH: A CASE STUDY

The GLOBAL excursion (Extended Curriculum for Science Infrastructure Online) project [14] is a European project which main aim is to enrich science teaching in European schools. Via a central web portal, called the Virtual Science Hub (ViSH), GLOBAL excursion provides scientists, teachers and their pupils a package of activities, materials and tools for enabling the integration of e-Infrastructures into school curricula. The ViSH platform includes a social network, an e-Learning authoring tool and a LOR that stores all the LOs created or uploaded by users and institutions.

The authoring tool allows ViSH users to create a novel LO called Virtual Excursion [15], [16]. Virtual Excursions are presented as rich interactive slideshows. They can contain diverse resources: multimedia files, e-Infrastructure resources (e.g. a webcam or a remote pendulum), web games and flashcards among others. Flashcards are resources presented as a background image with several "hot zones" identified by arrows where the user can touch and see additional contents that the teacher has previously tagged [17]. The e-Infrastructure resources are provided by scientific institutions and allow students to virtually visit different infrastructures such as research laboratories or natural parks. However, sometimes the guidance of an expert is required to enjoy these resources. For example, a scientist may be required to control a microscope and explain the concepts to the students.

The selected solution in the GLOBAL excursion project to connect scientist and classrooms in real time was to share the Virtual Excursions in a WVS. This was achieved by applying the presented model both to the ViSH LOR as well as to the authoring tool used to create the Virtual Excursions.

A. MashMeTV

In this web platform people can share many resources such as pictures, Slideshare or PDF presentations, blackboards, maps and YouTube videos. All elements are synchronized with the room (i.e. conference session) ensuring that all participants see the same at the same time. For this reason, MashMeTV was selected as the most appropriate WVS to co-browse synchronously the ViSH LOR resources. A new button was added in all excursions of the ViSH platform in order to init a MashMeTV videoconference session sharing the desired resource. This way, all participants can explore synchronously the Virtual Excursions and at the same time communicate in real time among them. As an example, Fig. 4 shows a flashcard shared in a MashMeTV session.

The first step to achieve integration was applying the model to the existing e-Learning authoring tool. As a result, the authoring tool provides a LO API which is capable of detecting all actions performed over a Virtual Excursion and replicating these actions based on their corresponding events. Since MashMeTV provides its own API, the integration with the ViSH LOR was performed successfully using the Iframe Gateway method. In this case the ViSH LOR acted as *iframeGateway* to connect the LO API with the official API of MashMeTV.

Since this integration, MashMeTV has been used regularly to hold meetings with scientists, students and teachers, sharing and co-browsing a lot of Virtual Excursions. Moreover, teachers of the ViSH Platform were fascinated with the possibility of creating their own learning resources and sharing them easily through a videoconference service. They were delighted because this feature allows them to guide their pupils in the exploration of different Virtual Excursions while they have real time expert guidance.

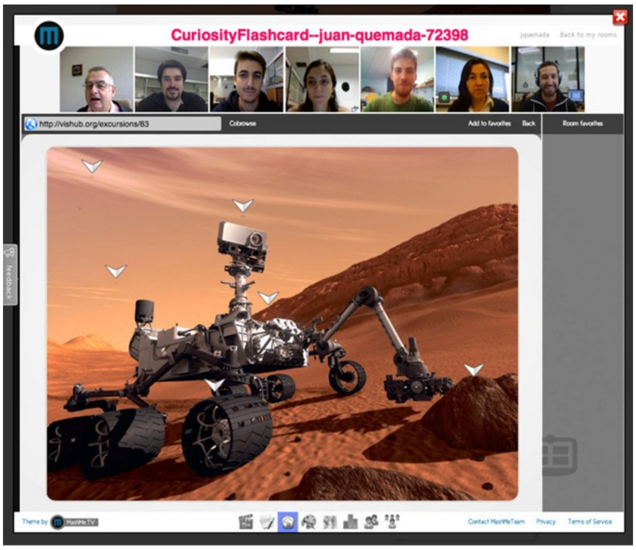

Fig. 4. Flashcard shared through MashMeTV

V. Conclusions and Future Work

We have presented a model to integrate LOs into WVSs. Achieving interoperability with WVSs can lead to several benefits such as co-viewing and synchronized co-browsing of the LOs. However, some efforts need to be undertaken to make this integration possible: LORs should provide LOs in web-ready format, e-Learning authoring tools should provide a suitable API for their LOs, and WVSs should provide an own API or include the LOR API and take charge of messaging. In case of using the WVS API, the LOR should act as a gateway between the LO and WVS APIs. Synchronized co-browsing also requires implementing some synchronization mechanism. Finally, the experience of applying the model in a real e-Learning scenario achieving interoperability with a WVS has been also presented.

New learning opportunities to increase students' readiness and engagement arise when integrating LOs into videoconference systems as a consequence of the combination of real time communication and synchronized co-browsing. A good example of this is the GLOBAL excursion project, in which the integration of e-Infrastructures resources (e.g. a microscope) with a videoconference service is used to connect scientists and classrooms.

Creating interoperable LOs that can be shared and co-browsed in videoconference services may be very easy for educators if e-Learning authoring tools follow a specific model and automate the process.

The immediate next step of this work consists of validate the model in more WVSs such as Google Hangouts.

In addition, this research opens new lines of investigation as a result of the integration of LOs into videoconference systems. We plan to use this model in the development of educational online multiplayer games that take advantage of videoconference features, where players can communicate and play in real time collaborating or competing among them.

Finally, based on the lessons learned from developing the Iframe Gateway method, we plan to adapt this model to build a LO Gateway with the main aim of achieving the interoperability of standardized e-Learning resources (e.g. SCORM packages) with web videoconference services.

VI. Acknowledgment

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The Use of Text Mining to Build a Pedagogical Agent Capable of Mediating Synchronous Online Discussions in the Context of Foreign Language Learning

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***Abstract*—The present paper discusses the use of text mining to support the design of a pedagogical agent that mediates synchronous online discussions of academic texts by undergraduate students of English as a foreign language. The pedagogical agent proposed here has the instructional role of a tutor collaborator that participates in the chat discussion following mediation strategies grounded on sociocultural theory to assist the collective writing. Furthermore, we propose a pedagogical agent model that uses text mining techniques to identify when students deviate from the main topics that should be addressed in their discussions in a real time chat. Another important function enabled by the use of the text mining tool involves the assessment of the discussion relevance in relation to the base text, which supports the pedagogical agent decision towards a more adequate intervention. The conception of using text mining to guide the pedagogical agent in the mediation of the students' discussions has been based on previous research that has already shown how this particular mining tool could support educators' work in the evaluation of essays and of students' contributions in discussion forums. Preliminary results of this study are also presented showing the agent's potential to foster students' online conversations.**

Keywords—text mining tool; pedagogical agent; online learning.

I. INTRODUCTION

In recent years, text mining have become more popular in the field of Education, being used mostly to help students in learning tasks and to assist educators in monitoring students' activities and evaluating their work. This paper aims to present a pedagogical agent which makes use of a text mining tool to assist collective writing in computer-mediated reading discussion. In order to establish the pedagogical agent's mediation strategies, the points of contact between Vygotsky's sociocultural theory and research on second and foreign language acquisition have been exploited. Moreover, the relevance of using the text mining tool as a base of knowledge for the pedagogical agent to deal with reading discussions chats is thoroughly discussed.

II. THEORETHICAL FRAMEWORK

A. Pedagogical Agent and Language Education

Intelligent tutoring systems (ITS) have been defined as computer systems whose goal is to provide customized instruction or feedback to learners [1], usually without intervention from a human teacher. ITS differ from traditional content-delivery computerized learning systems by adding intelligence to improve the effectiveness of a learner's experience [2]. They use a variety of computational resources to properly interact with the learner. Intelligent tutoring systems are often adaptive mechanisms which are capable of personalizing learning according to individual student characteristics, such as knowledge of the subject, mood and emotion [3] and learning style [4]. Such systems can use virtual characters as a way to interact with users. In this study, a virtual character has been designed in the form of a pedagogical agent whose goal is to mediate reading chat discussions between undergraduate students of English as a foreign language.

The use of Pedagogical Agents (PAs) in Educational applications has demonstrated that, by simulating social interaction, these animated characters may improve student's engagement and learning experience [5].

Pedagogical agents are human-like virtual characters used in interactive learning systems that can operate continuously and autonomously, searching and interpreting information to support learners' activities through a more natural interaction. Based on students' behavior and writings, the PAs are capable of adapting their actions and interventions, providing feedback

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and guiding problem solving, reflection, understanding and collaborative learning [6] [7] [8].

PAs are designed by the arrangement of image, sound and gesture to consistently represent by their behavior a human-like entity generating the feeling in the students that they have their own identity and life, what was called by Lester et al. [9] "the persona effect". This life-like behavior is considered to be an important motivational factor for students in interactive learning environments resulting in a positive effect on their perception (through affective dimensions such as clarity, credibility and encouragement) over the PAs' importance and their learning. The "persona effect" can, therefore, motivate students to engage in activities as they feel they may get help whenever they need[9]. Thus, the use of PAs intends to make learning a fun experience, keeping the student's engaged in a more extended interaction with the environment and minimizing the feeling of isolation in the context of distance education [9];[10]; [11]. Besides, the use of natural language mechanisms (e.g. AIML-Artificial Intelligence Markup Language) enables PAs to establish social bonds with the students, facilitating learning through a more compelling interaction with the learning environment and contents [12].

According to Gulz [13], the PAs' benefits for learning involve: the increase of motivation; perception of ease and comfort in the learning environment; the promotion of fundamental behaviors of learning; the ease of information and communication processes; the realization of a need for personal relationships in learning; and gains in terms of memory, understanding and problem solving.

Moreover, PAs can present contents to the students; they may guide task and problem solving through helpful statements and task resolution models. They can also highlight important issues, and recommend new exercises and reference materials according to students' progress [14].

Furthermore, according to Kim et al. [10], PAs can be designed to act based on human instructional roles, following pedagogical mediation metaphors, such as the expert, the motivator, the mentor [15], the pair [10], and the tutor [16].

Baylor and Kim [14] present the development and validation of three PAs' based on three instructional roles, i.e. the expert, the motivator and the mentor, functioning in an agent-based research environment (MIMIC - Multiple Intelligent Mentors Instructing Collaboratively). These roles were operationalized through image, animation, affect, voice, and dialogue composition. The design of the expert agent was based on studies that indicated that experts have a better performance and show emotional stability. Thus, the expert agent was designed as a middle-aged person with a more formal speech, having the role of providing information succinctly and accurately to students. The motivator agent was based on the idea that the support from a social model with a similar level of knowledge can promote both learning as motivation. In addition, verbal encouragement to students' performance facilitates their perception of self-efficacy in the task. Based on this, the motivator was personified as a younger person with an informal speech. It did not participate as an authority on the subject, but as an enthusiastic partner that suggested its own ideas, encouraging the student to continue in the tasks, and asking questions to promote reflection. Moreover, this agent would express the typical emotions of the learning process, such as frustration, confusion and pleasure, seeking empathy and connection with the students. The third agent role investigated by Baylor and Kim [15] was the mentor, designed to incorporate the features of both the motivator and the expert by acting as a collaborative guide that provided accurate information, but who would also show different emotions. The mentor agent was less formal than the expert agent and offered ideas and emotions with a more professional and confident tone in relation to the motivator. According to this categorization, the agent developed in this work has the role of a mentor, as detailed in the next section.

A similar metaphor for PAs design has been called the Learning Companion, in which the PA plays the role of a learning partner that simulates peer interaction in computer-based learning. The construction learning companions is based on the principle that interacting with a pair of similar degree of competence may increase the students' belief on their self-efficacy [10]. Based on the definition of Learning Companions, one might think that this type of agent resembles the role of the motivator agent, as defined by Baylor and Kim [15]. However, the performance of the Learning Companion agent also has features related to the role of expert, as it provides accurate information to support the completion of a given task.

In addition to these agent models, Graesser et al. [16] proposed a pedagogical agent to understand the contributions of students and simulate discursive patterns and pedagogical strategies typical of a human tutor, called AutoTutor. It was used to serve undergraduate students in introductory courses to computer use, by supporting students in knowledge building through a dialogic tutorial. The AutoTutor had several different features, such as the ability to question the student as to cover all the topics on the subject under study, to guide the student's thinking in solving the task and keeping his/her focus on the main issue. The agent could also motivate the student to continue the activity by offering positive feedback and making a summary at the end of the task.

It is worth mentioning here that the mediation metaphors that are the basis for the development of the expert, the motivator, the mentor and the tutor agents stem from a computer-based teaching and learning conception in which the focus is on the individual's production and on the interaction with the system. Furthermore, these PAs do not work with collaborative production in synchronous communication tools, using collective interaction data to make their interventions. Besides, these studies do not have a clear theoretical background from a teaching and learning perspective.

Conventional Learning Systems, as Kim et al. [10] claim, tend to support individualized learning of contents, leaving aside social interactions as a means for learning and for motivation. However, social interaction, according to the sociocultural perspective, is essential for the promotion of learning and development [17], [18], [19]. According to Heidig and Clarebout [20], more research is needed to identify conditions under which pedagogical agents can contribute to student learning. The authors highlight the fact that the exploration of appropriate roles for pedagogical agents as well as relevant characteristics of learners has been largely neglected in current research.

Within this scenario, the present study proposes a pedagogical agent that is capable of mediating students' discussions in a chat room, using the sociocultural theory as a basis for the interventions the agent makes in order to promote second and foreign language learning.

The pedagogical agent proposed here bears some similarities with the mentor agent described in Baylor and Kim [15], for it uses its expertise to give accurate information and encourage students, and tutor agent [16], by seeking not only to engage students to the topic of discussion, but to promote students' reflection for the improvement of their reading. Another important aspect to emphasize is the agent's proactive and reactive behavior towards students' actions, posing questions, giving positive feedback and answering to students' doubts regarding foreign language vocabulary.

B. The pedagogical agent according to sociocultural theory of learning

Sociocultural theory considers learning to be a regulatory process that is mediated by social interaction among individuals, cultural artifacts (computer, pedagogical agent) and speech [21]. Through interaction, knowledge constructed and shared (interpsychological activity), it is internalized by the individual (intrapsychological activity), and reused in future experiences [17], [18], [19], [22]. Thus, we understand a pedagogical agent as a tool capable of mediating learning, as it participates with students in a reading chat discussion, addressing their needs with an individualized intervention, fostering a higher regulation over language use and content information.

In [17] and [19], Vygotsky conceives a potential area for learning, called the Zone of Proximal Development (ZPD), which is measured by the distance between what the novice can accomplish alone (the current level of development), and what he can do under an expert supervision or in collaboration with more capable peers (the level of potential development). So learning is a process that must be analyzed through what the student can do while struggling to solve problems like linguistic and knowledge gaps to better communicate meaning.

Following the theoretical construct of the ZPD, the interaction with a pedagogical agent can promote language learning and the development of different skills [10]. For that reason, the present study proposes a PA that employs its language and content expertise to mediate students' discussion and whose mediation strategies are directed towards learners' current and potential actions as they struggle to negotiate, collaborate and to improve their foreign language production [23].

Furthermore, the assistance given by the pedagogical agent with the objective of helping students do the task of discussing properly a specific text can be related to the term scaffolding created by Wood, Bruner and Ross [24]. According to these authors, scaffolding happens when a teacher chooses the right intervention to help the student to actively develop his regulation over the task itself, promoting autonomy. During this mediation process, the continuous feedback on students' actions may motivate them to reflect upon language gaps to be solved. In relation to feedback according to the sociocultural theory, errors are seen as part of the natural process of learning and peers and experts can provide support as well as a counterpoint in the production of meaning. In this context, evaluative feedback is a social and interactive negotiation of meaning and form in which the teacher or a pedagogical agent, in the case of this study, responds to students' writings, transforming or asking the students to reformulate their sentences [25]. It is a pedagogical movement that promotes greater awareness and reflection of the students on their language and learning, motivating them to be more accurate in their writing, to write more and keep focus on the subject.

In this scenario, studies show that the collaborative nature of the interaction and the extensive use of language are essential conditions for the promotion of learning [26], [27], [28]. Within this perspective, group assignments are spaces that enable the co-construction of knowledge by sharing production goals, negotiation of meaning and form, mutual support and feedback. The design of the PA for this study aims to create a fertile environment for collaborative learning, in which its intervention simulates mediation movements observed in teacher-student and student-student interactions during collaborative tasks.

III. THE PEDAGOGICAL AGENT'S DESIGN

The sociocultural perspective towards foreign language learning and teaching reflect upon the design of the pedagogical agent's mediation strategies based on the use of a text mining tool in order to assess students' construction of meaning in a more accurate manner. The pedagogical agent developed for this research was called Pascall (Pedagogical Agent to Support Collaborative Language Learning) and is considered to be a proactive and reactive tutor collaborator [16] that seeks to mediate a discussion chat in a virtual learning environment. In the case of this particular implementation of the pedagogical agent, we have chosen the virtual learning environment Moodle, as it is the main virtual learning environment used in the university where this research has been carried out.

As an autonomous program, the pedagogical agent runs continuously, accessing Moodle's database to examine the registered chat dialogues and to trigger textual interventions inside the chat room. After an *n* number of initial messages exchange between the students, the pedagogical agent begins to store the conversation, in which the time of each message is recorded. Thus, these pieces of information can be used to investigate not only the chat content, but also the learner's participation.

Pascall's architecture consists of three knowledge bases according to Figure 1.

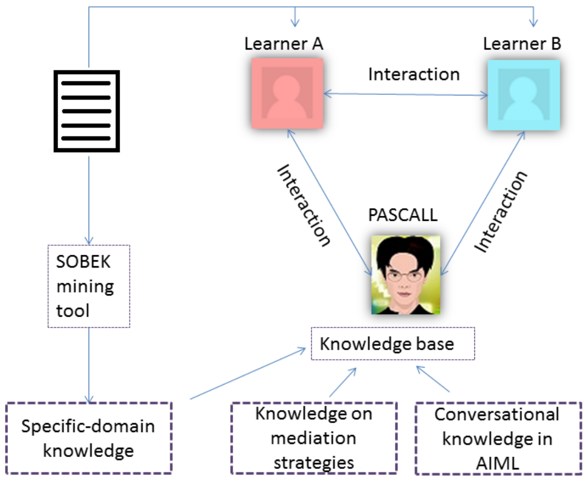

Figure1: The pedagogical agent model.

The first one is the knowledge on mediation strategies, with interventions directed towards identified language use programmed according to pedagogical goals and pedagogical constructs. Added to this, the second knowledge base consists of specific domain content elicited from texts by the mining tool called Sobek. This is one of the main information used by the pedagogical agent's language assessment and the corresponding mediation strategy.

The third knowledge base has been structured with AIML (Artificial Intelligence Markup Language) to store conversational knowledge in order to produce a more natural interaction with students. It assists the agent to recognize patterns in the user's interaction and provide an appropriated response. It is worth mentioning that, by using such mechanism, the pedagogical agent created here can be adapted for any course since it is possible to increment its AIML knowledge base with information about any theme.

Regarding the pedagogical agent's mediation strategies, it has been designed to support students' discussions through collaborative and negotiation movements, corrective and evaluative feedback, along with verbal encouragement. Relevant for this study, however, are the interventions the PA is programmed to do by assessing (1) the relevance of what is being said by the students, (2) theme deviation and (3) unexplored concepts, keeping them focused on the task of building a more complete and coherent reading.

Before the agents' mediation strategies are further discussed, the text mining tool Sobek and its main functions are presented in the next section.

A. The text mining tool Sobek

Text mining has been defined as a technique that has as a main goal to retrieve qualitative information from texts, which are considered to be non-structured sources of information [29]. The process of text mining consists in creating a model from the data retrieved, analyzing patterns and returning relevant information to the user. The use of text mining has grown exponentially in recent years due to the increasing amount of information found particularly in the Internet. A common use for text mining is to tag books, magazines, web searches, home pages or any other source of textual information. Through text mining it is possible to identify the key concepts of a text and relate them to one another.

In this work, we have used the text mining tool called Sobek [30], developed initially to be used by teachers in a distant learning courses as a way to summarize students' writings. The operation of Sobek is divided into three stages. The first stage is the identification of relevant concepts of a text; the second stage is the identification of relationships among concepts; the third stage is the graphical presentation of the results of the mining process in the form of a graph depicting the main concepts of the text and their relationships. Next we describe each stage and its main features.

The first stage of Sobek consists in separating the text into words. In this process, spaces and punctuation are considered as divisors. The separated words are then mapped into concepts that may consist of a single word (called a "simple concept") or many words or sentences (called "compound concept"). The mapping is a statistical process, which takes into consideration the frequency with which each word is found in the text. When a set of words frequently appear in sequence, the idea related to this set of words may not be described by a single word, hence a compound concept is formed (e.g. "Global Warming"). While Sobek is doing the process of identification of concepts, a set of words called "stop words" is used to remove those that do not add relevant information (e. g. articles; prepositions; pronouns). After identifying all different concepts, a method of stemming is activated to reduce possible redundancies such as concepts with the same meaning.

The second stage is the identification of relationships among concepts. A textual analysis is done comparing, for example, two concepts when they are distant not more than 'z' words of each other and when there is no end punctuation between them. Trying to reduce the number of connections among concepts to display only those that appear more constantly, Sobek establishes a maximum of 'r' links that could be allowed for each concept. This value is proportional to the frequency of that concept.

The third stage is the construction of a graph as a result of the extracted concepts from the text. In the graph built by Sobek, the concepts are presented as nodes, and these nodes display the relationships among them as links. To provide a more meaningful visualization of the graph, Sobek presents each node with a different size and color, differentiating them by bigger size and darker colors according to their frequency. This frequency will also implicitly increase the number of connections that a concept may have, thus, making the most frequent concepts even more important. The tool also has other functions to enable the editing of the graphs, such as functions for adding, removing and editing nodes.

B. Integrating SOBEK into the pedagogical agent model

The design of the pedagogical agent aims to create an environment for collaborative learning, in which the PA's intervention simulates mediation movements [31].

Before the chat session starts, learners must be presented with a text in order to establish the subject that will be discussed. This text is also used by the pedagogical agent to extract from it the main concepts and relationships, using Sobek in the background. This information serves as a comparison basis to evaluate whether the learners are discussing the given theme or not. During the chat session, the pedagogical agent collects the messages exchanged between the users. Those messages are mined using Sobek and the resultant concepts and relationships are compared with the ones extracted from the main text. When students log on Moodle's chat, the pedagogical agent is triggered, showing up visually just as another participant in the chat.

As mentioned in Section II-A, the pedagogical agent receives a text as an input, the same text students use to study before the chat session. This text has its concepts and the relationship between them extracted by the use of Sobek. In possession of this data, the PA constantly extract the concepts from the students chat and compares them to the concepts extracted from the original text. This comparison is made using the equation established by Azevedo et al. [32]. It compares the relative frequency of each concept and its relationships.

This comparison may have one of three possible outcomes:

1. The students did not mentioned any of the concepts found in the original text;
2. The students are mixing messages about the text with messages that deviate from it;
3. The students are discussing the text and a high number of concepts are similar.

For each situation, a series of predetermined messages are used to indicate the student about their progress and either motivates them to continue the good work or suggest them some topics they can talk about. In the first two scenarios, the PA indicates to the students that they are not properly discussing the text and indicates the most important concepts the students did not talk about. If all concepts were discussed by the students, than it simply indicates that they are deviating from the topic. In the last scenario, a positive reinforcement is given, as to incentive the students to continue the good work. These interventions intend to keep students focused on the task of developing a more complete and coherent discussion.

Interactions between the pedagogical agent and students are not limited to interpreting the chat content or standard messages. Students may request help from the PA at any moment. The PA is capable of providing help by translating words or sentences in English and Portuguese. Students may request this help by typing specific commands on the chat. The PA interprets those commands and uses internet resources to translate the required sentence.

Similar to this, students may also request the PA to give them synonyms or definitions about a concept. Using specific messages for each case, the PA acts according to the students request and provides them with the necessary help.

It is important to highlight that these mediation strategies follow a sociocultural perspective, as the PA role consists of raising students' awareness of their language production, and promotes the development of higher regulation over the task of discussing thoroughly a text. Besides, the PA as a tutor collaborator is proactive and reactive to students' actions, fostering an autonomous attitude towards their own learning process.

IV. THE STUDY

In our experiments we have used the open-source virtual learning environment Moodle. Among the many features available in the virtual learning environment, it has forums, quizzes, surveys, multimedia resources and chat rooms. All course materials can be created using Moodle, which makes it simple for teachers to use it and develop their own contents.

Moodle's data is stored in a relational database, which contains, among other information, all chat sessions. Therefore, it is possible to use these databases to retrieve the conversations from any chat room or user.

The Pedagogical agent described in this paper is capable of retrieving such information directly from Moodle's database. It collects, organizes and analyzes the messages exchanged by the users in order to identify specific contents or the main topics of the conversation. Whenever an intervention is required, the agent sends a command to Moodle's server specifying the type of intervention, message and intended chat room. Through this process the agent continually collects the messages from the database and sends intervention commands whenever necessary.

A. The experiment

The present study was conducted with undergraduate students of English language and literature in a university in southern Brazil. In an English class of 27 pre-intermediate students, a sequence of meetings was done in a computer lab where the main tasks involved the participants in discussing texts in Moodle's chat. The texts' theme was language teaching and technology and the discussions were based on comprehension questions. Immediately after each task, the students were asked to report their perceptions regarding the task, the performance of the pedagogical agent and their learning. The writings produced by each student and reports were, then, analyzed to investigate the effects of the pedagogical agent's mediation strategies on language learning.

The participants were divided into groups of three and entered in their own chat room. When students logged on Moodle's chat, the pedagogical agent was triggered, showing up visually just as another participant in the chat, but presenting itself as a tutor collaborator with a pedagogical intention to assist their discussion on the proposed text, as shown in Figure 2. The pedagogical agent worked mediating the collaborative writing task according to the students' actions.

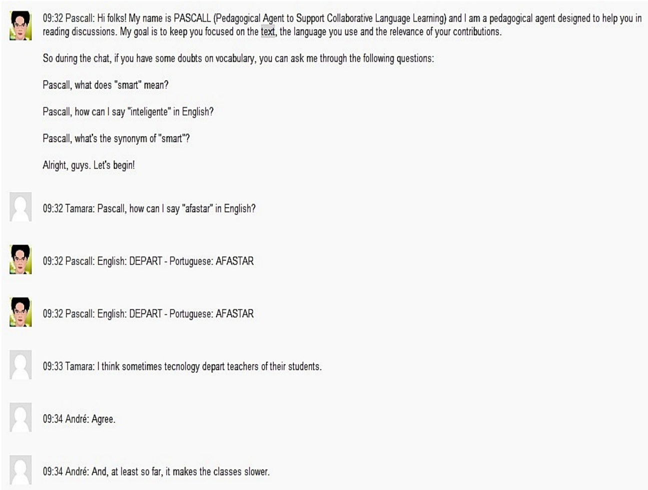

Figure 2: The PA introducing itself.

In order to promote a better use of the foreign language being studied, the PA made comments on the students' discussion in terms of its relevance, as previously stated. We can see in Figure 3 that the PA gave a positive feedback to the students' discussion.

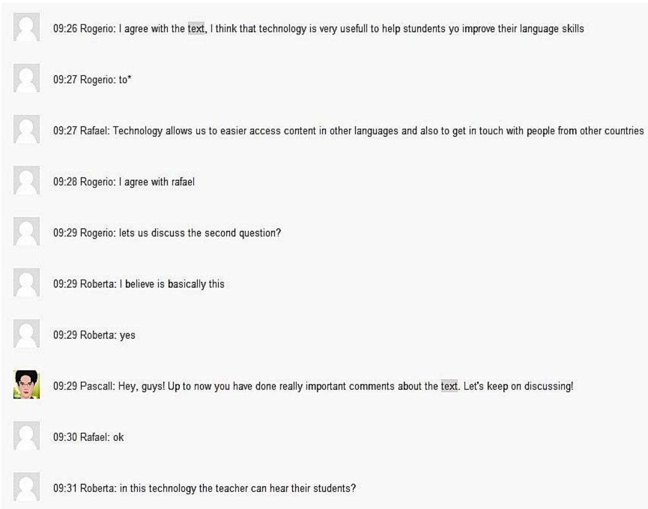

Figure 3: The PA's intervention on discussion relevance.

This intervention was created to address students that presented a highly relevant discussion compared with the text given to the students. The observation of the PA leads to the conclusion that that the intervention was appropriate, since students were bringing relevant contributions to the reading discussion. Besides, the students responded to the PA's request, showing that it was seen by the students in a positive way.

Besides assessing the relevance of students' contributions signaling the importance of meaning making, the pedagogical agent assisted learners in remembering important concepts that were unexplored, as Figure 4 indicates.

Figure 4: The PA's intervention on theme deviation.

It can be seen that the PA tried to bring the focus of the discussion back to the text through the indication of a topic that could be explored. It can be observed that the PA tried to bring the focus of the discussion back to the text through the indication of a topic that could be further exploited.

These are just a few examples of the interventions made by the PA in these initial experiments with a group of students of Languages.

After the task, students' individual reports suggest that they realized the interventions Pascall made during the chat, such as calling their attention to the relevance of their discussion, and suggesting a topic of text when they were talking about another subject. These interventions were considered useful for doing the task, since according to the participants, the pedagogical agent helped them remain focused on the discussion proposed, to be more active in group discussion and to explore the possibilities that a text offers to a more profitable discussion.

V. Concluding Remarks

The data suggest that the pedagogical agent Pascall, through the use of the text mining tool SOBEK, could make appropriate interventions in students' discussion by identifying both the relevance of what was being written and the theme deviation. These interventions were noticed by participants who responded positively to its mediation. Thus, this study indicates that the pedagogical agent developed can be a mediational tool in the development of reading comprehension and written expression in a foreign language. Also, this research contributes to the field of Computers in Education by applying theories of learning to the design of computational tools for educational purposes, bringing relevant contributions to computer-mediated communication. Finally, the study innovates by demonstrating the pedagogical application of a text mining tool regarding the construction of a pedagogical agent's mediational actions to help students bring relevant contributions to a reading discussion

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Towards an Understanding of ECE Students' Use of Online Homework Help Forums

Abstract— **Online discussion forums have emerged as a popular Web application to build and support online communities for numerous engineering interest areas and practice. However, a review of engineering education literature reveals scant research on the use of online discussion forums for engineering learning beyond the classroom. This study addresses this gap in knowledge through a study of the "Homework Help" section on AllAboutCircuits.com to examine what students sought help for and for what purpose. We downloaded over 6,000 discussion messages spanning over 8 years and extracted the textual data with a Python program. Instead of analyzing the data through manual means, we utilized the Natural Language Toolkit (NLTK) to capture textual patterns and leverage a topic modeling approach, Latent Dirichlet Allocation, to identify connected clusters of words. Linguistic Inquiry and Word Count (LIWC) analysis was also used to determine how often students use words associated with cognitive processes. We found that the homework help section of informal online discussion forums cater to students seeking help on fundamental ECE topics. Our findings also suggest that online discussion forums are supportive learning environments, as students freely engage in meaningful inquiries and social interactions with other learners.**

Keywords— online discussion forums; text mining; hybrid instruction; electrical and computer engineering

I. BACKGROUND

The current cohorts of engineering college students are referred by many as the Millennials or Generation Net [1]. Many of them have grown up with computer technology, and they are highly proficient at using computer devices and leveraging the Internet to support their learning beyond the classroom [1]. Some of these technologies include Wikipedia, MOOCs, video tutorials, E-textbooks and online discussion forums. Amongst these technologies, text-based online learning platform such as online discussion forums have emerged as an effective tool to support teaching and learning in a variety of settings including learning management systems, MOOCs and online courses. With increasing computing power and internet speeds, online discussion forums have improved leaps and bounds in terms of usability, functionality and user-friendliness. It is therefore no surprise that online discussion forums are also used to support online communities for specific engineering areas or practices beyond the classroom.

In this study, we direct our focus on online microelectronics communities which have grown tremendously over the past few years. Relying on discussion forums (or message boards) platforms, these communities have attracted hundreds of thousands of students and enthusiasts from all over the world. Table 1 describes the basic participation information of 5 popular online discussion forums associated with electrical and computer engineering. The participation figures in Table 1 suggest that the discussion forums are of significant reach to a large number of engineering students who in turn have contributed millions of message posts to these forums. This phenomenon also raises a question for both engineering education researchers and practitioners: What are students learning on these forums? As there are massive archives of participant data and learning activities, we are not able to immediately make sense of the learning activities in these forums.

TABLE I. ELECTRICAL AND COMPUTER ENGINEERING ONLINE DISCUSSION FORUMS

Site	Message Count	Membership
AllAboutCircuits.com*	570,000**	202,000
Arduino.cc	1,176,000	128,000
EdaBoard.com	1,174,000	483,000
Electro-Tech-Online.com	796,000	191,000
ElectronicsPoint.com	83,000	23,000

**Site of Study*
***Descriptive data rounded off to nearest thousand and compiled in April 2013.*

II. RESEARCH QUESTIONS

While the online communities themselves are tied to a broad content area, they cater to a wide variety of discussion topics through the setup of distinct discussion sections or sub-forum. One specific section that will be of much interest to engineering educators is the homework help discussion section. Within this discussion section, engineering students seek help on homework problems directly tied to ECE curriculum coursework.

A review of education research literature reveals that there is limited research on online homework help discussion forums associated with engineering learning. Thus, the purpose of this research is to fill this gap in knowledge by exploring what online ECE students sought help for and for what purposes. The research setting for this study is a homework help section of AllAboutCircuits.com, which is a prominent online community associated with a diverse range of engineering topics from the ECE domain. We examine the students' written contributions in search for consistent patterns of conversational behaviors, major themes of discussion and students' use of words associated with cognitive processes. Our research questions are:

1) Which words are frequently used by students who seek homework help?
2) What are the major themes of discussion?
3) How often do students use words associated with cognitive processes?

To answer the research questions, we leverage three text analysis approaches: keyword analysis, topic modeling and Linguistic Inquiry and Word Count (LIWC) analysis. In the following sections, we will highlight both the merits of using each of them and our findings.

III. Methods

A. Keyword Analysis

Keyword analysis is an analytical technique that looks for repeats of words within a text collection and computes the frequencies of occurrences for each word. This analysis technique allows one to examine the words that consistently appear in a text collection. As many English words with the same root will have similar meanings, there is a need to reduce words in the data to their root or stem form (for instance, both words "engineers" and "engineering" will be reduced to engineer). In this research, the well-established Snowball word stemmer was used to perform the word stemming process [2].

Amongst a variety of computational approaches used in keyword analysis, this research draws on the Natural Language Toolkit (NLTK) which is an established open source Python toolkit with very proficient libraries for text processing [3]. NLTK has been well-utilized in educational research to further the understanding of learning and interaction amongst students. Haythornthwaite and Gruzd [4] utilized NLTK to explore noun phrases in an online bulletin board for a graduate class and based on the prevalence of words such as "thanks" and "agree", they suggest that the bulletin board was a supportive avenue for learning. On the other hand, Worsley and Blikstein [5] used NLTK to explore students' speech about electronics and mechanical devices and found that speech markers (such as adverbial modifiers) that are indicative of domain-specific expertise. While these research work are exploratory in nature, they highlight the potential of NLTK in deepening our understanding of students' conversational behaviors and supporting the assessment of learning in online environments.

B. Topic Modeling

Topic modeling refers to a statistical approach aimed at identifying semantic topics within text documents [6]. Amongst several topic modeling techniques, Latent Dirichlet Allocation (LDA) is a widely used model as it is an unsupervised model which does not require the construction of additional training data sets. LDA can be described as a generative probabilistic model aimed at discovering latent topics within text documents together with the words that are associated with the latent topics [6]. In this research, we leveraged LDA to analyze the first posts in each discussion thread with the goal of identifying connected topics (made up of sets of related words) and trends within the identified topics. An open source package, GibbsLDA++ [7], has been used for this research.

Based on a limited literature review, we did not find any use of LDA in educational research. However, LDA has been well-exploited in the social sciences where researchers explore large corpuses of text data originating from speeches, newspaper articles and journal publications [8]., Based on the extensive research conducted through LDA, it appears that LDA is an appropriate approach for seeking meaning in large corpuses of text [8]. It is with this notion that we utilized LDA to explore discussion themes within the massive corpus of text originating from online discussion data in our site of study.

C. Lingusitic Inquiry and Word Count Analysis

LIWC (Linguistic Inquiry and Word Count) is a text analysis program that was developed to examine psychological processes in textual data based on 80 language categories that range from affective to cognitive processes [9]. LIWC checks each word of a text against internal dictionaries and reports the percentage of total words in each category. By counting words in psychologically relevant categories, LIWC is appropriate for detecting meaning in the content of what people write or talk about.

In education research, LIWC has been utilized to examine students' textual utterances in a diverse variety of settings. Much research is aimed at analyzing students' spoken and written language to analyze theoretical constructs tied to cognition and emotions. For instance, LIWC has been used to examine students' expressed emotions in an online discussion forum about the grades they received on term projects [10]. Mehl and Pennebaker [11] have used LIWC to examine students' use of language in their natural conversations outside of the classroom. LIWC has also been used to analyze students' writing styles and their relationship to their creativity levels obtained from a test [12] and other researchers have used LIWC to extract conversational features from message board used for engineering design projects [13]. These research studies suggest that LIWC is appropriate for examining psychological processes in students' written messages in the online discussion forums.

IV. Data Collection

The data collection draws from web scraping techniques. A total 87,264 web pages from the years 2003 to 2011 (in HTML format) from AllAboutCircuits.com were downloaded using an automated web crawler. A Python scraping program was written to extract participant information and textual contribution into a MySQL database. The focus of this research was placed on the first posts of each discussion thread in one of the fifteen sub-forums titled "Homework Help". The 6,749 first posts were sampled for data analysis and represent students' seeking of help. Table II summarizes the basic descriptive statistics for this sampled data set.

TABLE II. Participation Information of Homework Help Section

Variables	Count
Posts	6,749
Words	726,137
Average Length of Each Post	107

V. FINDINGS

A. Keyword Analysis

Based on the use of NLTK toolkit, we conducted an evaluation of the keywords and obtained a cumulative graph representing the top 50 most frequently occurring word in the Homework Help forum (see Fig. 1). It is not surprising that the word "circuit" and "voltage" and "power" were amongst the top 5 most frequently occurring words. On the other hand, words that are indicative of social moves are also found in the list. The words "thanks" and "please" occurred frequently according to the cumulative word count graph. This suggests that students are seeking help for their homework-related tasks but at the same time, they are socializing with the community members who are providing help to them.

Words that provide contextual information of students' learning task such as "problem" and "project" occurred to a lesser extent. The occurrence of these words suggests that this is a practice of this online community – students are providing contextual information so that help-givers will find it easier to provide help. Resource artifacts also feature frequently in our analysis. For instance, words such as "code" and "www" suggest that both program codes and web links to external resources frequently featured in students' questions.

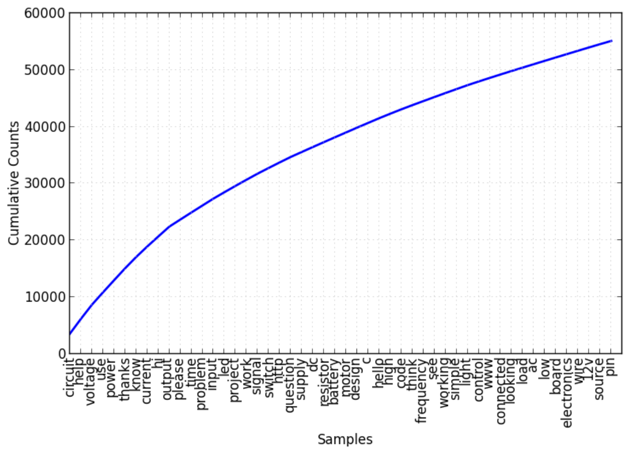

Fig. 1. Cumulative Word Count of Top 50 Frequently Occurring Words as determined by keyword analysis.

Based on the cumulative word counts, the top 20 most frequently occuring words that are closely associated with electrical and electronics engineering are also obtained (see Table III). This descriptive finding is compiled for the purpose of discussing words that occurred frequently in students' first post where they sought homework-related help. The majority of words, i.e. *circuit*, *voltage*, *power*, *current*, *output*, *input, LED*, *switch*, *DC*, *resistor*, *battery* and *electronics*, are intrduced to students in their initial circuits and electronics courses. These words are commonly associated with the contruction of simple DC circuits. Following these introductory courses, a more advanced electronic course would include AC analysis including the words *signal*, *motor*, *frequency, load* and *AC*, in addition to the words from the introductory courses. An introductory course in signals and systems would introduce *control* in conjunction with the previously used words *output*, *input*, *signal*, *frequency* and *load*. Although ECE students traditionally take introductory programming courses early in their curricula, only *C* and *code* made this list. Likewise, the words *digital* and *logic* from introductory digital design courses are not included. Additionally, words from more advanced courses, e.g. *electromagnetic*, *DSP* (digital signal processing), *FFT* (fast Fourier transform), *microwave* and *VHDL* (VHSIC hardware description language), are not contained among the most frequent words.

TABLE III. TOP 20 MOST FREQUENTLY OCCURRING WORDS ASSOCIATED WITH ELECTRICAL AND COMPUTER ENGINEERING

Rank	***Word***	***Rank***	***Word***
1	Circuit	11	Resistor
2	Voltage	12	Battery
3	Power	13	Motor
4	Current	14	C
5	Output	15	Code
6	Input	16	Frequency
7	LED	17	Control
8	Signal	18	Load
9	Switch	19	AC
10	DC	20	Electronics

B. Topic Modeling

In our research, LDA analysis return sets of connected words which allow us to make inferences from these sets of connected words to derive the topic or theme of discussion. In Table IV, we describe each topic and the words that are linked to each topic. Findings from LDA analysis (see Table IV) show that salient topics can be discovered by examining the sets of sample vocabulary.

Based on the sets of sample words, we can infer students are having discussions on various ECE topics such as microcontrollers, switches, transistors, circuits, motors, PCB design and PWM controllers. For instance, the interconnected set of words "switch, "relay", "button", "flip" and "trigger" is indicative of the topic of "electronic switches" while the connected words of "BJT", "capacitance" and "amplifiers" point to students' discussion on transistors. It appears that LDA is an appropriate approach to explore a relatively large corpus of text with the goal of understanding the overarching themes of discussions. Our findings add another dimension to our previous findings from keyword analysis by illuminating discussion topics that occurred but did not have words that appear frequently enough to feature in word count analysis. For instance, the word "motor" does not occur frequently to feature in top 50 frequently occurring words but turned up with other connected words such as “speed”, “control” and “drive” to suggest that students discussed about the broad topic of motors and servos.

TABLE IV. LDA TOPICS AND SAMPLE WORDS

LDA Topic	Sample Words
Switches	Switch, Relay, Button, Flip, Trigger
Transistors	BJT, Capacitance, Amplifiers
Engineering Project	Project, Build, Design
Circuits	DC, AC, Resistance
Motors	Motor, Speed, Control, Drive
PCB Design	Antenna, PCB, inductance
PWM Controllers	Sensor, PWM, Motion
Microcontrollers	12V, 6V, Calculations, PIC

C. Lingusitic Inquiry and Word Count Analysis

Through LIWC, we explore students’ written text by looking for pre-defined markers of cognitive mechanisms [9]. The “cognitive mechanism” linguistic category represents general cognition and provides important insights as to how students process and interpret information [9]. Within the cognitive mechanism category are the subcategories “insight”, “cause”, discrepancy”, “tentative” and “certainty” which each is represented by an predefined set of dictionary. Each subcategory of cognitive mechanism is represented by words in a predefined dictionary. For instance, the subcategory “insight” suggests that an individual may be able to grasp the solution to the problem at hand and comprises of 195 words including “realize”, “see” and “understand”.

Findings suggest that cognitive words that are indicative of insight, cause, discrepancy and tentativeness occur at a mean rate of approximately 3 (see Table V) while on the other hand words that is indicative of “certainty” occur at a substantially lower rate of less than 1 time per post. This finding reaffirms that students are indeed seeking homework help under the circumstance that they know little about a content area and are less certain about the question at hand.

TABLE V. LIWC FINDINGS

Cognitive Categories	Examples	# Words in Dictionary	Mean Word Count
Insight	Realize, see, understand	195	2.51
Cause	Because, infer, thus	108	2.83
Discrepancy	Should, would, could	76	2.34
Tentative	Maybe, perhaps, guess	155	3.25
Certainty	Always, never	83	0.99

VI. LIMITATIONS

Findings are limited to the “Homework Help” sub-forum in the site of study “All about Circuits” and may not be generalizable to other online help forums. As the title of the site of study “All about Circuits” suggests that discussion on the forums are limited to topics associated circuits or lower introductory ECE topics, it is possible that the site of study may have influenced the type of questions asked on “Homework Help” sub-forum. We however note that there are a number of other sub-forums dedicated to a diverse range of ECE topics including RF circuits, embedded systems and software programming.

VII. CONCLUSION

In this research, three text analysis methodologies were utilized to examine students’ first posts in a homework help sub-forum of a popular ECE online discussion forum to gain deeper insights into the help sought. Particularly, this research brings attention to the vast amount of learning taking place outside of the classroom in the form of asynchronous discussion. With the linguistic diversity prevalent in this educational setting, it appears that online informal discussion forums are a flexible and convenient tool for engineering students who want to quickly access the expertise of other engineering learners.

The first approach, keyword analysis, allows us to explore the most frequently occurring words and make inferences from the list of frequently occurring words. Through keyword analysis, we find that much of the vocabulary used in the students’ inquiries suggest that students sought help using fundamental electrical engineering words such as “power” and “circuits”. We then highlight both the lack of keywords from non-circuits based introductory level courses, e.g. digital design and introduction to programming, and the lack of keywords from advanced courses, e.g. electromagnetics and digital signal processing. Our findings suggest that students are also socializing, providing contextual information and sharing knowledge by making references to external resources. For instance, they were making social moves using “thanks” and provide the context of their problem at hand using words such as “project” and describing their “problem”. Furthermore, external web reference in form of “www” and code snippets featured frequently in the data. In sum, it appears from this preliminary work that students are engaging in a supportive learning environment. A subsequent analysis should incorporate keywords beyond the top fifty in order to determine how much less frequent missing keywords are.

In our second approach, we used LDA topic modeling and obtained sets of interrelated words. Based on our inferences on each set of connected words, we identified a handful of topics that are being discussed on the homework help sub-forum. We found that the themes of discussion are closely related with topics in the domain of ECE. For instance, the sets of connected words suggest that students are discussing about ECE topics such as microcontrollers, switches, transistors, circuits, motors, PCB design and PWM controllers. We conclude that online discussion forums feature significant amount of online discussion on topics that feature heavily in ECE curriculum.

In our third approach, we leveraged the LIWC program to examine markers of cognitive processes aimed at identifying the frequencies of use of words associated with five subcategories of cognitive mechanisms. The 5 dictionaries are termed "insight", "cause", "discrepancy", "tentative" and "certainty and each comprises of words we use to look matches in each discussion topic. As expected, our findings suggest that the cognitive process "certainty" was relatively less prevalent in the homework help-seeking discussion. This suggests that students approach online help forums with a degree of uncertainty and a lack of mastery on the content area of concern. In sum, LIWC shed light on the cognitive dimension of students' written text and deepened our understanding on their help-seeking approaches.

We believe that the findings can potentially inform practice, particularly giving engineering educators a quick snapshot of what types of help were sought online and which ECE topics were most likely to be challenging to the help-seeking students. In sum, we found that the homework help section of the studied informal online discussion forum cater to students learning about fundamental ECE topics and less on advanced topics. Our study also raises an important point – online help forums are supportive avenues for engineering students seeking to extend their knowledge and make connections to other students beyond the classroom.

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Catching the Wave: Big Data in the Classroom

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***Abstract*—Many diverse domains—in the sciences, engineering, healthcare, and homeland security—have been grappling with the analysis of "Big Data," which has become shorthand to represent extremely large amounts of diverse types of data. A recent Gartner report predicts that around 4.4 million IT jobs globally will be created by 2015 to support Big Data, with 1.9 million of those jobs in the United States. Therefore, understanding approaches and techniques for handling and analyzing Big Data from diverse domains has become crucial for not only in computing but also engineering students. The mini-workshop will make use of active and collaborative learning exercises to introduce faculty in computer science, software engineering, and other disciplines to concepts and techniques involved in managing and analyzing Big Data. Approaches for incorporating Big Data into the engineering and computing curricula will also be presented.**

Keywords—big data, data analytics, data mining, data-intensive applications

I. Motivation

Big Data has become a catchphrase to describe data so large that it is not amenable to processing or analysis using traditional database and software techniques; such Big Data is noted for its volume, varieties of data types, and rapid accumulation. IBM estimates that 2.5 quintillion bytes of data are created daily, and that 90% of the data being used in the world today was generated in the past couple of years [1]. The advent of Big Data poses considerable enterprise challenges: what portion of this Big Data get stored; how is this storage managed; how quickly can this Big Data be analyzed to enable enterprises to take quick action on enhance productivity, meet or change directions, reduce risk, and more; how can this data be stored securely; what data privacy issues are involved; and so on.

A 2011 McKinsey Global Institute research report projected that the United States needs 140,000 to 190,000 more workers with "deep analytical" expertise and 1.5 million more data-literate managers, whether retrained or hired [2]. Since then, Gartner predicts that 4.4 million IT jobs globally will be created by 2015 to support big data with 1.9 million of those jobs in the United States [3]. Big Data, or "large-scale, diverse, and high-resolution data sets" [4] is found in business, science, engineering, healthcare, critical infrastructure management, and a variety of other domains. A partial list of directorates and agencies from the NSF program solicitation on Big Data contains engineering, mathematics, geosciences, computer science, biological sciences, education, National Cancer Institute, National Human Genome Research Institute, the Office of Polar Programs, and more [4]. Therefore, exposure to Big Data and its analysis would greatly benefit students in engineering and computing programs.

This session will provide an introduction to Big Data and how it can be brought into the classroom. The rest of this paper will present a description of the workshop including the planned workshop agenda; the proposed workshop learning outcomes; and the professional preparation and background of the presenters.

The goals of this mini-workshop on Big Data align with FIE 2013's third focus area: interdisciplinary programs. The workshop provides its attendees with "collaborative learning experiences at the frontiers."

II. Workshop Description

This mini-workshop will demonstrate methods to incorporate concepts, topics, and assignments in Big Data management and Big Data analytics in computing and engineering courses. Drawing on their experience with teaching large scale data management and mining, the presenters will highlight Big Data's characteristics, supporting technologies, and scope.

Table I outlines the tentative agenda for the mini-workshop.

TABLE I. Tentative Workshop Agenda

Event	Duration
Presenters and participants introductions	5 min
Introduction to Big Data using a relevant exercise	10 min
Big Data technologies (Hadoop, AWS, etc.), demo, and a relevant exercise	20 min
Big Data analytical techniques, demo, and a relevant exercise	25 min
Incroporating Big Data into the curriculum	15 min
Big Data: participant discussion moderated by the presenters	14 min
Conclusion	1 min

The presenters will introduce typical issues in collecting, preparing, storing, and analyzing Big Data for use in teaching applications. Next, participants will work with sample course modules and exercises covering technologies such as high-

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performance file systems (e.g., Hadoop and Google File System); NoSQL database systems; cloud computing and storage; programming models (e.g., MapReduce) used in data-intensive applications; and data mining platforms such as Weka, Rattle, R, and Mahout.

Participants will then work through a short analytical exercise using a large data set. Finally, the workshop will conclude with a participant discussion on issues in embedding Big Data topics into existing classes and the influence of Big Data on careers for their graduates. The session will include demonstrations of software and data analysis techniques for Big Data as applied in inter-disciplinary settings, and discussions of sources for domain-specific data.

Attendees will be provided with sample lecture materials and exercises, which will consist of course modules that may be used in their own teaching practice.

III. Workshop Learning Outcomes

The learning outcomes for this mini-workshop are as follows.

- Attendees will explain the main issues and concepts in Big Data management and analytics.
- Attendees will discuss the influence of Big Data in different fields and identify career opportunities in Big Data Analytics for their students.
- Attendees will identify ways to incorporate Big Data management and analytics topics and assignments in relevant computing, engineering, and engineering technology courses.
- Attendees will apply skills needed to implement a Big Data management and analytics environment that can be used for pedagogical purposes.

IV. Qualifications of the Presenters

The two presenters are members of the PhD faculty in Computing and Information Sciences at Rochester Institute of Technology. The PhD program is an interdisciplinary *use-inspired* program that applies computing to solve specific problems across multiple domains.

Dr. Romanowski is an associate professor with RIT's Center for Multidisciplinary Studies, and conducts research in large-scale data mining, particularly in engineering design, product lifecycle management, and critical infrastructure. In addition to teaching undergraduate and graduate Computer Science courses in data mining and data cleaning, she teaches courses in quality management, design of experiments, statistics, history/manufacture of siege weapons, and new product design and development. She received her PhD in Industrial Engineering from the University at Buffalo (SUNY).

Dr. Raj is a professor in RIT's Computer Science department, and his current research interests currently include in large-scale data management, distributed/mobile computing, security, and critical infrastructure protection. He is also interested in computing education methodologies, and is involved in program assessment, evaluation and accreditation. Dr. Raj teaches courses in database systems, cloud and large-scale data management, distributed systems, and security. Prior to RIT, he was a software designer, developer, architect and manager in the Information Technology Division at Morgan Stanley, where he architected, built and managed globally distributed database infrastructures for financial applications handling Big Data. He received his PhD in Computer Science from the University of Washington, Seattle.

Both faculty members are experienced teachers who use active learning techniques extensively and teach in multiple settings: traditional classroom, online learning, and blended settings. They jointly taught a course on Big Data Analytics in the spring term at RIT. They also led a team of multidisciplinary faculty (including industrial engineering, computer science, software engineering, computing security, and information technology & sciences) who developed an advanced graduate certificate program in Big Data Analytics.

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dIsRuPtIoN

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***Abstract*—There have always been critics of education and such criticism has led to a slow ebb and flow in the predominant beliefs that surround the purpose of education [1]. However in the last several years a perfect storm appears to be brewing driven by the rising costs of higher education, continuing maturation of information technologies, and a public dialog that often characterizes higher education as in need of reform [2, 3]. While there is no general consensus on the future of higher education generally, and engineering education specifically, some believe that the model of higher education familiar to most engineering faculty will undergo dramatic changes in the next decade [4]. What is the probability that the engineering education will look significantly different in ten years' time? How might our current model be disrupted; how can engineering educators not only prepare for possible disruptions, but take advantage of new opportunities? What new directions for engineering education research open up if the structure of higher education changes? This special session will elicit from the experiences of participants ways they have (or have not) seem disruptive changes on their campus. By comparing experienced change to those predicted in studies that have examined how disruptions might affect higher education [5], we hope to help the session participants develop a preliminary set of theories of change that may guide their decision making and opinions regarding disruptive forces in higher education.**

***Keywords—disruption; higher education; technology; economy** (key words)*

I. WHY DISRUPTION AND WHY NOW?

The fact that from their inception nearly a millennium ago universities were designed with the goal of preserving and transmitting knowledge, presents modern-day challenges for higher education. The university as a societal institution can trace its lineage back nearly one thousand years to localities that scholars travelled to for education. The word "university" itself is shortened from the Latin phrase "*universitas magistrorum et scholarium*" which translates as "community of masters and scholars" reflecting the guild structure common at that point in time. This location-centric model made sense given the historical context; at that time oral recitation of written texts, hand-copied by students, was an efficient and massively parallel means of information transmission. Before the advent of the printing press information was an extremely valuable commodity- a single book could cost as much as a small farm but had value disproportional to today's cost [6]. The knowledge-centric structure of universities made sense when information was scarce, localized, and expensive to obtain. Some argue, however that this structure now serves to undermine their function in the information age [7]. While reform of education is a perennial topic, generally all efforts at change retain the primacy of knowledge. From the emergence of courses and the curriculum in the 16th century [8] to modern efforts to integrate videos, on-line courses, games, and the current focus on Massively Open On-line Courses (MOOCs), efforts at change generally address ways to reorder, redefine, acquire, retain, and/or transfer knowledge.

Despite the pressures for reform, universities have generally been resistant to change. Such resistance likely stems from the university's historical role as a guardian of tradition and its success in enculturation. Given today's model of universal education, faculty members are products of similar educational systems and thus think about education within the bounds, ideas, and terminology of that system. Indeed, our own educations have so well defined us that it can be extremely challenging to think about the educational system from alternative perspectives. An inability to step outside of the status quo, however, can lead to eventual disruption. Many organizational change models (e.g. evolutionary, social cognition, cultural, institutional, punctuated equilibrium, and Panarchy) describe systems which become increasingly rigid until they are forced to adapt. Weick and Quinn [9], in placing much of the change literature on a spectrum from episodic to continuous change points out that "*Lewin's three stages of change—unfreeze, change, and refreeze—continue to be a generic recipe for organizational development*" and that "*to understand organizational change one must first understand organizational inertia, its content, its tenacity, its interdependencies*."

This special session will examine what disruption might mean to engineering education, what forms it might take, and what opportunities disruption engenders. While for many the word "disruption" can be used in the sense of creating chaos, it means an interruption in the normal course of events. Disruption thus has the equipotential to harm institutions, organizations and individuals, as well as to lead to growth and evolution. Disruption in higher education, no matter how unlikely past events make it seem, is important to consider since the "community of masters and scholars" has a great impact on society. Universities remain open repositories of specialized expertise which allows individuals, institutions, and societies to function in a complex world of interconnected systems. Research and technologies that originate in universities drive economic growth, and industries demand an increasingly educated workforce. It can therefore be concluded that the impact of disruption on our educational system will

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directly impact our nation's competitiveness, vitality and prosperity.

II. Disruptions to be Considered

At the time this paper is being written the most talked about potential disruption to the historical model of engineering education is the Massively Open Online Course, or MOOC. While there have been MOOC-like online learning experiences for some time, the current focus was sharpened when over 160,000 students signed up for an online artificial intelligence course taught by Stanford professor Sebastian Thrun, that soon thereafter led to the founding of Udacity, one of the privately funded firms that offers MOOCs.

Fig. 1. Six inter-related and synergistic factors that the special session will initially utilize to characterize potential disruptions.

While MOOCs are currently the most visible and apparent of the forces that can potentially change the historical model of higher education, there are other disruptive forces that are also affecting universities. To frame the conversation the special session will preliminarily classify six potential dimensions of disruption, as shown in Figure 1. These six dimensions are, in no particular order:

- Technological: Advances in technology, typically related to transmission of information, which enable at least some of the traditional functions of a university education to be offered remotely.
- Organizational: How universities are structured and governed. This dimension includes changes in management and power structures within the university.
- Philosophical: Changes in beliefs and attitudes of these within the higher education system and society at large, which may include the value of higher education. The term philosophical denotes that beliefs are organized around some internally consistent schema, even when this schema is not easily articulated.
- Economic: All universities rely on sources of external funds for their operation--endowments, gifts, state and federal funds, and/or student tuition-- and thus changes to the revenue and operating costs of universities can be a catalyst for disruption.
- Regional: Disruptions can arise from local or regional trends such as population growth or decline, closing or off-shoring of major employers, or longer term population and demographic changes.
- Societal/Political: Universities, while historically insulated from larger social change, are affected by societal, as well as local and national, political factors. These may include regulatory policy or changes to how students fund college (e.g. government subsidization of student loans). Special interest groups can target universities, either to support or undermine their function.

Disruptions are rarely characterized by a single dimension. The previous example of MOOCs combines elements of technological innovations with economic dimensions given the relatively low cost (approximately $US 0.50 per student) to offer a large scale course. MOOCs also have elements of the philosophical dimension since their popularity reflects beliefs as to their efficacy, as well as the political dimension, since accepting credentials of MOOCs requires garnering support from multiple groups.

III. Goals of the Special Session

The goal of this special session will be to familiarize participants with current trends and literature around potentially disruptive events in engineering education, and to stimulate discussion amongst the community about these trends. At the end of the session participants will have been given the resources to independently explore several of the wide-ranging perspectives on potential future disruptive changes to higher education generally and engineering education specifically.

The special session is not designed to teach or communicate facts about disruption, but rather to evoke from participants their own beliefs and opinions about the likelihood and severity of disruptive events in their own university. The overarching goals of the workshop are to:

1. Create a forum in which a discussion of both likely and unlikely future scenarios of engineering education are discussed that build from the lived experiences of participants.
2. Change the conversation about disruption from one based on fear or scarcity to one that gives equal weight to opportunity and exploration.
3. Identify possible new opportunities that will arise for engineering education research and have participants self-identify possible new directions for their own research interests.
4. Develop a preliminary set of theories of change that can help guide participants' strategic decision making.

IV. Organization of Special Session

The organization of the special session will focus on eliciting experiences from participants that either support or refute the six hypothesized dimensions or modalities of disruption. The organization of the special session will help compare participant's beliefs and experiences with the larger national dialog. The session will tentatively be organized into six sequential activities

A. Introduction & Background Reading

A list of readings that cover various aspects of disruption in higher education will be compiled before the session and given to participants. Since this space is changing very rapidly, the list will be handed out at the start of the session, and also be made available after the session on a web site that will be provided to the participants. Participants will be informed of the goals of the session, organization, and time line. Some of the major works on disruption in higher education will be presented to ground later discussion.

B. Scenario Analysis

The jigsaw technique will be used to divide participants into small groups to analyze a potential scenario of disruption. Each participant will be handed a stack of cards at the door, and organized by groups given the letters on the cards. The first discussion will be for six different groups to discuss each of the dimensions that can characterize potential disruptions. This group will be disbanded, and new groups of six formed that contain at least one person who attended the discussion on each dimension. The groups will each be given a different scenario, and the groups will discuss the effect of the scenario on engineering education. An example scenario might be that "ABET announces it is closing its doors, and your program now has no requirement for accreditation." Following discussion, each group will report out on the results of the scenario analysis.

Following the first, hand-picked scenario, each group will be asked to develop their own scenario that combines one or more experiences of participants in the group, and analyze the disruptive effects on engineering education. For this second scenario the groups will be asked to identify three research topics or questions that would help them adapt to or profit from the disruption. Groups will again report out and outline their scenarios on large cards or poster boards.

C. Developing a Theory of Action

The groups will again be reorganized to the first groups in order to stimulate new conversations while avoiding the need for further introductions. The presenters will provide a brief background on theories of change/action to ground the next task for participants. Groups will be asked to develop several assumptions or hypotheses about possible disruptive changes that can be integrated into a theory of action. An example of such a hypothesis might be "New technologies for learning will continue to evolve, and increasingly support development of alternative pathways beyond traditional colleges and universities." Groups will be asked to write down their hypotheses on large cards or poster boards that can be displayed to other groups.

D. Final Report-Out and Conclusions

To conclude the session an open and free-ranging discussion of the session will be held to elicit if there is group or majority consensus for any of the hypotheses generated when theories of action/change were developed. Participants will be asked if any of the scenarios suggest research questions/directions that deserve further investigation or consideration by the engineering education community.

E. Post Session Actions

All written artifacts from the session will be collected, and a scribe will be assigned to record oral conversations. Each participant will sign a study release form to be able to use their written material. The outcomes of this session will be analyzed to identify possible disruptive scenarios. Results will be made available on a web site, and e-mailed to participants who were willing to provide their e-mail address on a list available during the session.

V. CONCLUSIONS

It is important that scholarship in Engineering Education not lose sight of the larger context and forces which affect higher education as a whole. The goal of this special session is to have the community identify possible disruptions to the current models of engineering education; recognize disruptions with their local context, and path(s) to achieve this goal. The outcomes of this session and feedback from the community will be analyzed to determine alignment with, as well as divergence from, the current dialogs around disruptions in higher education [2-5].

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A Teaching Method for Using Metaphors in Interaction Design

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***Abstract*— the consistent use of metaphors in the context of Human Computer Iteration (HCI) helps to reduce the cognitive load necessary for understanding the functionality of a computational interface. Students´ understanding about a good usage of metaphors in HCI improves their ability to properly critique and design computer interfaces. However, is not simple to students to learn how to use metaphors in interaction design. To teach students to develop interactive experiences by means of metaphors is not an easy task. This work proposes a teaching method for using metaphors during the design of website, desktop, mobile or tablet interfaces and present results of a successful case study concerning the proposed teaching method. The teaching method developed is a model of collaborative learning based on King's questioning model and Ferreira's creative dimensions, that consists in creative tasks allied to questionnaires with structured questions and are designed to encourage interaction, group learning and to foment creativity in students.**

Keywords—metaphors; interaction; design; teaching; learning

I. Introduction

According to Lakoff and Johnson [1], our conceptual thinking is fundamentally metaphoric in nature. They see metaphor not as a mere figure of speech but as a fundamental cognitive mechanism, where experiential structure is projected from a source domain to a target domain. Intuitive interaction with technology is based on the unconscious application of prior knowledge by the user. Besides, design is about invention. Invention can be product of juxtaposition. Metaphor is about juxtaposition. So, the link between metaphors and user interfaces is inevitable. Metaphors are a powerful and usual tool for designing intuitive interaction.

The use of metaphors in computational interfaces makes the user experience more familiar and concrete. Metaphor is not a mere figure of speech; it is a fundamental cognitive mechanism for understanding. According to Lakoff and Johnson [1], the essence of metaphor is understanding and experiencing one kind of thing in terms of another. Considering interaction design, it is desirable an interface familiar to the user, enabling an easy learning and use. Metaphors application reduces the time spent on user training or, in specific cases, no training is required.

The use of metaphorical concepts is one of the resources available for creating intuitive user interfaces. Entertainment websites, online stores, social networks, and others require an interface easy to learn and use. The interaction design should be well organized, easy to be interpreted and used by the users. Metaphoric concepts can be used in an expressive way to achieve this goal.

Metaphorical concepts are pervasive in the culture of a society. Lakoff and Johnson [1], stated that the metaphorical concept is inherent to subconscious and govern our whole way of thinking. Thus, the good use of metaphors in interface design is a feature that will make the interaction much easier to understand. Nielsen and Molich [2] established that we should minimize the cognitive load of the user. In other words, they stated that the designer should facilitate the reasoning required to interpret an interface. Also, they state that in a user interface there must be a match between the system and the real world, the designer should use phrases and concepts familiar to the user, rather than system-oriented terms.

The use of metaphors is a powerful resource that can be applied to achieve these heuristics. The appropriate application of metaphorical concepts turns an interface into a better interface. The interface design consists in defining how content is organized and presented to the user [3].

The consistent use of metaphors in the context HCI helps to reduce the cognitive load necessary for understanding the functionality of a computational interface. Students´ understanding about a good usage of metaphors in HCI improves their ability to properly critique and design computer interfaces.

However, there are misleading uses of metaphors, it is not simple to students to learn how to use metaphors in interaction design. To teach students to develop interactive experiences by means of metaphors it is not an easy task. Students need to understand the user experiences, concerns, skills, interests and expectations and must develop the ability to create good designs based on user's knowledge.

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Constructing effective metaphors is to some extent a complex skill because it depends on the creative ability of designers to see new analogies, in order to choose the right set of correspondences. These correspondences have to enhance some aspects and hide others, because metaphoric mediation carries elements of the concept that are consistent, but also inconsistent when using metaphors to comprehend one thing in terms of the other. For Schwartz and Fischer [4], metaphors have highlights levels of complexity as well as the need for sufficient support to build complex understandings, but it does not easy capture the diversity of contexts that students might experience that could lead to the same abstraction. Metaphors can be difficult to learn and teach, because they have a high level of complexity. Students may have different interpretations of each other, which makes teaching difficult.

According to Hodges [5], if we examine the metaphor closely, its connotations are often the darkest when applied to teaching. Having a problem in one's research is motivating; having a problem in one's teaching is, well, a problem. In order to overcome the difficulty to teach metaphors in HCI, we suggest the teacher must apply a teaching method that encourages creativity and also criticism in interaction design.

In this work, we aim to awaken and stimulate the use of metaphors in teaching and learning interaction design with the aim to stimulate students' abilities to discern what is a good or bad design, allowing students to differentiate an interaction design that it is aesthetically good but possesses a bad functional design, and to propose new ideas and solutions.

In this work, we propose a teaching method to teach metaphors in human computer interaction design that fosters student's creativity and criticism. This method is based on collaborative learning and creative dimensions proposed by Ferreira [6] and the discussion method proposed by King [7].

The creative dimensions, proposed by Ferreira [6], contain underlying dialogical processes that aligns dialogues with mental processes linked to both adaptive and innovative creativity. The creative dimensions constitute a pedagogical framework for design exercises for use in the teaching of human computer interaction, making possible to teachers create significant human computer interaction collaborative learning experiences to students, fostering them to activate mental processes underlying creativity.

On the other hand, in the discussion method group proposed by King [7], questions that trigger patterns of discourse in learning groups are designed to facilitate the construction of complex knowledge and problem solving.

Our teaching method proposes a combination Ferreira's framework [6] and Kings [7] types of questions to propose a repertory of interaction design exercises exploring the use of metaphors. In our teaching method, we also approach the most common metaphorical concepts as structural, visual, functional, and positional metaphors, and consider where, when, why and how they are applied in the field of HCI. This metaphorical knowledge is part of the teaching method and are used during the tasks and questions created.

In this work, we present a case study comparing the teaching method proposed in an undergraduate HCI class (treatment group) and a method involving students' discussions and informal teacher mediation in another undergraduate HCI class (control group). The case study conducted showed significant results.

In section II, we show the importance of the application of metaphoric concepts to human computer interaction and show systematic aspects of metaphors. In section III, we describe the teaching method proposed in this article. In sections IV and V, we present a case study of the application of the teaching method proposed and the results obtained.

II. METAPHORICAL CONCEPTS APPLIED IN HUMAN COMPUTER INTERATION

Metaphorical concepts are applied in the design of computational interfaces in order to facilitate the human-computer interaction. The interaction is facilitated by means of the user's prior knowledge, making the user experience rich and intuitive. In order to consistently apply metaphors we need to know and understand how they are structured, and know in which situations it is appropriate to apply them. Nielsen [8] advocates that a metaphor misused diverts the user understanding to something not desired. Hence, a contextualized interpretation is necessary to appropriately apply a metaphorical concept. A contextualized interpretation provides a subconscious understanding of a metaphor.

According to Lakoff and Johnson [1], a subconscious understanding of a metaphor is the cause of its systematic understanding. For example, the phrase "I will destroy it with my speech" is based on the metaphor "argument is war", after reading this phrase our subconscious systematically follows the practice of the society. The metaphorical concept does not lead to an association with the concept of a war, an individual with experience are able to know that someone will not shattered, but their arguments are deconstructed. The systematic aspect highlights some characteristics of confrontation and hidden the feature of physical trauma. The systematic aspect evokes structural, functional, visual, and positional aspects.

A. *Structural Metaphors*

Structural metaphors are formed from the structure of an object, entity, group, finally elements of everyday life. The idea is to use an organizational hierarchy, for example, a website of a library should contain the same organizational structure of a library, in which books are organized by class and type.

B. *Functional Metaphors*

Functional Metaphors contextualize actions that can be done on a website or in another environment. The functional metaphors evoke prior knowledge of the user in relation to something that has already been seen or used in their daily lives. In a text editor find examples of functional metaphors. Can metaphorically "cut", "paste", "copy" documents or fragments of a document into another, as if using paper, scissors and glue. So the tasks in the website become easy to understand and use.

C. *Visual Metaphors*

A visual metaphor can be defined as the representation of a person, place, thing, or idea by way of a visual image that suggests a particular association or point of similarity. Visual metaphors are linked to graphical elements common to a particular culture. According to Lakoff and Johnson [1], The concepts inherent subconscious govern our way of being, from speech, to the way we act and one of these concepts is the metaphorical concept. A usual visual metaphors example is the use of floppy disks images to represent "buttons" present in many different interfaces. It is used to save a document during text editing.

D. *Positional Metaphors*

According to Lakoff and Johnson [1] positional metaphors are those in which a system of concepts is organized by reason of another. The positional metaphors use the concept of spatial orientation. For example say that happy is up, sad is down. Then we have the understanding that good is up and bad is down. This name is given because in most cases there is a spatial orientation: upward, downward, outward, inward, and so on. An example is the metaphor "happy is up". Another example is that people usually places names or most important items at the top of a list, this is due to the metaphor "is more important up".

The use of metaphors in HCI is evident in many interaction patterns and interface designs. For example, the Apple´s desktop metaphor, wizard pattern, canvas plus pallet pattern, menus, buttons, dashboards, carousel pattern, breadcrumbs pattern, and so on.

Once described some metaphoric uses in human interaction computer, then we will address the teaching method proposed in this work.

III. Teaching Method for Using Metaphors in Interaction Design

The use of metaphors is essential to the user experience become simple and intuitive. It facilitates user understanding and interactivity. According to Baumer [9] metaphors can be powerful aids for understanding because they can help the understanding of novel concepts.

However, learn to apply metaphors in computing environments it is a difficult task. Although metaphors abound in human thinking, they can be surprisingly difficult to notice simply due to their ubiquity.

In this work, we developed a teaching method based on collaborative learning for teaching metaphors in interaction design. Collaborative learning is a successful method to awaken creativity. Creative solutions emerge from interactions that encourage students to express and evolve their ideas in specific problems.

According to Jonassen and Land [10], knowledge originates from productive discourse among individuals, the social relationships that bind them, and the physical artifacts, theories, models and methods that they use and produce. Productive discussions provide satisfactory results in collaborative learning, providing students the opportunity to share and co-construct knowledge.

Creative solutions are built during joint activities that trigger productive discussions. Creative and collaborative dimensions proposed by Ferreira [6] promote productive discussions, where students are encouraged to widen and deepen the design space. Students extend the design space when a new idea emerge and deepen the space of the project when an idea is developed.

Ferreira´s pedagogical framework allows the teacher to elaborate tasks that nourishes creative discussions during collaborative problem solving in interaction design [6]. The author considers that creative products occurs as stimulation of many different planes. The framework contains seven collaborative and creative dimensions to be applied by the teacher. According to Ferreira [6], the dimensions are: immersion, unpacking opportunities, exploring complementary ways, surpassing limits, expanding, discovering and developing unpredictable places. The dimensions contains dialogic processes that are dialogs aligned with mental creative processes associated to both adaptive and innovative creativity. Dialogic processes afford ideas build on other ideas, while people collaborate. The framework helps and challenges teachers to be aware of how complex students´ activities can be elaborated during collaborative learning. Considering students perspectives, during productive discussions they are able to detect relevant and irrelevant information, recognize the familiar, deal with new information, adapt and reapply techniques, among other creative important processes.

The use of provocative questions is another strategy that encourages students to interact productively. The students absorb and transcend knowledge when they engage themselves in profitable interactions.

King´s model approaches provocative questioning to induce relevant cognitive, meta-cognitive and socio-cognitive processes in participants [7]. Effective learning interactions induce complex cognitive processes including the analytical thinking necessary to create metaphors.

According to King [7], learning is constructed during interaction with others. During the interaction the students engage in the exchange of ideas, opinions and perspectives. The speech is composed of provocative questions, explanations, justifications, assumptions and conclusions. The construction of knowledge occurs when students explain concepts to each other. The questioning is a procedure that asks questions and answers. The interaction during the discussion results in a high level of learning. The model proposed by King consists of structured questions on issues of entry, for example: "How similar to?", "How does it relate?", "What do you remember and why?”. Comprehension questions, for example: "What does it mean?", "What's important." Connection issues, for example: "How are similar?", "What is different between?", "How can it be used for?", "What are the strengths and weaknesses?" [7]. Strategic issues, which can be planning, monitoring and evaluation.

The method proposed in this paper involves the development of group assignments focusing on the use of metaphors in HCI. Using our method, the teacher is able to elaborate group tasks and questions that encourage students engage themselves in productive discussions.

The teacher is invited to approach the dimensions proposed by Ferreira [6], questioning the model proposed by King [7] and knowledge about metaphors when designing exercises.

The teaching method involves structured questions as described in the model proposed by King. The questions are prepared according to the scenario presented to the student. The scenarios involve well and badly designed websites, when we focus on metaphoric concepts. The connection between the scenario and the questions is based on the dimensions proposed by Ferreira [6]. The tasks elaborated considering Ferreira´s framework and King´s model allow the students to expand the solution space, while discussing ideas jointly situated in a specific, smaller, bigger or different context.

Ferreira´s framework motivates the activation of mental processes relevant to creativity, while the questions from King´s model provoke them even more for reflection and to be creative. For example, students are encouraged to seek relationships among different ideas, think out of a particular context, find solutions and ideas out of context, interact with each other, expand the solution space, and think differently.

In this way, the students have the opportunity to scrutinize metaphors in different contexts and are urged to find solutions and improvements in the application of metaphoric concepts in interaction design. Besides, the combination of these techniques provides the student with the ability to generate creative solutions and alternatives during the group discussions. According to Preece [3], the generation of alternatives is a key aspect in the interaction design.

IV. THE CASE STUDY

The case study aims to examine the effectiveness of teaching the use of metaphors in interaction design by means the proposed teaching method.

In this preliminary case study, four tasks based on the proposed method were analyzed. The preliminary results indicated that the proposed teaching method has potential to help teachers to mediate students' creativity when using metaphors in interaction design.

The students investigated were engaged in two classes of undergraduate Software Engineering at Federal University of Goiás in 2011 and 2012. There were 44 students in the class of 2011 and 42 students in the class of 2012. Each class was divided into groups of 6 (six) students and each group was evaluated by means of discourse analysis of online discussions.

A. Students' Profile and Communication Tools Used

Students are studying Software Engineering at the Federal University of Goiás. Students have the profile of software developer. They are learning about the concepts related to interface design, as metaphors, usability guidelines and interaction patterns in the human computer interaction design course.

A communication tool used was the Moodle platform, which facilitates iterations among students. Each student post messages concerning their responses and opinions. The Moodle is a tool for course managing that also can be used for distance learning. Using the forums the student can post a message at any time and place.

B. Description of Tasks (Treatment Group)

The tasks required are described following.

1) Discuss having in mind the questions related to the website Taisho: www.taishoflorianopolis.com.br. During the discussions you must engage critically and constructively with the ideas of others. Express yours opinions, inferences, and propose appropriate solutions. Following we describe the questions regarding the Taisho website:

Why is it important to use a visual metaphor on the website? The elements observed on the website are similar to real objects? How the geisha and the shamisen relate to each other? The menu contained in the Website is an example of positional metaphor? Did the visual metaphors facilitate user interaction in the website? Are the metaphors used readily apparent to any user? Explain why the metaphors were used? Explain how each metaphor interferes with the user's perception? How the used metaphors are similar to elements of everyday life? Are the metaphors used inherent in the culture of the target audience? What are the strengths and weaknesses of the use of visual metaphors in the website? Is the user able to associate the elements present in the metaphorical interface actions and objects represented? The website has a stable context? The positioning of the metaphors in the interface facilitates the identification of the company name? The name has a reasonable size and its location is noticeable? The different metaphorical elements are in harmony? These elements contribute to the user understanding about the information contained in the website? The interface emphasizes the services offered by the company? The interface services are clear from the user perspective?

2) Discuss having in mind the questions related to the websites Sitotis: www.sitotis.hr and Thedeepestsite: www.thedeepestsite.com. During the discussions you must engage critically and constructively with the ideas of others. Express their opinions, inferences, and propose appropriate solutions. Following we describe the questions regarding the websites:

The metaphor in this company logo helps in understanding related to your industry? From the perspective of the user interface in relation to which it is possible to satisfactorily answer the purpose of the website? The website Interface is sufficiently self-explanatory? The metaphors present in the website immediately contribute to the understanding of its interface? The user interface is constrained by the reliance of the text contained in the description of the website to orient yourself? You understand so simple services offered by the website? The positioning of the website menu provides the user to find the desired options in a simple and immediate? The user can effortlessly navigate the website? It is able to distinguish the options? It has a precise notion of what is in each option? The graphics and animations present on website show the actual content? The metaphors used emphasize a content merely illustrative? Or are indispensable in navigating the website? The user is able to associate the elements present in the metaphorical interface actions and objects that represent? Scrolling the page is done vertically? The metaphor in this present action is clearly perceived? From the perspective of the user interface in relation to which it is possible to satisfactorily answer the purpose of the website? The website Interface is sufficiently self-explanatory? The metaphors present in the website immediately contribute to the understanding of its interface? The user can effortlessly navigate the website? It is able to distinguish the options? It has a precise notion of what is in each option?

3. Choose a Website to design your Mobile interface.

a) Take a look at the patterns shown in class 10 and 11 concerning mobile and navigation patterns. Also take a look at the supplementary bibliography

b) Use metaphors in the design of the website. Discuss having in mind the usability guidelines, particularly guidelines for mobile intrfaces. Think outside the box when designing the website. Consider the following questions about metaphors:

- What types of metaphors are more suited to the context of your mobile interface?
- Does the metaphor used help the user to concentrate on the main service offered by the website?
- How visual metaphors can be used to enhance the understanding and simplicity of the website in a mobile environment without sacrificing your design?
- Is it possible to use metaphors emphasize most relevant content to users?
- How can we subtly integrate metaphors and the graphic style of the website?
- Does the metaphor used provide users a logical path to follow, minimizing the effort required for understanding, making navigation easy and obvious?
- What functional metaphors can be used to facilitate the execution of some tasks?
- The use of structural metaphors can make navigation easier and more intuitive for the user?

4. *Each student must individually choose a context to adapt the wizard pattern using metaphors. Defend your choice in your group grounding yours arguments on the items "when" and "why" of the wizard pattern. Each student must design a wizard and defend your idea, based on item "as" the wizard should be implemented. Discuss, choose and refine the best idea considering the following questions:*

- The Wizard makes clear to the user what is the goal to be achieved?
- The user is notified if he tries to start a new job before completing the current?
- The user has the option to go back and change the data entered in the previous step?
- It is visible to the user in that step is missing and how to achieve the goal?
- The Wizard is simple and intuitive and does not require much effort on the user understand how to use it?
- Do the metaphors used help the wizard to became more simple and intuitive?
- Do the metaphors used help the user to concentrate on the goal to be achieved?
- Why metaphors were used? The metaphors contribute significantly to the user reach success in every step and fulfill the purpose of the wizard?

C. Description of Tasks (Control Group)

The tasks were in accordance with the following collaborative script:

Read a text about metaphors and evaluate the use of metaphors in the Websites Taisho and Sitotis. Based on the text and previous classes on this subject. Express your opinions regarding the use of metaphors in the Website.

D. Model Used in the Discourse Analysis

The model used in the discourse analysis was proposed by Newman, Webb's and Cochrane [11].

The Newman, Webb and Cochrane's Model is described by ten categories:

1. Relevance: Relevant states or diversions.

2. Importance: Important points and issues or unimportant points and trivial issues.

3. Novelty, new info, ideas, and solutions: New problem related information or repeating what has been said.

4. Bringing outside knowledge or experience to bear on problem: Drawing on personal experience or sticking to prejudice or assumptions.

5. Ambiguities; clarified or confused: Clear statements or confused statements.

6. Linking ideas, interpretation: Linking facts, ideas and notions or repeating information without making inferences or offering an interpretation.

7. Justification: Providing proof or examples or irrelevant or obscuring questions or examples.

8. Critical assessment: Critical assessment or evaluation of own or others' contribution or uncritical acceptance or unreasoned rejection.

9. Practical utility (grounding): Relate possible solutions to familiar situation or discuss in a vacuum.

10. Width of understanding (complete picture): Wide discussion or narrow discussion.

Categories 1 to 9 were explored in this case study.

E. Results

Each student was individually analyzed according to the model of Newman, Webb's and Cochtane [11]. The result obtained by all students in the group, produced the group average. The average of all groups produced the overall result of the class.

Statistics of the overall outcome of the class in 2011 is shown in table I.

TABLE I. STATISTICS OF INTERACIONS IN 2011

Category	Average
1.Relevance	19.5%
2.Importance	18.5%
3.Novely, new info, ideas, solutions	3.25%
4.Bringing outside knowledge or experience to bear or problem	8.25%
5.Ambiguities	24.37%
6.Linking ideas, interpretation	9.37%
7.Justification	2%
8.Critical assessment	35.62%
9.Practical utility (grounding)	10.87%
Overall average of the class in all categories	14.63%

Each category was examined individually in each group and the results were obtained by calculating the percentage from 0 to 100 per category group. The percentage was obtained by examining the student's posts. Each student post was analyzed according to each category. The result was obtained by analyzing the positive factors of each category.

During the course in 2011, it was not used the teaching method proposed in this article. The students were asked to evaluate and discuss the use of metaphors in websites considering no question.

Table II contains the general outcome of the interactions analysis in 2012.

TABLE II. STATISTICS OF INTERACTIONS IN 2012

Category	Average
1.Relevance	71.65%
2.Importance	58.73%
3.Novely, new info, ideas, solutions	32.86%
4.Bringing outside knowledge or experience to bear or problem	10.68%
5.Ambiguities	5.48%
6.Linking ideas, interpretation	10.27%
7.Justification	19.48%
8.Critical assessment	49.71%
9.Practical utility (grounding)	10.06%
Overall average of the class in all categories	29.82%

In category 1 we obtained 71.65% of relevant assertions. This result indicates that students had a significant improvement in the ability to make relevant statements. In category 2 it was obtained 58.73% of important issues. The result obtained in the category two indicates a significant improvement in addressing important issues. In the category 3 it was obtained 32.86% of new information, ideas and solutions. Students were able to propose new ideas, solutions and information. In category 4 we obtained 10.68%. Students were able to bring the information out of knowledge. In category 5 it was obtained 5.48% of ambiguities. In category 6 we obtained 10.27% of union ideas and new interpretations. In category 7 we obtained 19.48% of justification. Students were able to justify their ideas and affirmations. In category 8 we obtained 49.71% of critical assessment. The students' ability to make critical evaluations greatly improved. In category 9 we obtained 10.06% of practical utility. The average in all categories of the class of 2012 was 29.82%.

The results achieved were satisfactory. Compared with the class in 2011, class in 2012 achieved an overall gain of 15.19 percent. There was a clear improvement in all categories. In some categories there were a significant gain. Gains related to category 3 were 29.61 percent and earnings were related to category 8 of 14.09 percent. The category 1 and category 2 also greatly benefited. We note that the category 3 was the most favored. The students have acquired the ability to propose something new, new ideas and solutions, which is essential for a software engineer and interaction designer. Category 8 related to critical thinking also had a great improvement.

The statistics presented show that the use of our teaching method in teaching the use of metaphors interaction design instigates and encourages the student to infer criticism and find more effective and creative solutions for the design of computational interfaces.

In tasks two and three we analyzed the products designed and presented by each group of students. In the analysis we used the creativity checklist for website design of Zeng [12], analyzing important design factors, such as: aesthetically appealing design, interactive design, novel and flexible design, affective design, design important, common and simple design and personalized design.

Analysis of the products was successful. The results obtained in speech analysis have been confirmed in the analysis of the product. Students who possessed better performance in the categories of speech produced and presented the best products.

The critics and creativity promoted by collaboration and productive interactions among students, trigged by the application of the teaching method, contributed effectively in student learning. The students applied the concepts discussed adequately. The discussions resulted in products of high quality design.

V. CONCLUSIONS

In this paper, we highlight the use of metaphors in interaction design. The use of metaphors improves the interaction design, providing more respect and importance to computational interfaces. We addressed different types of metaphors, such as visual, functional, structural and positional metaphor. The proper use of metaphors produces a positive and significant impact on usability of user interfaces. Their use in user interfaces can improve its interface and provide substantial gains in user productivity.

Students find it difficult to learn and apply metaphorical concepts in interaction design. In order to overcome this problem, we addressed a teaching method to teach creativity and criticism in the context of interaction design using metaphors. A case study was designed and successfully applied. The preliminary results show that the teaching method based on collaborative learning through the development of questions that stimulate group discussion achieved good results. There was a significant improvement in the class where the method was applied compared to class where there was no application of the method.

The results show the relevance of the study and the teaching method applied. This work contributes to teachers to arouse students' creativity, directing and encouraging them to infer creative solutions and to proper criticize interaction design. This contributes greatly to their learning. In this way, the student aggregates the knowledge necessary to criticize and design a more intuitive interface that is simpler to learn and use.

To assure that the teaching method can indeed provide an effective approach to teaching metaphors in HCI, we intend to further investigate its application in future HCI undergraduate courses. We will compare students' performance considering tasks based on the teaching method to ill-structured and structured tasks not based on the teaching method.

ACKNOWLEDGMENT

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Computer Science Education as Part of an Undergraduate Program in Community Information Systems

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***Abstract*— Social information systems have recently emerged as an empowering force for communities, organizations, and businesses. Consequently, new academic programs have been proposed around the globe, aiming at establishing a framework within which students gain experience in the socio-technical process of designing information systems in business, libraries, health, government, education and beyond. These new interdisciplinary programs often regard computer science (CS) as one of their supporting pillars and therefore include some core CS courses, aiming at educating broad-minded practitioners rather than expert programmers in the field of information systems. This paper presents some thoughts on incorporating CS education in academic programs intended for non-CS majors and proposes an approach called 'Program by Design' for the first CS course in a new undergraduate program in community information systems.**

Keywords—Introductory Programming Course, Pedagogy, Design Recipes.

I. Introduction

In the last two decades we have witnessed an invasion of homes, workplaces, public spaces, and both local and global organizations by information technology tools and systems. The advents of the World Wide Web, wireless communications, and miniaturized computing technology have considerably expanded this invasion into mobile devices and remote communities. The widespread everyday use of computers and information systems reflects a shift in conceptualizing the technology as more social than it was perceived before: 'the computer started as a totalitarian tool, but has now also been embraced as a social tool' [1]. More recently, over the last several years, social information systems have gained significant popularity. Social networking sites, social sharing and tagging systems and social media attract several million users a day all over the globe. These kinds of information systems provide their individual users with increased social presence, much broader access to information and knowledge, and powerful means of communication. At the same time, social information systems emerge as an empowering force for both local and global communities, organizations, and businesses.

Following these radical changes [2], a new interdisciplinary area of study has evolved, arguing that the social and the technological mutually shape each other. Studies in this area touch several different fields, including CS, information systems, information science, and some social sciences [3]. By examining the social aspects of computing, the fields of Social Informatics and Community Informatics aim to ensure that technical research agendas and information systems designs are relevant to the lives of people and organizations. Community Informatics aims further at empowering communities through the use of technology, especially those groups who are excluded from the mainstream communication systems [4].

The increasing interest among different communities of practice in integrating human and social considerations into traditional information systems curricula has led to the development of new academic programs around the globe. These are aimed at establishing a framework within which students develop analytical skills to identify and evaluate the social consequences of systems based on information and communication technologies (ICT-based systems), and gain experience in the socio-technical process of designing information systems in business, libraries, health, government, education and beyond. The latest model curricula for undergraduate degrees in information systems recommended in 2009 by a joint task force of the Association for Computing Machinery (ACM) and the Association for Information Systems (AIS) also supports reaching beyond the schools of management and business. While information systems curricula have been traditionally targeted to business schools, the current task force believes that the discipline provides expertise that is critically important for an increasing number of domains [5].

Currently, many undergraduate programs in information systems (IS) around the globe operate either as part of the faculty of engineering or within the context of the business environment and related activities. This is also the case in our country, where the new community–oriented IS program here reported has only recently opened. Although other IS programs in the country might offer one or more courses dealing specifically with social aspects of IS and ICT, these courses are considered marginal.

The new undergraduate program in Community Information Systems has been developed in our College in light of the global trends discussed above and, in addition, as a response to the educational gap identified between various population sectors in our country. The program seeks to be sensitive to the increasing demand for higher education of the population in a rural part of the country, by considering the multi-cultural facets of businesses, organizations, and communities, and to empower these developing communities by using advanced technologies and information systems. The curriculum combines theory and practice while emphasizing subjects that are relevant to the workforce and the organizations surrounding the college, thus creating "Practice of Relevance" for its students [6]. Section II further describes the program and its curriculum as an intersection of disciplines.

The discipline of computer science (CS) is often perceived by IS programs as one of their supporting pillars. CS methods and ideas, which are at the root of ICT innovations and information systems design processes, are thought to have the potential to contribute to a greater understanding of those creations. Moreover, advancing students' understanding of computing has been thought of as critical to developing the needed workforce for the 21st century [7]. Therefore, students in IS programs in general, and in an interdisciplinary program such as Community IS in particular, should study fundamental CS courses in order to acquire the needed broad foundation in computing and consider its breadth of application. Section III therefore proposes a CS track tailored for non-CS majors in order to give them an understanding of the principles and practices of computing as well as its potential for transforming the world [8]. The 'Program by Design' approach [9] found especially appropriate for the first course in this CS track is detailed in Section IV. The last section of this paper offers early remarks on implementing 'Program by Design' at Zefat Academic College.

II. About the Community IS Program

The College's undergraduate program in Community IS has been approved by the national council for higher education at the end of 2010 and the first students have started their course of study in the fall term of 2011. The program's main assumption is that the revolutionary development of information technologies in general and of information systems in particular, changes organizational structure and organizational practices. Therefore, the workforce as a whole will benefit from acquiring basic academic knowledge in information systems, not only the engineers or those in managerial positions [7]. The notion of "community" in Community Information Systems is broad, including business communities as well as non-profit organizations, global or local organizations, public communities, cultural communities, and rural communities.

Imagining information system as a junction connecting (i) human users, (ii) supporting technologies, and (iii) organizational environment, the new curriculum includes (i) psychological and sociological aspects, (ii) information technologies and systems, and (iii) issues of organizational culture. This interdisciplinary approach can be seen also in Community Informatics (CI) undergraduate and graduate programs in Canada, USA, Australia, Italy, and many more [10] and in the emerging field of ICT and Development. The interdisciplinary nature of these fields calls for creating interdisciplinary academic programs that will support educating "more capable learners, more innovative teachers, more creative thinkers, more effective leaders and more engaged global citizens" [11]. Such programs enable students' specialization both in the technical and the social aspects of information systems. They also expose learners to the breadth of human arenas and communities supported by information systems like public health, economic development, education, and many more.

The three years curriculum is structured around "Information Technologies and Systems" as a core area of study. Required core courses provide half of the program credits - 60 out of 120 credits, where one credit typically equals fifteen class hours.

Additional ten credits are offered through elective courses in the core area of study. The rest of the credits are equally divided between two supporting areas of study: (a) "The Knowledge Society" and (b) "Information in Organizations". As can be seen in Table 1, students are exposed to the interdisciplinary nature of the program from Year 1. In the second and third years, students elect either area (a) or (b) as an area of specialization.

The core of the curriculum contains required foundation courses in three tracks: information and communication technologies (ICT), information systems (IS), and computer science (CS). The latter track is further described in Section III below. Area (a) "The Knowledge Society" includes required courses like digital culture, sociology of the internet, and evaluating digital communities. Area (b) "Information in Organizations" includes required courses like knowledge management and organizational behavior. As Table 1 demonstrates, while students elect only one area of specialization, they also take some required courses in the other area. That way the program provides the multidisciplinary knowledge required for entry-level positions in a wide spectrum of organizations.

TABLE I. DISTRIBUTION OF COURSES IN DIFFERENT AREAS OF STUDY

Area of study		***Year 1***	***Year 2***	***Year 3***	***Sum of Credits***
Core: Information Technologies and Systems	Required credits	21	22	17	60
	Elective credits		4	6	10
Sum of core credits		**21**	**26**	**23**	**70**
Areas of specialization:	Required credits in Area (a)	10	6	4	20
(a) The Knowledge Society	Required credits in Area (b)	10	6	4	20
(b) Information in Organizations	Elective (a) OR (b)		4	6	10
Sum of credits in areas of specialization		**20**	**16**	**14**	**50**

The structure of the Community Information Systems program separates the core of the curriculum from the electives with the intent of supporting the creation of a sound knowledge base of information systems, at a level appropriate for undergraduate students. At the same time, the courses in both areas of specializations mark the social, cultural, organizational, and human aspects as central to the knowledge base of information systems, thus can support the conceptual development of a multi-faceted body of knowledge by those who will study according to the new curriculum in Community Information Systems.

As a result of such integrated curriculum, we view graduates who are both information-technology-oriented and social-oriented, and thus can empower the communities where they live and work.

III. THE COMPUTER SCIENCE TRACK

As has been noted above, the new curriculum builds upon three parallel core tracks – 20 credits each, one of which focuses on computing principles and practices. This computer science track has been designed to suit the characteristics of the students in the program on the one hand, and to make computer science discourse and culture understandable by those students on the other hand. In other words, it is this track's goal to enable the graduates' participation in the professional discourse used among programmers, software designers, and software development teams. Towards this goal, four successive courses (4 credits each) are offered at the main computer science track, as is illustrated in Fig. 1. Java was selected for the second and the third object-oriented programming (OOP) courses because it is considered simpler than C++ for introducing OOP concepts for non-CS majors.

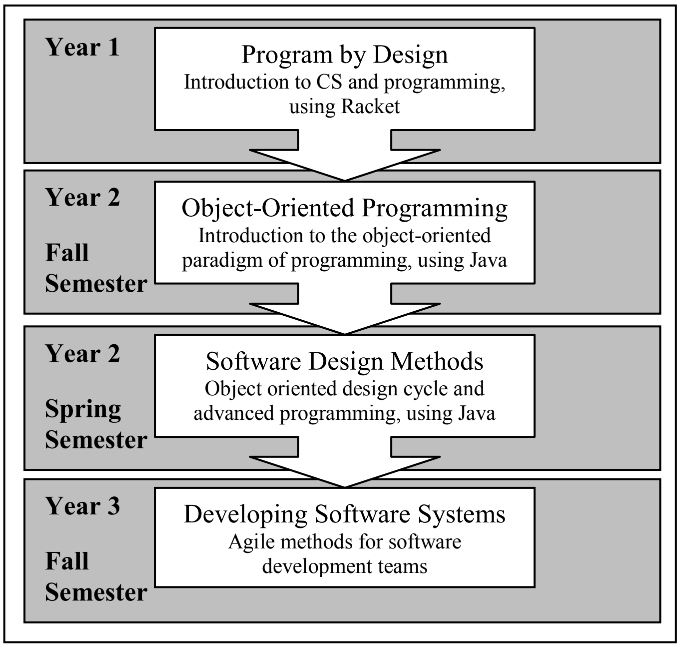

Fig. 1. The Flow of the Required Courses in the Computer Science Track

Together with few more CS courses (required courses such as data structures and electives such as applications programming), the 20 credits CS track integrates theory and practice while engaging students in the full cycle of software design. Since the students are not majoring in CS, and thus might not have an advanced mathematical and scientific background, the CS track starts with an educational approach called 'Program by Design' [9, 12] which is based on Racket programming [13]. As is detailed in the next section, this approach seems especially appropriate for a first programming course for non-CS majors, by focusing on developing design practices and desired programming habits from day one, by immersing learners into the profession's jargon, and by experiencing real coding with pictures instead of the conventional arithmetic jumpstart [14].

IV. THE FIRST COURSE IN THE COMPUTER SCIENCE TRACK

'Program by Design' is a longitudinal educational effort whose mission is 'to turn computing and programming into an indispensable part of the liberal arts curriculum'[1] both in high schools and undergraduate colleges. Led by Matthias Felleisen, the 2011 SIGCSE award winner for outstanding contribution to CS education, a group of CS professors and their students from several universities developed an innovative curricula and outreach program in order to address some of the most well-known issues in introductory programming courses [22], like the "blank page" syndrome, program diagnostics, visualizing programming and thinking processes [15], emphasizing testing [16], and tailoring IDEs for learners' needs and prior knowledge by offering a series of pedagogic language subsets, in which at every level the error messages never depend on knowledge that the student does not yet have.

Rooted in the paradigm of functional programing [16], 'Program by Design' is a functions-first approach to teaching introductory programming and problem-solving emphasizing good software engineering practices such as early testing from the beginning [17]. This is combined with the Racket IDE [13], featuring different language levels, simple syntax, customized error messages, and support for 'algebra of images' that enables students to write code for graphic- and animation-rich computing problems [14]. Most importantly, this educational approach offers design recipes to lead beginner students through a sequence of steps to obtain an understanding of the problem's nature and the solution program's behavior, hence the approach title. Testing is an integral part of the design recipe enabling test-first development [18]. Thus, the multi-step design recipe is useful not only to write programs but also to diagnose them. The design recipe scales naturally to the design of more and more complex systems of functions. This in turn empowers students to design programs for deep and interesting problems after just a minimum of introduction to the language, the environment, and the design recipes [9, 19].

The features of 'Program by Design' make the approach especially suitable as a starter for a computer science track of courses in the liberal-arts-oriented undergraduate curriculum in Community Information Systems. Since 'Program by Design' also includes support for transitioning to object-oriented

[1] http://www.programbydesign.org/overview

programming in Java and a method for using design recipes as part of an Object Oriented Programming IDE, the second course in the computer science track builds naturally on the first while further focusing on the systematic design of programs and classes as a preparation for the more advanced computer science courses (see the courses of Year 2 and Year 3 in Fig. 1).

An overview of the main computer science concepts in the first course is provided in Table 2. The course meets once a week for a four-hour lab session. The sessions are freely organized as a blend of short lecturer presentations, individual lab work, pair programming, and reflective class discussions. During the first weeks of the course, the students focus on fundamentals of programming by dealing with tasks involving pictures of their own choice, like overlaying one picture upon another, cropping certain parts of a picture, and drawing "the big picture" by combining picture parts [14]. Such focus is made available by the special library of functions that supports "algebra of images" included in the "beginner student" dialect of Racket IDE. Programming with pictures also enables students to creatively develop a small-scale programming project at an early stage of the course.

TABLE II. COURSE STRUCTURE

Week	Content
1-2	Built-in functions for manipulating pictures
3	Global variables as names for complex functional expressions
4	Contracts and error tracking
5	First mini-project: flags
6	Defining new functions
7	Parameters as local variables, scope
8	Design recipes and test cases
9	Second mini-project: simple animation
10-11	Conditionals
12	Structures
13	Final project

One recurring pedagogical pattern is weaved into many of the learning experiences and curriculum materials. In coordination with the test-first approach [18] and with Racket's unique function called check-expect[2] [12] that play an essential role in developing the culture of 'Program by Design', students are constantly asked to predict what they would expect to happen in a given situation before running the program, and write it down; to carefully observe and check the results of running the program; and finally to explain the results (which may or may not be what they predicted). This learning pattern follows the very well-known Predict-Observe-Explain structure [20] found successful in science education [21]. By using such pattern within the context of learning to program and by being able to embed it within the actual code, non-CS majors have the opportunity to experience one of the key components of the professional process of program design even at very early stages.

V. SUMMARY

A first course in computer science is in some sense an almost impossible task [14], in which students with various backgrounds need to learn (a) the grammar and the components of a programming language and (b) how to analyze a problem and design a program to solve it using that language. It is considered quite easy to get caught up in the details of (a) at the expense of (b), but the language itself might be obsolete by the time the students finish their course of study. The much more lasting knowledge is constructed through dealing with how to design a program that is both correct and easy to write, read, modify, and repair.

This might be true for any first computer science course, whether in middle school, high school, or college. It is certainly true for an introductory course for non-CS majors who are not intended to become professional programmers, as is the case described above. The focus on design patterns, which are step-by-step "recipes" for getting from a vague description of a problem to a working computer program, gives such students the "taste" of how professional programmers work in real-life contexts. The emphasis on test-first tools and pair programming helps the students experience a culture of programming and thus better understand the professional discourse among teams of programmers.

As the new program in Community Information Systems has only recently opened at our college, the implementation of 'Program by Design' with the first students has been in its early trial phase and the following conclusions are thus preliminary. However, even at this early stage, three central principles have proven viable for non-CS majors with variable background in programming. First, using pedagogically-grounded language tools and IDEs can indeed support novice learners' focus on the design process rather on the specifics of the language. Second, initiating the programming venture with tasks within the world of pictures, graphics, and animations, while building on an "algebra of images" rather than on arithmetic, opens up a whole new and unprejudiced context for both novices and those who have had some previous programming experience (or even a lot of experience). Within such a context, creativity often shows itself both at the level of the design process and at the level of the product. And third, applying test-first design and strict documentation requirements as early as possible (the third or four week) enforces disciplined programming while illustrating in a concrete way the program's desired behavior. Within the context of pictorial functional programming, students can combine small pieces of code into quite a complex program at an early stage. From the very beginning of the course they practice writing test cases before writing each function definition, and gain experience in phrasing each piece's contract [19], expected result, and test cases.

[2] Racket has a check-expect function which can be used inline with other Racket code to compare the result of two expressions.

In summary, although the students in the Community IS program are not expected to become professional programmers, their exposure to these basic features of software engineering makes them more able to talk to computer scientists, understand these professionals' concerns, collaborate with them in developing and maintaining organizational and communal IT projects, and at the same time to develop their own interdisciplinary career on a proper foundation. In the specific case here described, it is too early to tell how successful the CS introductory course will be in these regards. However, considering other cases, it is clear that one key to the success will be the distilling of well-known functional principles of programming into generally applicable design recipes that work also in other paradigms like that of object-oriented programming.

In light of current trends that call for programming for all[3] and regard coding as the literacy of the 21st century, the proposed CS track tailored for non-CS majors presents a valuable alternative to consider. Together with its 'Program by Design'-based introductory course, such a CS track has the potential to give students majoring in any field an understanding of the principles of computing and knowledge about the practices of computing professionals. That knowledge will undoubtedly support students' ability to make the choice so much needed "In the emergent, highly programmed landscape ahead… - Program or Be Programmed" [23].

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Assessing the Effectiveness of Video Feedback in the Computing Field

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***Abstract*—Engineering students exhibit a wide array of learning styles across the perception, input, organization, processing, and understanding dimensions. To improve students performance in the classroom, many techniques have been developed to address these variances. The computing fields, however, tend to have a large percentage of students who are visual learners. These students learn best by seeing, and they can perform very well in the classroom with the appropriate usage of teaching styles.**

However, when it comes to providing feedback to students on submitted assignments, the main method employed is the written comment, which is not conducive to visual learners. This method is most prevalent in the academic community because overall, it is the simplest form of feedback that a faculty member can provide to students. However, written feedback is often highly ineffective at improving student performance, as many students simply do not read the comments because the students feel they are not relevant to their performance.

This paper presents an assessment of an alternative method for providing feedback to students: video feedback. In lieu of written feedback, students are provided feedback for software engineering exercises through the use of a short video made via video capture. The video captures in multimedia format the instructors perceptions and actions when grading a given assignment. The video includes both aural commentary as the assignment is assessed, as well as dynamic visuals of the grading process, demonstrating failures and improvements that can be made in the submitted assignment. The article describes the pedagogical foundation for the technique, specifics of the technique used, student perceptions of the technique, and an assessment of the learning gains from using such a method in a junior level class. In general, students are show to prefer the technique versus traditional grading, and an improvement in overall outcomes for the course is shown to exist as well.

I. Introduction

It is well known within the educational community that students exhibit different learning styles. Effective educators use different techniques to address these learning styles in the lecture and lab environment. Active learning, Co-Operative Learning, problem based learning, inquiry based learning, POGIL, and other techniques are all routinely applied in the classroom to improve student achievement.

Feedback has been shown to be the single most powerful influence on student success[1]. For feedback to be meaningful, it must meet many criteria, including being applicable to the student [2], delivered in a timely fashion, engaging to the students, and relevant to the topic at hand[3]. If students do not feel that this is true, they often ignore the feedback, either throwing away the assignment or simply looking at the final grade[4].

To facilitate better feedback, effective instructors use grading rubrics to assess student performance. Rubrics aid faculty members in being more efficient and consistent in grading. However, too much reliance on simply grading with rubrics has been attributed to causing "more superficial thinking, less interest in whatever one is doing, less perseverance in the face of failure, and a tendency to attribute the outcome to innate ability and other factors thought to be beyond ones control."[5].

Despite all of the changes to the classroom brought on by technology, the composition of student feedback has generally remained unchanged. Written comments make up 79% of feedback received by students, though 45% of students reported that they rarely received individual written feedback on assignments [6], and many students readily admit that they do not read written comments[7]. This is unfortunate, for as Hounsell states:

> *"It has long been recognized, by researchers and practitioners alike, that feedback plays a decisive role in learning and development, within and beyond formal educational settings. We learn faster, and much more effectively, when we have a clear sense of how well we are doing and what we might need to do in order to improve."*[8]

In certain environments, oral feedback has been used. Oral comments have long been used in the artistic areas, where an adjudicator records audio feedback to a musical ensemble overtop of a performance recording[9]. Oral comments have also been used informally in class and in team "coaching" situations where the instructor takes on a "mentoring" role.

Recent work, however, has shown that audio commentary has significant advantages in helping students to learn. In research studies, students have shown a preference for audio commentary over written comments [10]. Students believed that audio feedback was of higher quality than written feedback, easier to understand, and more personal than written feedback[11]. Audio feedback also has been linked to a feeling of increased personal involvement and increased retention of content[12]. These are clearly beneficial aspects of audio feedback.

However, while very beneficial to auditory learners, such an approach may not be as beneficial to visual learners. Visual learners tend to learn best through picture, charts, diagrams,

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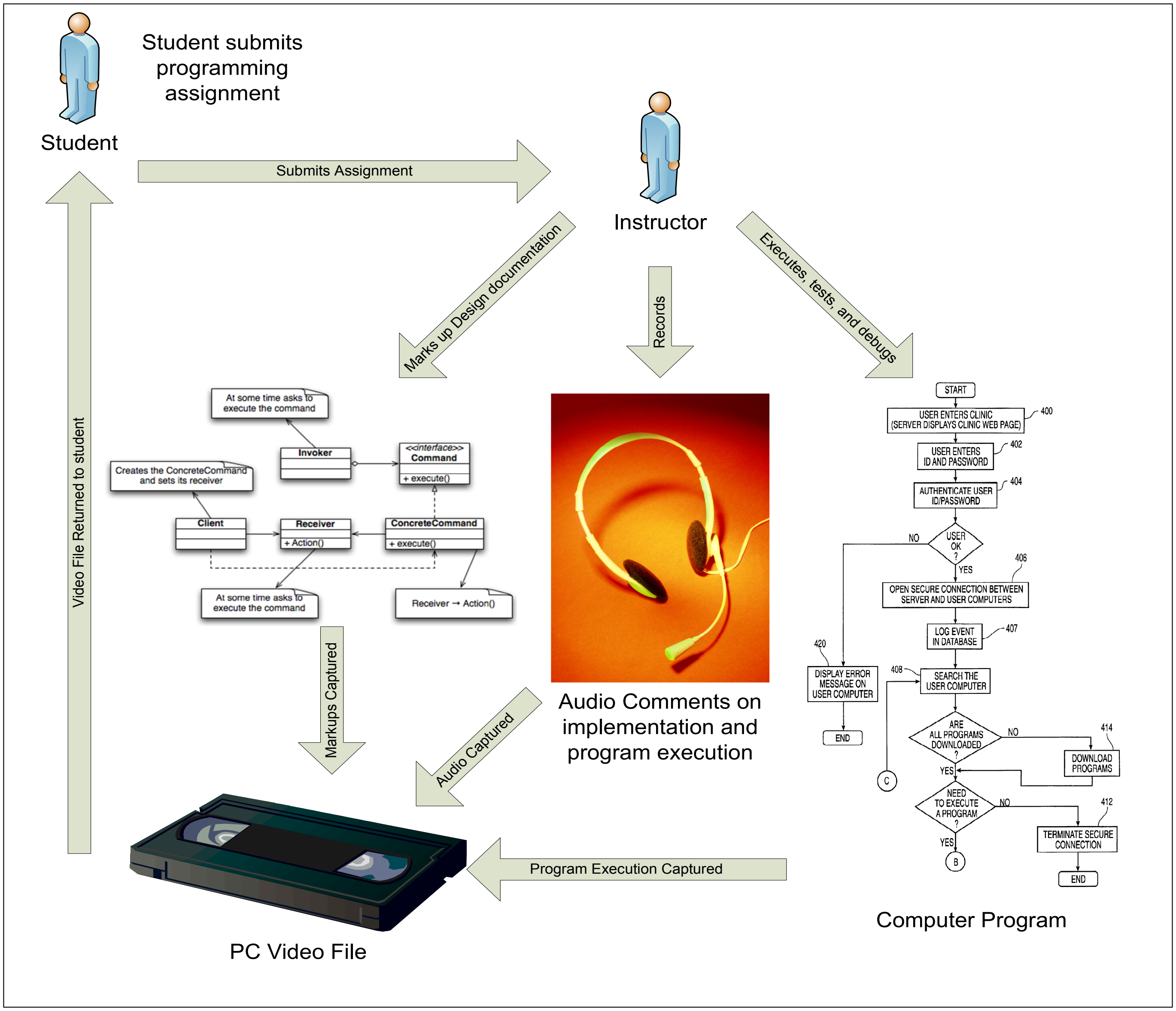

Fig. 1. Video Grading Process

flowcharts, visual similarities, and color coded markups. Visual learners also tend to be the majority of students in the engineering disciplines[13]. Certain engineering fields, software engineering, civil engineering, and architectural engineering, for example, are extremely visual in nature, and problems with design may better expressed visually through markups and sketches than oral commentary. Audio commentary in and of itself does not aid the visual learner over written comments. Thus, while audio commentary is an improvement over written feedback, it still is not optimal. To truly reach all student learning styles, feedback to the students must also incorporate visual feedback. This has led to the concept of multimedia feedback using customized videos. With this approach, it is now possible for students to receive both oral and visual feedback in a timely fashion.

II. Multimedia Grading using Videos

Video grading uses many of the same production techniques as the inverted classroom, in that the instructor creates a video during the grading session, except that the video is customized to each student or student team based on submitted work, and the focus of the video is to provide targeted meaningful feedback rather than to introduce a new concept. This is, in some manner, more difficult than the traditional usage of videos, as the traditional usage of videos requires the instructor to carefully design the video to maximize all students' learning whereas this approach generates a customized video for each student or team.

Video grading, shown in Figure 1, starts in much the same manner as any other form of electronic grading. A student submits to an instructor an assignment in electronic format. In the software engineering field, this includes a lab report with documentation and source code for a program implementation.

- “I thought the video was interesting. It was very nice to receive more feedback than a few red words within the code. Perhaps going through the report wasn’t necessary, unless it was to answer questions being asked in it. It just seemed you were reading to me what I had written to you. Going through the code was very helpful though.” CE2810, Spring 2012
- “As per your request I just wanted to let you know that I felt the video feedback was very nice. It was really helpful to see what you thought of my code and where/how it could be improved. In particular, I didn’t even think about putting attributes static where appropriate. The only problem I can see with the video feedback is that the video files are massive! 11 megabytes when MSOE only offers us a measly 95...” CE2810, Spring 2012

Fig. 2. Sample student comment on video grading from the first course.

Instead of simply marking up the assignment with annotations, the instructor captures the markups as they are created and adds additional oral explanations.

While video grading can aid students in any assignment, in the computing area it is especially relevant. In the software engineering field, many of the deliverables from students manifest themselves as executable code. The instructor can execute the programs and capture the output, clearly showing the behavior of the system. The student, in turn, can see exactly what the instructor was marking up and hear exactly why the markups were made.

One distinct advantage of this process is that in addition to aiding visual learners, it really helps the students to see the non-linear process of assessing a submission. For example, when an instructor grades an assignment, he may refer back to a previous page if something contradictory is found later on or if a duplicated point is found. With this approach, since the student is visualizing exactly what the instructor saw when the assignment was graded, the student sees the instructor returning to the previous location and clearly can follow the reference.

III. Student Assessment of Technique

Video grading has been used in multiple courses at the Milwaukee School of Engineering since the Spring of 2012.

The first course for which video feedback was used was an embedded systems course. In this course, students created simple embedded systems in the C programming language, and demonstrated their operation on an embedded board. Deliverables for assignments consisted of C source code, build files, and a simple lab report describing the design and implementation of the program. Video feedback was tried purely on an experimental basis, and comments mainly dealt with explaining the problems of implemented source code as well as explaining the meaning of associated compiler warnings which were generated during code compilation. A brief review of the submitted reports was also provided. Students provided informal feedback to the professor through freeform e-mail messages, and overall, the comments were found to be very favorable, as is shown in Figure 2.

This initial success led to the application of the process in a software requirements course. In this course, students elicited requirements from stakeholders for a medical project. Deliverables were principally in the document format and were completed in teams of 4 to 5. Feedback from the professor mainly focused on the critique of the requirements artifacts, as well as questions addressing ambiguities found in the artifact. Unlike the first experience, there were no executable programs delivered by the students. Students found this to be a very beneficial experience, and responded very positively to the experience[14].

Simultaneously with the requirements course, the technique was applied to a course in operating systems design. In this course, students learned about the design aspects for an operating system. Deliverables for this course consisted principally of C programs and design documentation for those programs. Feedback from the professor focused on several aspects, including source code commenting, source code structure and syntax usage, debugging of source code, and ad-hoc testing of the code in a Linux virtual machine.

At the end of the course, students were asked to complete a brief survey detailing their experiences. The survey was intended to answer multiple questions about the approach. First and foremost, there was a need to know if the students watched the videos. No matter how successful they might be, if the students did not watch the videos, then they would not receive the feedback on their assignment, negating the purpose for the video grading session. This then led into an assessment of the effectiveness of the video presentations and commentary. If the students did not feel the feedback was at least equivalent to traditional feedback mechanisms, then the technique would not be successful. The final area of assessment dealt with the technical issues of video feedback, such as making certain the videos were legible and could be seen clearly, as well as were the videos of the proper length.

Overall, based on the survey results shown in Figure 3, the technique was viewed extremely favorably by the students. 86% of students indicated they watched the majority of the videos, with only 14% indicating they watched only 2 videos. While it is impossible to determine if the students were attentive to the video, the fact that they watched the videos seems to indicate they were interested in the feedback that was provided.

While the quantitative assessment provided a strong endorsement for the technique, the written comments provided by the students indicated a few areas of concern. One area students exhibited concern over was the ability to re-review the comments. With traditional paper based comments, a student can easily re-read the comments from the instructor. This process was not as easy to do with video grading, as the only way to review the commentary was to watch and listen to the video again, taking more time. Furthermore, locating a specific comment was believed to be easier with traditional paper grading, as again, a student could skim all comments until the desired comment was found.

Another area of concern expressed by students was the relationship between coverage and time. While the students stated that full coverage of a large lab might be time prohibitive, they

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I found the video format more helpful than traditional paper-based assignment feedback.	29%	57%	7%	0%	7%
I found the audio commentary more helpful than traditional written comments.	50%	29%	14%	0%	0%
I was able to read the text on the video.	57%	36%	0%	0%	7%
I was able to clearly see what was being described in the video.	31%	62%	0%	0%	8%
I prefer video feedback to traditional feedback in computer courses.	38%	54%	0%	0%	8%
I felt that the length of the videos were:	**Way Too Short** 0%	**Too Short** 0%	**About Right** 100%	**Too Long** 0%	**Way Too Long** 0%
How many of the videos did you watch?	4 or more 57%	3 29%	2 14%	1 0%	0 0%

Fig. 3. Student survey results.

- Excluding the audio, as I see that's in the following question, the video format helps most in being able to show a test run of the assignments.
- I thought it was very insightful to hear what you were thinking as you were thinking it. Sometimes a lot of that thought process is lost when written down, so a video record helps catch that info. Additionally, it helps that we see exactly what problems you're having with running the program, if there are any.
- Easier to reread paper than go back in video.
- While hearing the feedback vs reading the feedback makes no difference to me, handwriting at times can be very hard to read. This was eliminated using the videos.
- The audio commentary has much higher potential for actual reviewing of the code than of written comments. I think a large part is the ability to be nonlinear in how the code is analyzed, as opposed to written comments on a listing having to be in order of each file. More depth can also be gone into on specific points of the code than what can be fit in the margins of a listing. The downside came from the fact that for larger labs, only a small portion of the code was really covered in the videos; however the amount of time required to go more in-depth on larger labs could be prohibitive in itself. I feel that a combination of audio and written comments, maybe with the audio focusing on higher level structural/design with more targeted written comments where required, would provide more useful feedback with larger labs.
- Would have liked them to be slightly longer on labs which contained more code
- I think they were pretty solid. They provided just the right amount of information. It was nice.
- I think in a course like operating systems, where the labs are a little more technical and have a product where we need to demonstrate something, video grading is very helpful.
- You should look into some video editing tools to help with proper compression. This would help with the issues of distributing the videos.

Fig. 4. Sample student comment on video grading from CS3841 Design of Operating Systems.

expressed a concern that in trying to fit the grading session into a short video, problems in the assignment might be missed.

IV. Comparison of Student Outcome Performance

The Design of Operating course had been taught multiple times previously by the same instructor. The lab sequence was identical in learning outcomes and the same grading rubrics were used in previous offerings of the course. Thus, it was possible to compare students' performance across the different offerings to determine the impact of video grading.

For each lab assignment, students were assessed in a number of areas using a 5 point grading rubric. While the specifics of the rubric varied between assignments, a score of "5" was defined to represent work which was fully compliant with the assessment criteria and no major or minor errors were noted. A score of "4" indicated the assessment item was mostly complete, though some minor error was detected in the work. A score of "3" indicated the work was slightly flawed, with multiple minor errors being detected during assessment. A score of "2" indicated the work had a significant flaw present which was uncovered during assessment. A score of "1" indicated the work was significantly flawed, with multiple major errors being detected during assessment. "0" indicated the item was absent and therefore could not be assessed.

Figure 5 provides a plot of student achievement on each of the laboratory assignments conducted in the Design of Operating Systems course. The chart includes the average assessments on programming and design related rubric assessments. Any assessments of writing skills or other "non-technical" aspects of the assignments were removed from the assessment to allow a focus on the core technical material of the course. It includes two control groups representing last two offerings of the course using "traditional" grading techniques as well the "experimental" course using video grading. The chart indicates that the video grading cohort tended to score lower on the first lab than the two control groups. However, the final three labs show scores higher than the two experimental groups. Furthermore, with the exception of lab 3 which was one of the two most technically challenging labs to the students in the course, the video grading class tended to improve their performance with each submitted lab.

The differences between student performance are more striking if the results are normalized to the first lab score, as is shown in Figure 5. In essence, with the exception of one of the control groups, students always scored better on the

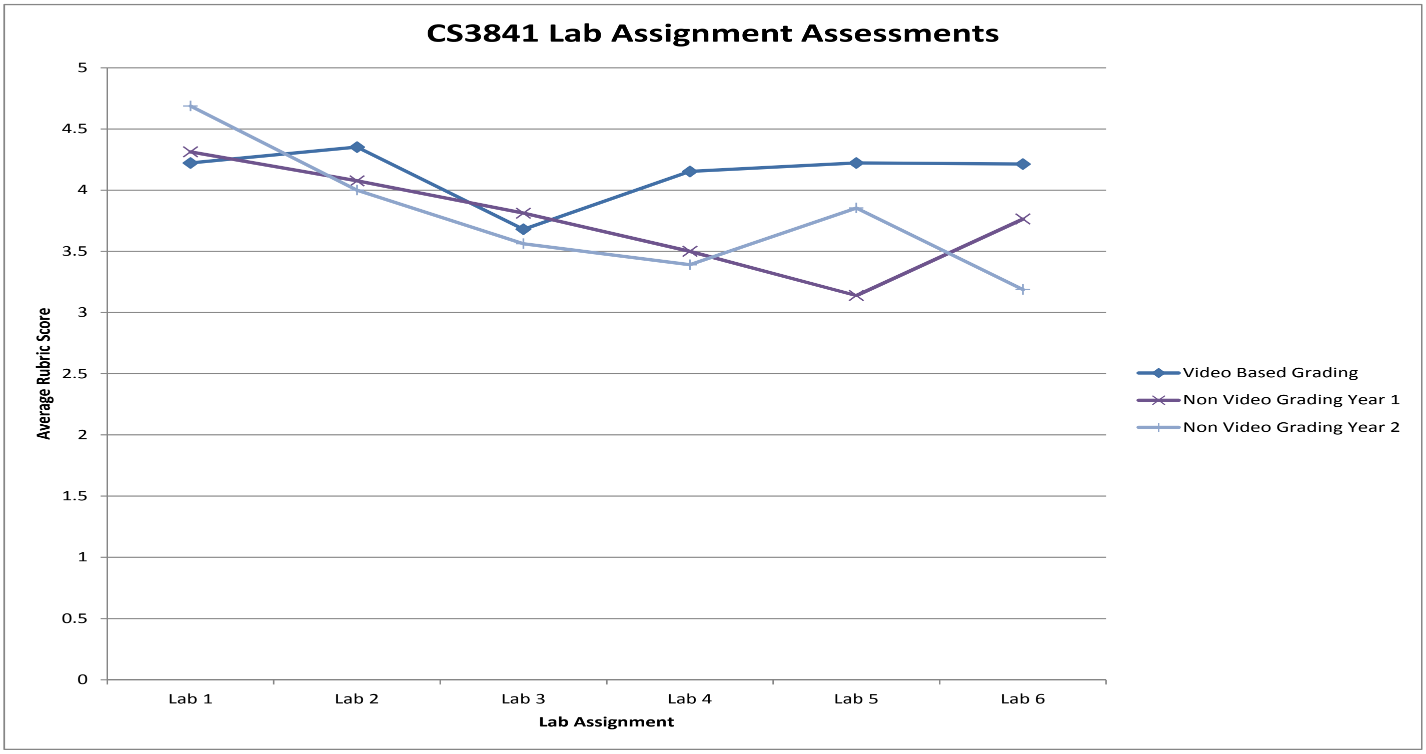

Fig. 5. Average student achievement on selected rubric assessments for operating systems labs.

lab assignments which were graded using video grading. And, whereas in the control groups, the overall student achievement on the last labs was less[1] than what was obtained on the first lab, the students in the course using video grading achieved approximately the same across all labs. This indicates that the students in the video grading course effectively performed better on the same assignments than those in the non-video grading course.

V. Impact upon the Faculty Member

A shift in technology can have significant impacts upon the faculty member. When considering a technique such as video grading, it is important to weigh the change in effort in order to apply the technology.

The first question which must be answered is does video grading require additional faculty time or does it offer a reduction in the time spent grading. Overall, it was found that video grading did not increase the time spent grading by a significant amount. Given that the operating systems design course had been taught previously and used the same sets of labs, a direct comparison could be made, normalized for the number of students. Overall, the net amount of time spent grading per student was within 5% when using video grading and traditional grading using a rubric and tablet PC to markup report submissions.

[1] While diminishing assessments like this can be disconcerting, the latter labs were significantly harder than the first lab, and thus, it is not surprising that student achievement on later labs is lower than the first lab, as there simply are more areas in which a student can make a mistake due to increased complexity.

The time spent assessing the submission was about the same as would be spent with traditional feedback mechanisms. There was an added processing component that would not be present in traditional grading dealing with generating the videos from the video capture. For an video of approximately 5 minutes, this post-processing added 3 minutes to the amount of time spent grading each assignment. However, this processing was batched and performed off-line when the professor was not present, making the recording time the limiting factor for grading.

From an anecdotal level, there did seem to be more students coming in during office hours to discuss problems with lab assignments versus previous offerings. This have been a small sign of increased student engagement in the course. However, detailed quantifiable data is not available to further quantify this impact.

VI. Conclusions and Future Work

From the data available, it is very difficult to assess causality for the performance improvement seen in the data. Based on the lab 1 assignment, which is primarily a pre-requisite assessment, it would have been assumed that the video grading group should have performed lower than previous sections, as at the start, they lacked fundamental skills. However, this trend did not occur, and the video grading course outperformed students in the other two offerings.

Part of the performance improvement may have come from students being more engaged in the course because of the video grading. As a student, it is very easy to disregard a comment from an instructor when the student is unable to

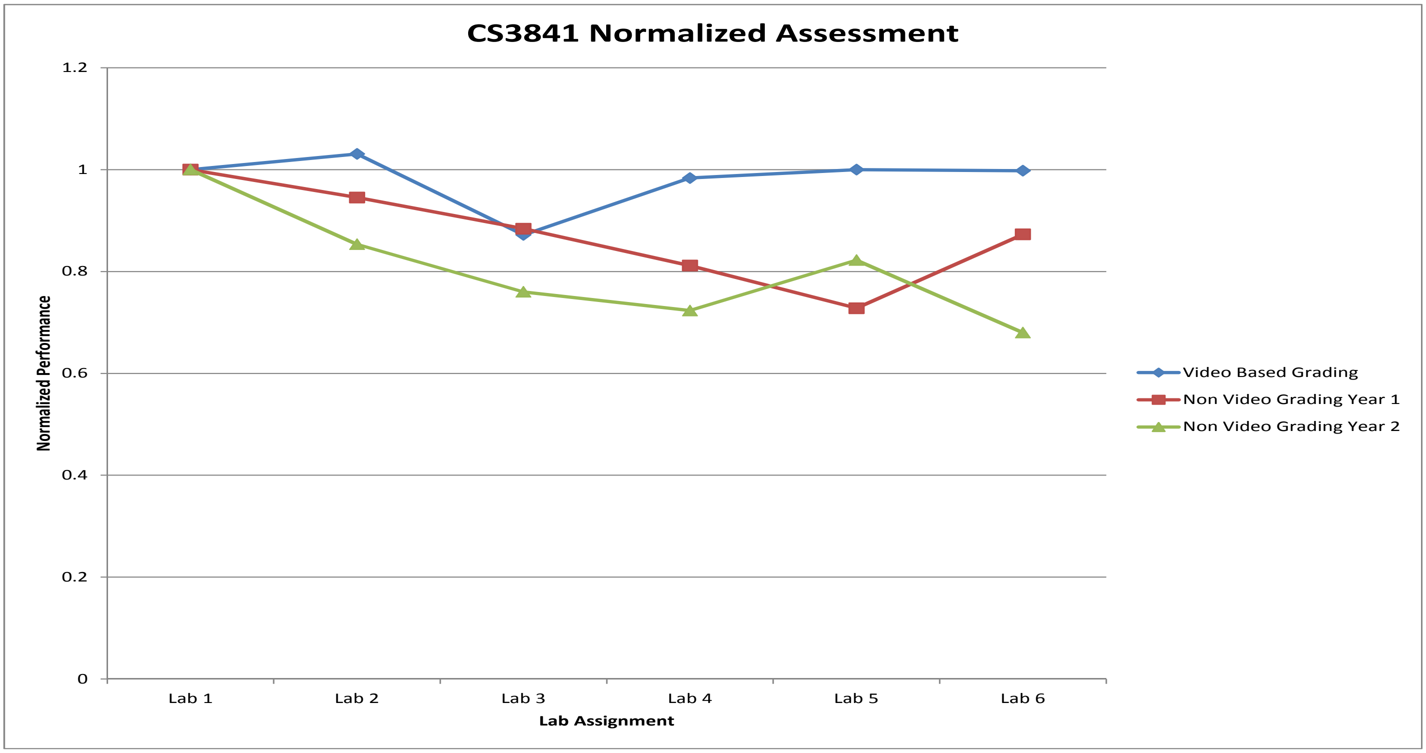

Fig. 6. Normalized student achievement on selected rubric assessments for operating systems labs.

reproduce the problem on his or her own computer. However, it is harder to disregard the problem if specific video evidence is provided showing exactly the manner in which the software behaved when provided with a set of input stimuli. This extra engagement certainly may have forced students to understand their mistakes from one lab assignment so as not to repeat them on the next assignment. This may have also contributed to the increase in office hour visits.

Students may also have had a more personal attachment to the feedback provided since it came in a video format. In traditional grading, the student only sees the final, impersonal marks on the page. With video grading, the student can hear the instructor speaking as well as see the thought process going into the assessment, improving information transfer. This in-depth understanding of thought process applied by the professor may help to elevate the student's own thought processes as the next lab is completed, again improving their performance.

There is obviously much more research to be done to assess the effectiveness of video grading. To make video grading successful, it is imperative that the results are duplicated in other larger studies. The scope of this evaluation was small (one class at one institution) and the sample size was also very limited. However, it is believed that this is an acceptable way for assessing student work that offers advantages in the digital age, especially in the computing field where assignments involve complex dynamic systems.

Once it can be determined if this technique is effective, it is important to further understand the cognitive aspects which contribute to the success of the technique. Does the student perform better because they are more engaged in the course, or do they perform better because the multi-sense feedback is more effective than traditional feedback forms? This aspect requires collaboration outside of the engineering discipline to completely explain.

One of the most important questions to answer is what type of assignment benefits the most from this form of assessment. This course focused on using the technique with simple programming exercises, but the approach could be applied to UML designs, user interface designs, and other aspects of software engineering.

It is also important to try and understand the learning styles of the students who benefit the most from video grading. It is possible that some types of students might receive a greater benefit from this approach versus traditional techniques, whereas other students might be placed at a disadvantage by using such a technique.

This technique also has vast applications to non-traditional learning. Distance education courses often are viewed as impersonal by students. A technique such as this might increase students interest in the course through asynchronous personalization of feedback. Another area of potential application is the Massive Open Online Course movement (MOOC). Due to their size, assessment in MOOCs is typically limited to automated assessments or peer assessments by fellow students. A video grading technique might increase student engagement and improve the very poor completion rates (less than 3%) for the courses[15].

VII. SUMMARY

This article has described an innovative grading technique for engineering assignments. Using this technique, assessments are returned to the students using a video capture system. In addition to seeing the assignment marked up in a dynamic fashion, students are provided with audio comments which further describe the thoughts of the instructor when grading the assignment.

Overall, the process is found to be time effective, varying by less than 5% versus traditional grading techniques. More importantly, however, students tended to achieve higher scores on assignments when video grading was employed than they did with traditional grading.

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Portable Lab Modules on Cloud Computing

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***Abstract*— Cloud computing is a highly scalable model for delivering information technology resources and applications, on demand, as a service, to end users through the network. In recent years, cloud computing has been adopted rapidly and extensively in industry. Notable public cloud services include Amazon Elastic Compute Cloud (EC2) and Google App Engine, among others. There is a fast growing demand for professionals with cloud computing skills. However, the demand is not being fulfilled, partially due to the inability of educational institutions to keep up with technological advancements, as well as a lack of hands-on educational material.**

We have been developing portable virtual lab modules which can be used to teach basic cloud computing concepts and skills early and often. The labs run on virtual machines and can be ported between different courses and between different platforms. The virtual labs can be deployed in centralized or decentralized ways. To meet the learning outcomes, the students are expected to: 1) comprehend the fundamental concepts of cloud computing; 2) identify the building blocks of cloud computing systems; 3) understand the basic operation of open source cloud infrastructures; and 4) recognize commonly used, commercial cloud computing services and applications.

Keywords—cloud computing; virtualization; virtual laboratory; online education

I. Introduction

Cloud computing has made transformative changes in Information Technology (IT) services in industry, government and education. Cloud computing is a highly scalable model for delivering IT resources and applications, on demand, as a service, to end users through the network [1]. Notable public cloud services include Amazon Elastic Compute Cloud (EC2) and Google App Engine, among others. Meanwhile, many companies and institutions have been deploying private cloud infrastructures, hosted on platforms such as Xen, KVM, OpenVZ, VMware vSphere and Microsoft Hyper-V. Cloud computing can be implemented in different ways. Therefore, there are many different cloud solutions provided by different vendors such as VMware, Citrix, Red Hat and Microsoft. The existing education material is usually designed by a particular vendor and focuses on vendor-specific technology.

There is a fast growing demand for professionals with cloud computing skills. A quick search at online job sites such as monster.com, or dice.com, will demonstrate that there are a great number of open positions for information technology professionals with cloud computing skills. It is likely that today's professionals will work in a more and more virtualized environment that requires basic cloud computing skills. Not only information technology specialists, but also professionals in science and engineering, will need some basic understanding of cloud concepts. However, there are few educational resources which cover cloud computing in a vendor-neutral way [2].

We are working on developing hands-on instructional material on cloud computing, covering the general concepts and various open source and commercial solutions. Instead of making major curriculum revisions or inserting new courses into the already crowded curriculum, we plan to develop portable lab modules which can be reused in multiple courses as supplemental projects.

II. Project Description

A. Purpose

The purpose of this project is to introduce basic cloud computing concepts to a large group of students early and often. Many virtual labs can be performed in centralized or decentralized ways [3]. In the centralized approach, the virtual lab environments are hosted on the central servers on campus, remotely accessible by students using a client program. In the decentralized approach, the students can download and run the virtual lab environments on their personal computers using a hosted hypervisor such as VMware Workstation or Oracle VirtualBox. As a result, the students will be able to conduct the labs at any place and at any time. Due to the availability of free hosted hypervisor programs such as Oracle VirtualBox, the costs of the decentralized approach are relatively low.

The tentative titles of lab modules are as follows: 1) Open Source Cloud I: Container-based Cloud; 2) Open Source Cloud II: Xen Cloud Platform; 3) Open Source Cloud III: Virtual Computing Lab; 4) Cloud Management using Red Hat Enterprise Virtualization (RHEV); 5) Exploring Amazon Elastic Compute Cloud; 6) Google Cloud Connect; 7) Microsoft Windows Azure and Hyper-V; and 8) Distributed Cloud Storage.

The lab modules are portable in that they are independent and can be used in different courses, moved between different platforms and deployed in different institutions. Since the lab modules do not depend on each other, the instructor can adopt the ones which can fit into her/his schedule.

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B. Method

The labs are to be performed on different virtual cloud environments. As shown in Fig.1, a virtual cloud environment typically contains one or more custom virtual machines and virtual networks, supported by bare-metal (native) hypervisor or hosted hypervisor. The hosted hypervisor runs on top of a conventional operating system such as Windows or Linux and supports guest virtual machines. Examples of hosted hypervisor include Oracle VirtualBox and VMware Workstation, among others. The bare-metal hypervisor is installed directly on the host physical server, controls the physical server and supports guest virtual machines. Examples of bare-metal (native) hypervisor include Xen, KVM, VMware ESXi, and Microsoft Hyper-V, among others. In Fig. 1, on the first layer of virtual machines, another layer of bare-metal (native) hypervisor or hosted hypervisor or container-capable operating system is installed to support more virtual machines, forming the building blocks of private clouds. This type of VM-inside-VM or Cloud-inside-Cloud solutions may not be efficient for real-world enterprise applications but are useful in academic teaching and research owing to its portability [4]. By setting up the hypervisor on a virtual machine, it is possible to create an image of the whole system which contains a virtual cloud environment. This image can be moved (ported) around and deployed easily on different platforms.

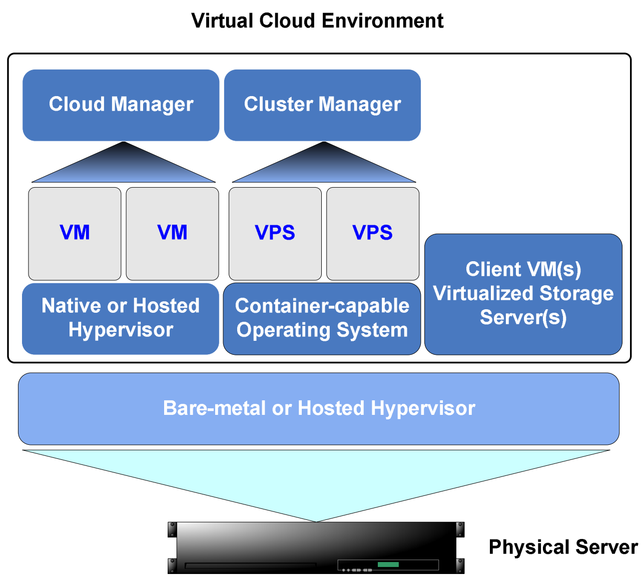

Fig. 1. A typical virtual cloud environment

The project development will follow a four-step procedure. In the first step, the outcomes and tasks of each lab are identified. For example, an outcome can be defined as so: "After this lab is completed, the students will understand the process for setting up a private cloud system using Microsoft Hyper-V." In the second step, the lab manual, the answer sheet, the virtual cloud environment, and supporting material (e.g. demonstration videos) will be developed. In the third step, the newly created lab modules will be tested and deployed. In the fourth step, the lab modules will be evaluated and adapted.

In the past few years, we have created multiple custom virtual environments and deploy them in centralized and decentralized settings. We have accumulated extensive experiences in designing virtual labs. Most of the newly created labs in this project will be hosted by a centralized cloud infrastructure including fifteen high-performance servers that were received through an equipment grant from Hewlett-Packard. Some labs can also be deployed in a decentralized manner, in which students run the virtual labs on their personal computers.

C. Assessment

To meet the learning outcomes, the students are expected to: 1) comprehend the fundamental concepts of cloud computing; 2) identify the building blocks of cloud computing systems; 3) understand the basic operation of open source cloud infrastructures; and 4) recognize commonly used, commercial cloud computing services and applications.

This project is still work in progress. To measure whether the learning outcomes are met at the end of the project, the lab reports submitted by students will be evaluated. In addition, a pre-class survey and a post-class survey will be conducted anonymously and voluntarily to assess the outcomes, the degree of interest, the degree of satisfaction with the project, the usability and the availability of the virtual cloud environments. The surveys will contain true/false, multiple choice, multiple answer and opinion scale questions.

III. Summary

The goal of this project is to design portable lab modules which can be used to introduce basic cloud computing concepts to students with various background early and often. The project is currently in the phase of developing custom virtual cloud environments. The lab modules, once completed, can be deployed independently, in decentralized and centralized manners. The students will be able to perform the labs using the virtual environments.

We believe this approach will serve the students well because 1) it provides students with multiple opportunities to learn cloud computing; 2) it does not require major changes to the curriculum and 3) it can be deployed and adjusted quickly.

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Functional Approaches to Teaching Concurrency

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***Abstract*—Traditional approaches to addressing issues of concurrency rely on mechanisms added to standard imperative languages such as Java, such as "synchronized" methods and blocks, combined with a "wait/notify" mechanism used to block and awaken processes when a shared resource is not in an acceptable state. The problem with this approach, however, is that mutable state is potentially accessible via many paths, and each such path must be analyzed for possible race conditions, deadlocks, and safety violations.**

The root cause of many concurrency problems is attributable to shared, mutable state. In light of this, two approaches to mitigating concurrency problems are immutable variables and state isolation within distinct concurrent actors. Erlang, a language developed at Ericsson for distributed, fault-tolerant switches, is a language supporting both approaches.

This paper reports on an experiment to include Erlang as part of an existing course on concurrent systems design. This version of the course is currently underway, and the Erlang material is being introduced as this is written. Results from the approach will be ready well before the conference, and should serve as an inspiration (or warning) to others considering such a change.

Keywords—software engineering; concurrent and distributed systems; functional languages; computing education.

I. INTRODUCTION

In simpler times, relatively few software engineers were concerned with concurrency. For the most part such concerns were restricted to those developing operating systems, networking protocols, and database transaction processing systems. The vast majority of engineers worked in the stable world of sequential processes, where program statements were executed in the order written, and where reproducibility could be assumed when diagnosing and repairing faults. While graduates of computing programs were usually exposed to concurrency issues in an operating systems or database management course, the material could be safely ignored once the final exam was over.

This is no longer the case - today's software environment is one of large-scale distributed processing, with local concurrency on multi-core computers. To increase performance in the future, developers will have to rely on explicitly concurrent and distributed computation. All of the problems that hounded the select few in the past - race conditions, deadlocks, liveness concerns, safety issues, irreproducible execution - must now be faced by the majority of software engineers.

II. THE BANE OF CONCURRENCY - SHARED, MUTABLE STATE

It is not at all obvious that traditional imperative languages, such as Java and C, are up to the challenge presented by pervasive concurrency. These languages are prone to race conditions, where a variable's value depends on the execution order of instructions in independent concurrent entities (threads, processes, tasks). For example, it is a trivial (and enlightening) exercise to create race conditions in Java on a multicore system - simply have two or more independent threads increment a public shared variable one million times. Even if the variable is declared **volatile** - as a hedge against memory caching inconsistencies - interleaved instructions almost always results in a final value much less than expected.

Imperative languages typically address this problem by providing a locking mechanism to ensure mutually exclusive access to shared, mutable state. Sometimes this is built into the language: Java supports **synchronized** methods and blocks to lock an object, as well as **wait** and **notify** to synchronize on the object's state [1]. C provides similar functionality in the POSIX Pthreads library [2] via semaphores and condition variables. These mechanisms, based on classic work of Dijkstra [3] and Hoare [4], are sufficient to address concurrency issues. Unfortunately, they are also prone to erroneous use.

Thus, even with this support, it is difficult to design and implement thread-safe components and systems. This is especially true when the increased performance is the primary motivation for concurrency. For safety, exclusive access is required when manipulating mutable state. For performance, the locking to ensure exclusion must not be too conservative. What is more, reasoning about the paths through which unexpected state conflicts may arise is especially difficult under concurrency. It is part of the Java concurrency community's lore that most Java programs are only accidentally thread safe - to date. Catastrophic synchronization errors can remain hidden for months or years until triggered by just the right combination of concurrent activity [5].

III. FUNCTIONAL LANGUAGES - A WAY OUT?

If concurrency problems are exacerbated by simultaneous attempts to alter shared, mutable state, two alternatives become apparent: eliminate mutable state and/or eliminate sharing.

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Emphasizing immutability has been the province of functional languages, beginning with LISP [6] and continuing up to modern successors such as Clojure [7] and Haskell [8]. While unfamiliar to many software developers, after decades of development these languages appear poised to challenge conventional wisdom that only imperative languages provide the flexibility and performance required by modern applications. Not only do compilers for these languages generate code competitive with those for C, Java, etc., they also model a world of pure values, along with functions to transform them. Without mutable variables, function side-effects are impossible and common sources of race conditions eliminated.

Actor languages [9] address sharing by encapsulating any mutable state in an active actor process (or thread). Actors receive serialized requests for service; since requests themselves are normally immutable, and only the actor can change its internal state, data races among requestors are eliminated.

Some emerging languages, such as Scala [10] and Erlang [11], provide linguistic support for both immutable state and actor based concurrency. Advocates for these languages argue that by eliminating shared, mutable state, these systems enable simpler designs and more easily verified construction of concurrent and distributed systems. It is not that deadlock, livelock, etc. magically disappear, but they become less likely and easier to discover, diagnose and repair.

What is more, proponents argue, functional languages scale better in an age of multicore processors and pervasive hardware caching. Ericsson used Erlang, for instance, to create highly reliable, distributed telephony switches based on Erlang's "inexpensive process" model. The YAWS web server, written in Erlang, continues to provide service well beyond a load that causes a traditional Apache server to die [12]. In large measure this is due to the pervasive (not to say profligate) use of Erlang processes, whose low overhead is largely attributable to immutable state.

Over the past several years, I have become convinced that there is at least a grain of truth to the claims of functional language supporters. In any event, given the rise commercial systems using this technology, such as GitHub [12] and Twitter [13], as well as open-source databases like CouchDB [14], it is time software engineering programs acknowledge these developments in their courses.

IV. THE EXPERIMENT

This spring, I am using both Java and Erlang in the department's course on *Principles of Concurrent System Design*. As it turns out, this spring quarter has proven ideal for this experiment:

1. I am teaching the one and only section of the course (thus there is no need to coordinate with other course sections).
2. This is the final course offering, as in the fall of 2013 RIT is moving from quarters to semesters. This last offering serves as a "stalking horse" for the organization of a new semester course covering concurrent and distributed systems.
3. Only eight students are enrolled, making it easier to address issues that inevitably arise when undertaking such experiments.

What could possibly go wrong? Well, two significant risks come to mind.

First, students may spend so much time mastering Erlang as a technology that they have no time left to learn how to apply it functional approaches effectively. Second, unless we are careful, students may fail to understand how Erlang's approach differs from that of Java (with which they are most familiar). The first problem may be alleviated by intelligent use of on-line materials and in-class exercises; for the second, I plan to assign problems where the solutions in Java and Erlang are significantly different.

It could be argued that Scala, with its surface similarity to Java, would be a better vehicle for the experiment. So why was Erlang selected?

First, the similarities between Java and Scala, once one gets past the curly braces, are deceiving. Scala is a large, flexible language that embodies the concepts of "class" and "object" in novel ways. The sheer size of Scala and its libraries threatened to overwhelm presentation of concepts.

Second, Erlang has a radically different concrete syntax, and uses a Prolog-like matching mechanism to disambiguate different invocations of a given function. There is little chance that students will "write Java code in Erlang."

Third, Erlang's processes are orthogonal to any operating system thread support. As mentioned above, this makes the use of processes (and attendant concurrency) the natural way to partition Erlang computations; there is no way to avoid processes when using Erlang.

Finally, processes can only interact by sending and receiving asynchronous messages. Message passing nicely complements shared memory access in Java.

V. COURSE OUTLINE

The course comprises two modules. The first four weeks are devoted to traditional, state-based concurrency with Java - to do otherwise would be an injustice to those students who will work with imperative languages after graduation. In addition to small in-class activities, teams of four each develop a concurrent game in Java.

The remaining six weeks are devoted to concurrency and basic distributed processing using Erlang. The initial plan is to devote a week and a half to the sequential, functional subset of Erlang, followed by two and a half weeks on Erlang for concurrent and distributed systems. The final two weeks will use Erlang as a vehicle to discuss both classic problems in concurrent and distributed systems (e.g., Dining Philosophers) as well as pragmatic issues of performance, load balancing, etc. In addition, the teams will design and construct a concurrent application with Erlang.

As of the date this paper was submitted, the Java module is over and students are completing the sequential Erlang component. So far, concerns about student ability to come up to speed with a functional language have proven largely unfounded. The next few weeks will determine whether or not the class is able to work effectively in the Erlang environment and create interesting concurrent (or distributed) applications.

VI. Initial Submission Conclusions

My expectation is that students will, on the whole, come to grips with the concepts of functional concurrent development, and amaze me with their projects. I certainly hope so - otherwise the department will have to reconsider the use of Erlang (or any other functional, actor-based system) in the new semester course.

The theory (or hope) is that both state-based and immutable, function-oriented concurrency can be covered in the new course. Come FIE in the fall, we'll know.

VII. Post-Course Conclusions

My expectations were, if anything, exceeded. Indeed, the final class of seven students was enthusiastic about learning both the functional approach Erlang promotes as well as using Erlang to build concurrent and distributed systems.

After a series of in-class activities and homework problems, the class asked to work on a final project (of about two weeks duration) as a single group. While our software engineering program emphasizes teamwork and team-based projects, usually the team size is restricted to three or four students. However, after I told them I'd expect a project at least twice as ambitious as I would for two smaller teams, I allowed the class to proceed as a single team.

In the end, they created a distributed, extensible, multi-user game based on the old *Adventure* game from the 70s and 80s. I was more than happy with the text command approach, as it kept the focus on design incorporating both concurrency and distribution, as well as on the intelligent use of Erlang's data types and process structuring mechanisms. The demonstration on the final day was awe-inspiring, as was the final product. What's more, while individual contributions varied, it was clear from the documentation and version control logs that every team member made a significant contribution.

As to acceptance of Erlang, I asked the class for their opinion as to whether Erlang (or a similar functional language) should be incorporated into the semester version of the concurrent and distributed systems course. The vote was unanimous in favor of retaining Erlang. As one student put it:

> We've been using Java for years, so the concurrency constructs in the end were just a simple increment. Erlang forces you to think about both problem solving and concurrency in a radically different way, and made it valuable.

In summary, the combination of Java's traditional concurrency control via locks and conditions with the functional approach of Erlang and its preference for message based interaction seems to have given student's a deeper understanding of the issues raised by concurrency. Based on this experiment, we are comfortable with the decision to continue teaching both approaches as an integral part of the new semester course.

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Using an Embroidery Machine to Achieve a Deeper Understanding of Electromechanical Applications

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***Abstract*—Understanding the functionality of real-world machines and thinking about their improvements is a method to deepen the acquired knowledge of electrical and mechanical engineering students. The Department of Electrical Engineering, Mechanical Engineering and Technical Journalism of the Bonn-Rhine-Sieg University of Applied Sciences in Germany provides a project-based learning environment in the so-called "project weeks". Three weeks of a term are available to do some real-world projects besides the regular courses [1]. This provides a "project-based" learning environment that enables the students to connect theory and practice and to apply knowledge and skills to solve practical problems. In the winter term 2012/13 an unusual open-defined project was offered for the first time to third-semester students showing high potentials. The students were presented with an unknown embroidery machine and their task was to improve it, depending on their knowledge and abilities.**

This article describes a project in which an embroidery machine was used as a basis for developing better understanding of many aspects of electrical and mechanical engineering.

Keywords—embroidery machine, microcontroller, programming, project management

I. Introduction

Undergraduate students of electrical and mechanical engineering have to learn lots of different subjects like mathematics, computer sciences, microcontrollers, principles of electrical engineering, measurement engineering and others. To achieve a deep understanding and to see the connection between all of these different areas, students need to apply and improve their knowledge (obtained so far by theoretical lectures) on electrical and mechanical applications of the real world.

The department of Electrical Engineering, Mechanical Engineering and Technical Journalism provides a project-based learning environment in the so-called "project weeks". Three weeks of a term are available for projects besides the regular courses [1]. This provides a "project-based" or "problem-based" learning **Error! Reference source not found.** which enables students to connect theory and practice and apply knowledge and skills to solve problems. Creativity and soft skills can be trained. The projects from which the students can choose are artificial ones and real ones.

This article describes a very open-defined project of the winter term 2012/13 which was offered to third semester students. They were confronted with an embroidery machine and the task to improve it in whatever ideas they had depending on their knowledge and abilities. Section II describes the motivation for using an embroidery machine and how the three weeks were prepared and organized in front. Section III describes the realization of the project. Section IV will give an outlook and Section V discusses the evaluation of the project.

II. Motivation for Using an Embroidery Machine as a Tool in a Problem-Based Project

The project weeks at the Bonn-Rhine-Sieg University in Germany (BRSU) are a good possibility for students to apply their knowledge already obtained in lectures and hands-on labs of previous terms. Some of the offered projects have very specific goals, others are more open because the subject is very new and/or it runs the first time and no experiences exist for the teachers. These are some kind of little research projects.

How did the idea of using an embroidery machine come up? The two authors (one professor and one research associate) are big fans of sewing, stitching and other kinds of crafts. So, it seemed kind of naturally that one day the idea would come up to use a programmable embroidery machine as a topic for a project. It also would make a contrast to most of the other projects dealing with automobiles or robots. As described in [2], an embroidery machine includes many aspects electrical and mechanical engineering students get taught during their study and it fits perfectly the requirements of the project weeks at the BRSU. Additionally, a very happy event occurred, the IVC (Institute of Visual Computing) at our university offered to support our idea by offering the money for the machine.

A. Preparation

The preparation started by searching for an embroidery machine which would meet the requirements and would have a reasonable price. The decision for a Brother machine of type Innov-is 950 was made.

This machine is a sophisticated embedded system with high precision, automated stitching control and a touch-screen interface.

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The main goal was set up by the authors: The students should improve the unknown embroidery machine in different pre-defined ways (defined by the authors, like stitching arbitrary pictures obtained by photos). The authors have to make clear to the students that it is mandatory to have some promising beginnings or even results within the team at the end of the three weeks in order to obtain a project success. The students have to discuss carefully all together possible ways to go.

The following project tasks were defined by the authors:

- Apply known methods from software/project engineering
- Understand the mechanism of the embroidery machine
- Document all newly obtained technical expertise
- Do a detailed investigation in the literature and on the internet to find out if similar things were done before by others.

B. Skills to be Taught in the Project Weeks

During the project weeks the students should reach the following learning goals with respect to the curriculum of the university for the project weeks. They should:

- Organize themselves as a team including choosing a team leader,
- Develop a project plan,
- Experience self-directed learning,
- Establish team meetings and define milestones,
- Apply knowledge obtained in lectures of previous terms, and
- Write a project documentation and prepare a presentation.

The last day of the last project week is saved for the presentation. The students summarize their results and evaluate their work.

The supervisors (the two authors) give feedback during the whole project, help with problems, make sure the team is able to work and check the documentation regularly.

III. First Results of the Project

Projects are organized in small groups at BRSU, normally including 15 students. They are supervised by one professor and a resaearch associate of the faculty. Because of the innovation of the project the authors decided to keep the team a little bit smaller then usually, so only 8 students could assign to this project.

Figure 2: Promotion and logo for the project

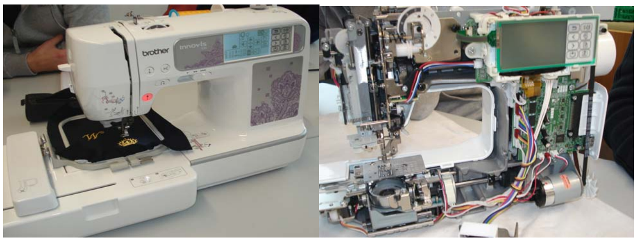

Figure 3: Brother embroidery machine, disassembled (right)

A. First Week

A lecture was held on the first day of the first project week. The authors gave information about team work (project organization methods like SCRUM and tools), goals and tasks for each of the three project weeks.

On the second day, the team was left alone. Only after half a day, the team made the request to be allowed to disassemble the machine in order to understand its mechanism. Of course, this was allowed by the supervisors.

The team started to prioritize possible ideas for improvement of the machine (given by the authors) and put them into two categories nice to have and realistic to do. They divided their group into sub teams, selected a team leader and assigned tasks to each of the sub-teams.

During the first week the students understood and documented the mechanism of the stitching process. At the end of this week they came up with the idea to build and program their own motor control systems: motor control for moving the stitching frame and for the needle itself. In this way they could bypass the software embedded in the machine which seemed to be in no way accessible to them. The authors discussed this direction and decided to give up the idea of going into the software and follow the path proposed by the students instead. Because of the open-defined project this was alright and not such a big surprise. So, the authors put together a list of needed technical things to be ordered for use in the second week.

B. Second Week

The authors used the time in-between the first two project weeks to check the documentation, and gave their feedback at the first day of the second project week. Mostly, this included comments about better understanding or missing descriptions.

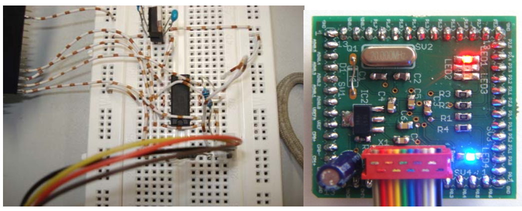

Figure 4: Development board of motor control for moving the stitching frame (left), "BRSU plug-in board" (right)

To build their own motor control systems, the students started with the installation of a microcontroller on a development board and connected it to the stepper for moving the stitching frame of the embroidery machine.

From previous lectures (by the authors and other members of the faculty) they knew the microcontroller C8051F021 from Silicon Labs used on a BRSU-developed board, the so-called "BRSU-evaluation system" including the "BRSU plug-in board" **Error! Reference source not found.**. The students implemented a program in the programming language C to control the motor of the embroidery machine responsible for moving in x- and y-direction for creating a stitching pattern/image. In this phase the teaching assistant worked close with the students to help and support them.

C. Third Week

The last week was used to improve and to eliminate bugs of the motor control for moving the stitching frame. Additionally, the students started to build a development board to control the motor responsible for the needle movements, which is an analog controlled one. The students decided to work with a PWM (pulse width modulation) circuit.

They also finalized their documentation and worked on the presentation to be presented by their team leader at the last day of the third week in front of the authors and the whole group.

I. POSSIBLE FURTHER ENHANCEMENTS

Using the project documentation future student teams in upcoming project weeks can go on understanding the machine even better and work on improving the machine, like:

- Improve the motor control responsible for moving the stitching frame.
- Understand the embedded software.

It seems that a wide range of further projects is possible using the first steps made in this initial project.

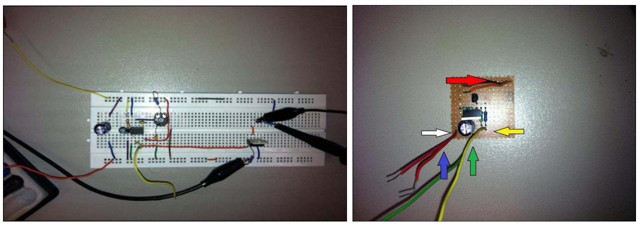

Figure 5: Development board of the student's motor control for the needle (left), final board (right)

IV. EVALUATION

The student's feedback was collected by the authors at the end of the third week by asking questions like:

- Did you obtain new technical understanding?
- Was the project too difficult or too easy for you?
- Did you obtain experiences in project organization, management and team work?
- How did you feel about the very open-defined project goals?

The students reported that they learned new technical knowledge as well as team working skills. Further, they reported that they were able to make good use of the theoretical lectures of the two previous terms. However, all students complained having only one machine to do testing and understanding the mechanism was not enough. They further reported that they would have liked more specified engineering tasks to investigate at the beginning of the project but, on the other hand, claimed that the openly designed project had also its advantages like fitting the tasks better to the real existing abilities of the group. They all summarized that only three weeks are not enough to really follow up all the ideas they had.

V. SUMMARY

A major concern of the Department of Electrical Engineering, Mechanical Engineering and Technical Journalism of the Bonn-Rhine-Sieg University is to provide its students the opportunity to work on real-world problems. Therefore, our department has introduced three project weeks per semester.

In the winter term 2012/13, an open-defined project was offered for third-term students for the first time by a professor and a research associate. The students were confronted with an embroidery machine. Their task was to understand the machine and to improve it depending on their abilities with support from the supervisors.

The embroidery machine as a small and compact device turned out to provide many different electromechanical aspects and was a good tool to be used as a main focus for students during practically project weeks.

ACKNOWLEDGMENT

The authors would like to thank their students who made the project so successful, the whole engineering department who helped to install the project and the IVC (Institute of Visual Computing at BRSU) for supporting it.

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Pedagogical Analysis and Multifaceted Evaluation of an Engineering Co-op Program

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***Abstract*—The ever-increasing complexity and challenges of the higher education coupled with more public scrutiny for its efficacy necessitate more in depth analysis and evaluation of the educational best practices. One such practice is the cooperative (co-op) education. While co-op education has been around for more than a century, its implementation is still barely more than nominal in higher education. Even though there are studies published to demonstrate its effectiveness, more in depth studies, both spatial and temporal, seem to be warranted to narrow the widening gap between students' jobs-first and institutions' intellectual-experience-first expectations. In this paper, we summarize the first and highly successful co-op program in Turkey at TOBB University of Economics and Technology (TOBB ETU). Our analysis include a taxonomy of different co-op programs to contextualize TOBB ETU's. Further, we touch upon the theoretical underpinnings from a variety of generally accepted foundational work. As part of the evaluation of the program, we provide a preliminary assessment of a longitudinal study as the first from Turkey and one of a very few from the non-US, international institutions. We believe that ours is the first to report an evaluation of co-op programs in terms of pre-co-op, post-co-op and graduated students *separately*.**

I. INTRODUCTION

As part of the increased focus on the efforts to assess student learning outcomes in higher education, different forms of learning are also gaining attention. Figure 1 shows a high-

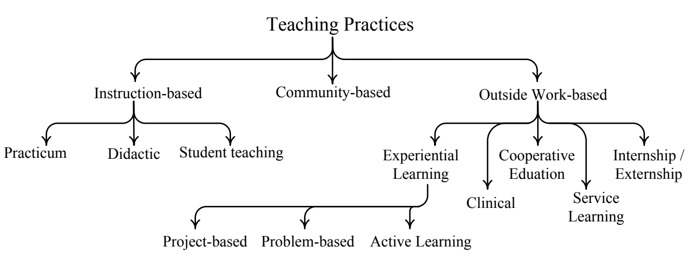

Fig. 1: A high-level taxonomy of teaching strategies in higher education for improved learning.

level taxonomy for various different teaching strategies and techniques that may be employed by instructors to increase student learning and retention[1]. The focus of this paper is on reporting the results of a preliminary assessment of the first cooperative education program in Turkey adopted by the TOBB University of Economics and Technology (TOBB ETU) for the past ten years. We note that this is the first of a set of longitudinal studies to assess the TOBB ETU co-op program from multiple perspectives. Even though there are some studies published to demonstrate the effectiveness of co-op education, as detailed in Section III-A, more in depth studies, both spatial and temporal, seem to be warranted to narrow the widening gap between students' (jobs first then intellectual development) and institutions' (intellectual and social experience first then jobs) expectations, as recently reported in 2012 Freshman Survey by the Cooperative Institutional Research Program [1] of UCLA. Similar divide between student expectation and university offering in terms of intellectual and social experience has also been highlighted by Salman Khan of the Khan Academy [2]. He states that students with co-op program experience graduate with a more expansive world view and more maturity. However, there is still resistance, as self-evident from the very low percentage of universities offering co-op education[2], to co-op education as a legitimate component of academic learning techniques and more validation efforts, as reported in this paper, are needed.

While we included co-op education separate from experiential learning in Figure 1, some experts consider the former as a form of the latter. The term experiential learning is usually attributed to David A. Kolb [5], who has formulated it in terms of the Kurt Lewin's model of action research [6], John Dewey's model of learning [7], Piaget's model of learning and cognitive development [8]. Kolb defines learning in [5] as "*the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience*". His Experiential Learning Theory (ELT) models the learning process as a closed loop consisting of four, interconnected stages; active experimentation, concrete experience, reflective observation, and abstract conceptualization, as shown in Figure 2 [9].

It is not surprising then, from the emphasis Kolb's ELT puts on experience for learning, that some consider co-op education as a form of experiential learning. Yet, there is no conclusive evidence to show that all four stages of the ELT is manifest in a typical co-op education. A goal of this study is to seek some preliminary answers to this open question as well.

[1]While it is outside of the scope of this paper to get into the details of each item in Figure 1, we use it to contextualize our study.

[2]It is not easy to find the exact percentage of the universities offering a co-op program. If one were to look at the only co-op international professional organization WACE's (The World Council and Assembly on Cooperative Education) list [3] of universities with co-op education, there are only 50 for the US out of 4,495 Title IV-eligible institutions [4] of higher education, the low ratio, and, hence resistance for wider practice can be clearly seen.

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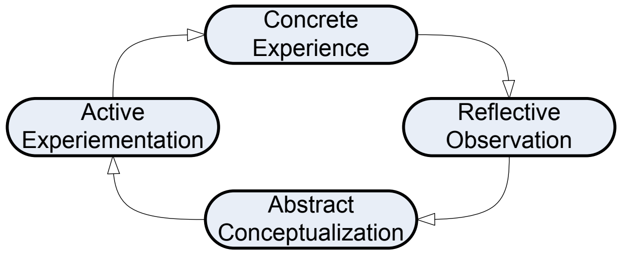

Fig. 2: Kolb's closed loop of Experiential Learning Theory model.

Cooperative education may be defined as the application of the classroom theoretical knowledge in a real-world workplace setting during the program of a college degree. While co-op education has been around for more than a century, its implementation is still barely more than nominal in higher education both in the US and worldwide. In this paper, we summarize the first and highly successful co-op program in Turkey at TOBB ETU. As part of the evaluation of the program, we provide survey results from pre-co-op, post co-op and graduated students[3]. A through statistical analysis of the survey data is presented to assess the co-op program from different perspectives. Such a longitudinal study seems to be missing in the literature both for the US institutions, where co-op programs originated, and for the international universities. We note that this paper presents what we term as a prelude to a longer-term longitudinal study to assess the overall success of the first co-op program in Turkey that can provide important clues and insight to the universities worldwide.

The rest of this paper is organized as follows: Section II delves into the pedagogical and theoretical underpinnings of co-op education. A taxonomy of co-op education programs as implemented by universities across the globe is presented in Section III together with the related work. Section IV summarizes TOBB ETU's co-op program details. Survey results, their analyses and a discussion are provided in Section V. Concluding remarks and synopsis of future work are given in Section VI.

II. Pedagogical Framework for Co-op

First, we provide a brief summary of the recent developments and trends of college students and the employers who are hiring college graduates. Priority of incoming college students is dominated by job-related reasons and financial concerns after graduation with unprecedented percentages (close to 90%) according to the UCLA's 2012 Freshman Survey [1]. Further, students are increasingly more dissatisfied with the didactic style of teaching and would like to be actively involved, self-directed, and responsible for their own learning [10]. The industry is reporting with more frequency that the recent college graduates are deficient in communication skills, ability to work in teams, flexibility, ability to accept ambiguity comfortably, ability to work with people with diverse backgrounds, understanding globalization, and ethics [11]. Employers are demanding skills not developed in schools [10].

In light of these observations, co-op education seems to be well poised to address most of these student and industry concerns. Even though there are studies published to demonstrate its effectiveness, more in depth studies, both spatial and temporal, seem to be warranted to better align the concerns of the higher education institutions, students and the employers with respect to the co-op programs. At the same time, there has been a significant resistance and skepticism against co-op education, as evident with very low percentage of institutions offering one[2], even by the faculty of the institutions adopting the co-op education. More validation and assessment efforts are thus needed.

In the following subsections, we briefly summarize the pertinent pedagogical theory behind the co-op education to delineate its academic rationale. A synopsis of the benefits of different stakeholders is also provided.

A. Theoretical Background

As we have discussed in Section I, Jean Piaget's landmark work on cognitive theory (humans as active processors of information around them) [8] has been the basis of the most of the theoretical work on co-op education. Another foundational work that is cited by all the theoretical models to explain co-op education is the philosophy of John Dewey's [7] that education and learning are social and interactive processes. Dewey's work is considered to be central to any discussion of experiential learning and co-op education.

Kolb [5], as noted in Section I, is the developer of the experiential learning concept. With his emphasis on experience, the connection to co-op education is clear.

Sternberg and Wagner's theory [12] about *Practical Intelligence* (PI) is another building block of the co-op education's pedagogical framework. They postulate that PI is what enables us to acquire practical skills. Thereby, they provide a broader conceptualization of intelligence than traditional intelligence and standardized tests. Thus, they draw attention to the importance of intelligence not only in schools but in everyday life, including both job-related and domestic settings. In Jean Lave's Situated Learning Theory, it is the human social activity that yields learning [13]. Learners participate as newcomers in communities of practitioners in acquisition of knowledge. Finally it is also noteworthy to mention the organizational framework developed in [11] that categorizes educational impact of work-related experience on student learning into three nested domains: Single-work experience, entire college experience and schooling in general contexts.

B. Benefits of Co-op Education

The benefits accrued as a result of co-op education may be analyzed in terms of the four major stakeholders of the process:

[3]As part of our ongoing work, we are in the process of surveying other university students without co-op programs, employers of our co-op program, university administration and engineering faculty members.

1) Student Benefits [14]-[19]: Practical real-world and career-related experience, enhancing and reinforcing academic learning, exposure to specialized facilities, test driving career goals, increasing self-confidence, effective networking opportunities, employability, documented work experience, interdisciplinary experience from the workplace, starting salary, more responsible jobs, reducing the college education price tag, increased disciplined thinking, improved learning, taking responsibility for learning, learning how to learn, improved problem solving and analytical thinking, improved performance in the classroom, increased GPA, and increased commitment to educational goals.
2) Employer Benefits [20], [14] : Hiring more motivated new employees, improving the corporate image, saving on the cost of operation, forming a more dynamic work environment, coming up with a pool for career recruitment, establishing university connections, low cost recruiting with less steeper learning curve for the hires, research link, and fresh ideas from the universities.
3) Institution (university) Benefits [14]: Easier job placement of students after graduation, enhanced relationships with industry, curriculum development, staff development, fresh ideas from industry via co-op students, and potential for research and other collaborations.
4) Faculty Benefits [14] [16]: Research collaboration opportunities, funding possibilities, potential to update teaching style and repertoire to stay relevant and current, enriching the classroom from the fresh ideas brought from the workplace, and opportunity for program assessment, such as for ABET.

It is quite likely that there are direct and indirect benefits to the economy and society. However, these are difficult to quantify and have not been reported in the literature.

III. Related Work and Taxonomy

A. Related Work

The first study published about co-op education [21] states that there is strong evidence that the co-op program is an educational strategy of considerable merit. National Research Council's (NRC) Panel on Technology Education [22] concludes that co-op contributes significantly to the career preparation of students and recommends expansion of co-op education. Positive impact of co-op programs on self-esteem, autonomy, sense of purpose and interpersonal relationships of participating students is presented in [10]. An assessment of a co-op program in Computer Science is reported in [23]. The positive impact of co-op programs on GPA, length at school, starting salary, reduced job search time and development of soft skills is provided in [24]. A satisfactory implementation of an unstructured but inexpensive program in Finland is detailed in [25]. The assessment of co-op program benefits to employers is conducted in [26] with the conclusion that cooperative education is beneficial to companies that support it. Rationale for co-op education in Computer Science without an assessment is given in [16].

Distinguishing characteristics and areas of our contributions are as follows: There are limited number of survey-based assessment reports published in the literature. Ours adds a valuable and recent contribution to the assessment of co-op programs. To the best of our knowledge, the majority of the co-op program assessments are from the US institutions with some Canadian universities. We report a preliminary assessment of a longitudinal study as the first from Turkey and one of a very few from the non-US, international institutions. To the best of our knowledge, ours is the first to report an assessment of co-op programs from students' perspective who have not started any co-op yet, who have done at least one and who have graduated ***separately***.

B. Co-op Education Taxonomy

Since the first co-op program was initiated at the University of Cincinnati in 1906 by Herman Schneider, a number of operational options has emerged for its implementation [27]. Figure 3 shows a simple classification of the co-op program options in terms of operational decision parameters.

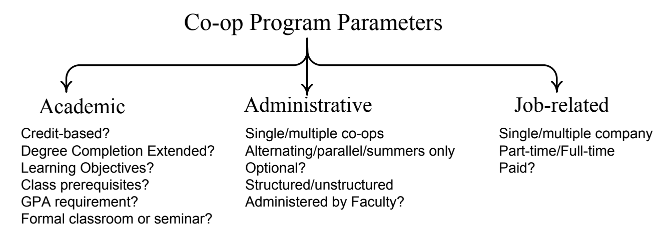

Fig. 3: A simple taxonomy of co-op program implementations.

IV. Co-op at TOBB ETU

TOBB ETU is established in 2003 in the capital city of Ankara, Turkey and started to take its first students in the 2004-2005 academic year. The university has grown in the last ten years to six colleges (Engineering, Medicine, Economics and Administrative Sciences, Science and Letters, Fine Arts, and Law) and about 30 departments. The total undergraduate student body is a little over 3500 students, and there are about 430 graduate students in M.Sc. and Ph.D. programs. Full time faculty members are about 250 and the school has around 120 staff members.

Engineering school is founded with Computer Engineering Department, Electrical and Electronics Engineering Department, Industrial Engineering Department, Mechanical Engineering Department and recently added Biomedical Engineering Department and Material Science and Nanotechnology Engineering Department to its body. Established engineering departments accept a strict 80 undergraduate students each year and the new departments take 20 to 40 students via a nationwide national university entrance examination. All engineering departments attract very successful high school graduates in the top 1% as full-scholarship students (no tuition, monthly stipend). About half of the students have some form of scholarship like no tuition, reduced tuition, etc.

TABLE I: Co-op terms in a typical curriculum for TOBB ETU students.

Year	Fall Semester	Spring Semester	Summer Semester	August
1st	1/1	1/2	2/1	Off
2nd	2/2	3/1	Co-Op	Off
3rd	3/2	Co-Op	4/1	Off
4th	Co-Op	4/2	-	-

TOBB ETU is a foundation university, and is established and supported by the Union of Chambers and Commodity Exchanges of Turkey (TOBB)[4], the largest non-governmental business organization in Turkey with branches all over the country and with a total membership of more than 1.3 million enterprises. Due to the strong relationship with the business world in Turkey, the founding organization TOBB established the university with the aim of building a strong university-industry relationship. For this purpose, the university chose the co-op model from its start as a mandatory part of the education. All programs are required to participate and all students are required to participate in order to graduate. The current 4-year programs follow the schedule in Table I with 8 in-school education semesters and 3 in-industry full-time internship, therefore a total 11 semesters in 4 years. Each semester is 3.5 months long. Due to the time-compressed schedule, in-school education semesters are tight with more lecture hours. For example, 3-credit courses have 4 hour lectures a week for 6 weeks and 3 hour lectures for the remaining 6 week, a total of 42 hour lectures in a semester. Due to the programming difficulties some lectures are done on Saturdays and some out of class exams are scheduled for evening and weekend hours. There are also less holiday time in between semesters and during the summer. This is the only school-wide co-op program among Turkish universities with such a heavy schedule.

The co-op program is executed by an administrative office at the university in co-operation with the schools and faculty. The office maintains a large list of co-op enterprises, currently more than 1200. Students who are scheduled to go to the co-op term enter their company preferences in a web-based information system. Companies can view students' CVs, can schedule an interview with them and select the students who requested a co-op with them based on their qualifications. A faculty member visits the location where the student is working at least once during the co-op term. At the end of the co-op term students are required to write a detailed report about the company and the institution where they worked, the work they have done, and their experiences. The company evaluates the student using a standard evaluation form. The student report and the company evaluation form are returned to the student's department and the student advisors evaluate the reports and the company evaluation forms of the students. All returning students are required to present their work in 20 minutes in front of other co-op students and the faculty in one of the presentation sessions. All other students can also attend the presentations. The faculty advisors at the end of this evaluation process enter a Pass/Fail grade for the students. Student who did not do satisfactory work and received low evaluation points from the company are required to repeat the co-op term. Students who did not submit satisfactory reports are required to re-write their reports upon the request of the faculty advisors.

[4]http://tobb.org.tr.

V. Methodology and Evaluation

In order to evaluate the co-op program at TOBB ETU, we grouped students into three different categories and asked them different survey questions. These categories are formed by students who have not yet attended to any co-op (Group 1), students who have participated in at least one co-op and still continue their education (Group 2), and alumni (Group 3). Since co-op is mandatory at TOBB ETU, Group 3 students have completed all three co-ops successfully before graduating.

Since the co-op terms start from the third year, students in Group 1 consists of freshman and sophomore. Table II presents the survey questions of this group.

TABLE II: Survey questions for Group 1 students, who have not done any co-op yet

Q1. I was familiar with the co-op program at TOBB ETU before coming here.
Q2. The co-op program played a significant role in choosing TOBB ETU
Q3. The co-op experience will increase my chance of finding a better job after graduation
Q4. I believe that I will benefit from Coop Education
Q5. I have to study harder in order to show what I know during my co-op.
Q6. I would still participate in all three co-ops even if they were optional
Q7. Reduced holiday time did not have an effect on my decision to study at TOBB ETU.

After students complete at least one co-op term, we wanted to see how the co-op experience meets their expectations and if they still think they will benefit from this program. Table III shows all survey questions for Group 2.

After students graduate, we wanted to record if they $really$ benefited from the co-op program. TOBB ETU had its first graduates at the end of 2007-08 academic year and we contacted them through the alumni office, which keeps the contact information for most students graduated so far. While some of these graduated students are currently enrolled in M.Sc. and Ph.D. programs at TOBB ETU for graduate studies, most of them work outside (in academia or industry). Our questions for this group are presented in Table IV.

The number of participants in groups 1, 2, and 3 is recorded as 187, 64, and 314, respectively. Surveys are done anonymously, the respondents are not asked about their identity. They are asked about their gender though, and the male and female distributions are 53% and 47% for Group 1, 89% and 11% for Group 2, and 61% and 39% for Group 3 respectively.

Q1. I have been exposed to real-world problems through the co-op program in my field of study that would have been impossible with only in-class college experience
Q2. The co-op experience has broadened my professional perspective and practical problem solving skills.
Q3. My co-op experience helped me see some of my academic deficiency areas
Q4. I started taking my studies more seriously and studying harder as a result of the co-op experience
Q5. My contribution to classes in terms of questions, comments, or interactions with professors increased after the co-op experience
Q6. I felt that I need to take better advantage of the educational opportunities at school after the co-op experience
Q7. My co-op experience helped me deal with class term projects more effectively in terms of ideas and producing better quality work
Q8. Based on my co-op experience so far, the co-op is likely to increase my overall academic success
Q9. The co-op experience increased my self-confidence
Q10. As a result of your co-op program, I am able to relate class material to the real world problems and developments better
Q11. I feel academically more mature after the co-op experience
Q12. 14. I expect that my co-op experience will reduce my job search time after graduation
Q13. My soft skills (communication, presentation, group work, interpersonal relationships) improved after the co-op experience
Q14. I started taking more proactive role in deciding what elective courses, independent studies and/or research (seminar) courses I should take after the co-op program
Q15. Overall, my co-op program enhanced and reinforced my learning as part of the college experience
Q16. My co-op experience was helpful in discovering my areas of academic and/or professional interests
Q17. Overall, I believe that I will benefit from Coop Education

TABLE III: Survey questions for Group 2 students, who have participated in at least one co-op and still continue their education.

Q1. I have matured professionally as a result of co-op experience.
Q2. Co-op delayed my graduation
Q3. Co-op program contributed to my professional development?
Q4. There should be a co-op program for grad students, too?

TABLE IV: Survey questions for alumni (Group 3)

A. Analysis and results

Survey responses for most questions are in the form of Likert scale [28] with 5 response types: strongly disagree (SD), disagree (D), neutral (N), agreed (A), strongly agreed (SA).

23.0% female respondents and 21.9% male respondents agree (A) and 12.8% female respondents and 11.8% male respondents strongly agree (SA) with Q2 in II (Figure 4a). A total of 69.5% of all respondents in Group 1 agree or strongly agree that they chose TOBB-ETU because of the co-op program. And we should note again that Group 1 consists of students who entered TOBB ETU but did not experience co-op yet.

Figure 4b and Figure 4c present Group 1 responses for Q3 and Q4 in Table II, respectively.

Here, we obtain similar responses; while total 79% of the students agree or strongly agree with Q3, 75% of the participants agree or strongly agree with Q4. These results clearly show the importance of the co-op program among prospective college students and the positive expectations about the program. The male and female answers are very close to each other. In Figure 4d we see the responses for whether students still participate in all three co-ops in case they were optional (Q6, Table II). 67% of the students agree or strongly agree with attending all co-ops even if they were optional. This number coincides with responses in Figure 4a for Q2.

Since Q3, Q4, and Q5 in Table III are similar, we show the student responses to these questions in Figure 4e. The total percentages of the students who agree or strongly agree with these questions are 52%, 58%, and 45%, respectively. These results suggest that an effective co-op program helps students see their academic deficiency areas and take classes more seriously.

Figure 4f presents the responses for Q13 of Table III and Q1 of Table IV combined. The percentage of alumni who agrees or strongly agrees that they matured professionally as a result of co-op experience is 57% as shown in Figure 4f. Although this number is less than the percentage of the participants in Group 2 who agree or strongly agree that their soft skills improved after co-op, these numbers still present an important role of co-op for improving student skills in professional development.

In Figure 4g, we show Group 2 responses for Q15 in Table III. 60% of the students agree or strongly agree that co-op enhanced and reinforced their learning. Based on this percentage, we can conclude that co-op meets student expectations in general. Since Q1 and Q2 in Table III are similar, we show Group 2 responses to these questions in the same figure (Figure 4h). After students attend at least one co-op, 56% of them agree or strongly agree with facing the real-world problems that would have been impossible without co-op and 63% of them agree or strongly agree with improving their professional perspective and practical problem solving skills.

Figure 4i, Figure 4j, and Figure 4k depict all student responses to all questions in Groups 1, 2, and 3. Overall, at least 50% of participants have positive responses to the co-op program. Finally, in Figure 4l we show Group 2's error plot, which shows the variability of responses. We note that the error plots of both Groups 1 and 2 have similar patterns and thus they are omitted for brevity.

B. Discussion

Since TOBB ETU was established 10 years ago, the co-op program is still new to the university, students, and the companies. Thus, there are some operational issues regarding the program. Reduced holiday time, companies assigning tasks to students which are not related to or in line with their educational goals, insufficient open positions for co-op students in top companies, and companies not involving students in important projects because of confidentiality or security are are the main reasons for negative feedbacks from students. However, as indicated by the responses, almost all students and alumni see the benefits of this program. These problems are likely to settle down with more operational experience as we go through this unique educational program.

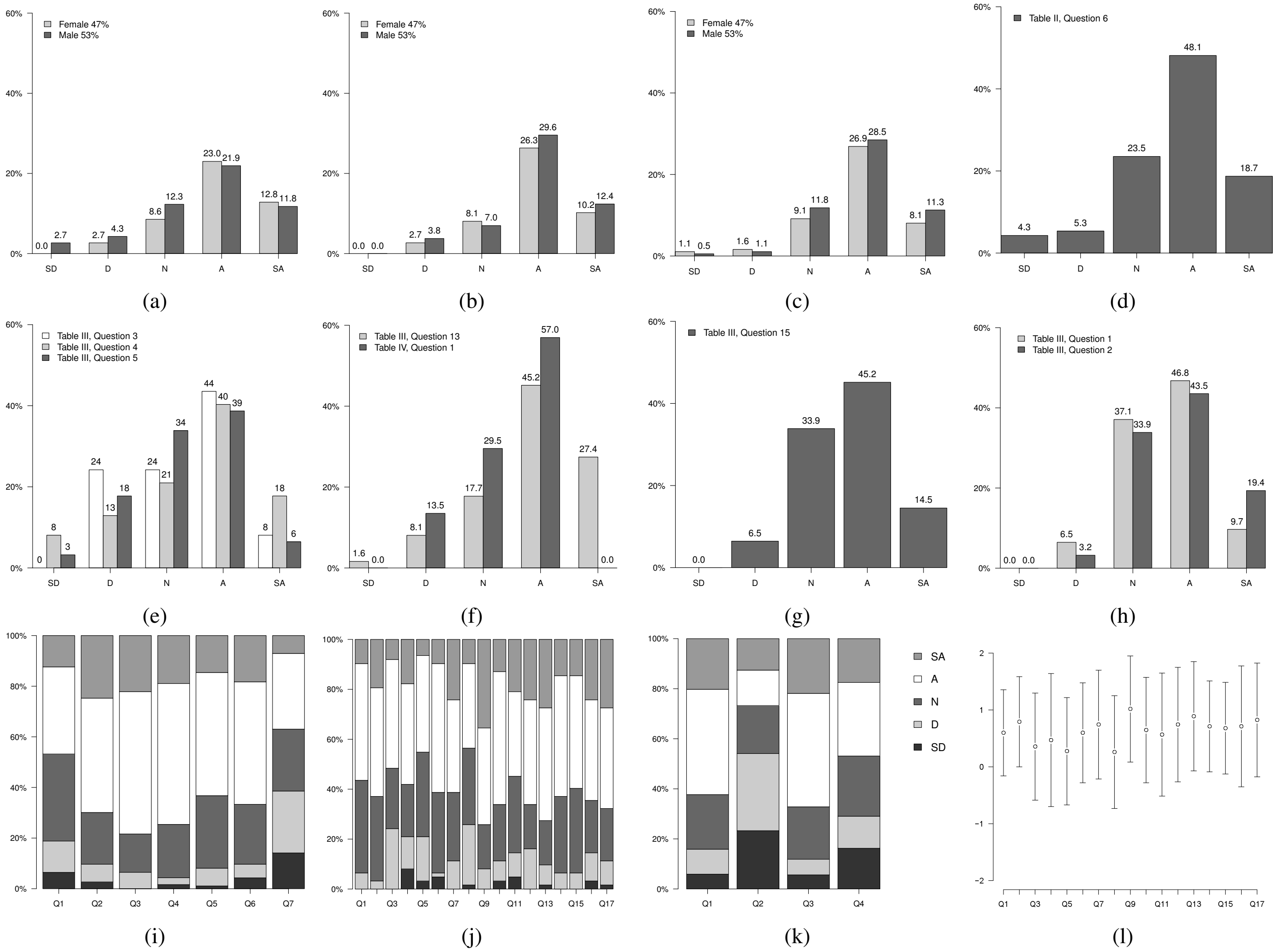

Fig. 4: Assessment plots. All y-axes are percentages and x-axes are survey responses. (a) Question 2 of Table II, (b) Question 3 of Table II, (c) Question 4 of Table II, (d) Question 6 of Table II, (e) Questions 3, 4, and 5 of Table III, (f) Question 13 of Table III and Question 1 of Table IV, (g) Question 15 of Table III, (h) Questions 1 and 2 of Table III, (i) All questions of Table II, (j) All questions of Table III, (k) All questions of Table IV, (l) Error plot of all questions from Table III. SD: Strongly Disagree, D: Disagree, N: Neutral, A: Agree, SA: Strongly Agree.

VI. Conclusion and Future Work

The playing field of the higher education has been changing rapidly. Educators and the institutions are urged to come with new, and of course effective, methodologies for producing longer lasting learning under the pressure of changing student profiles and attitudes. In this paper, we have provided an assessment of a century-old practice of co-op education which is still met with resistance and skepticism in terms of its place in higher education. We report the first co-op education program implemented in Turkey at TOBB University of Economics and Technology. Distinguishing characteristics and areas of our contributions are as follows: There are limited number of survey-based assessment reports published in the literature about co-op programs. To the best of our knowledge, the majority of the co-op program assessments are from the US institutions with some Canadian universities. We report a preliminary assessment of a longitudinal study as the first from Turkey and one of a very few from the non-US, international institutions. We believe that ours is the first to report assessment of co-op program from students perspective who have not started any co-op yet, who have done at least one co-op term and who have graduated from college ***separately***. Based on the survey results, we conclude that the TOBB ETU co-op program is highly valued and prominent determinant for the incoming students. Specifically, 69.5% of all respondents in the incoming students agree or strongly agree that they chose TOBB ETU because of the co-op program. In addition, majority of the students who have done at least one co-op agree or strongly agree that co-op enhanced and reinforced their learning. Finally, the value of the TOBB ETU co-op program is still appreciated by graduated students several years after the college.

We note that this paper presents results of what we term as a prelude to a longitudinal study to assess the overall success of the first co-op program in Turkey. As part of the future work, we will be expanding the current survey to include employers, faculty, university administration and students from other universities without co-op program to assess many different dimensions of the co-op experience.

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Software for Senior Citizens

An Experiential Learning Course in Gerontology, Software Usability and Digital Literacy

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***Abstract*—Two trends in the developed world – the marked growth in the percentage of the population identified as "elderly", and an increased reliance on computing technology – make it imperative that the high technology designers of tomorrow understand the challenges, capabilities and context of elderly users. Our graduate course on "software for senior citizens" provides a broad background of material from human-computer interaction, gerontology, literacy studies and cognitive and learning sciences. Students also gain first-hand experience through weekly tutoring sessions with local elderly residents. These sessions yield observations and generate contacts from which students generate research projects. This paper discusses our goals and motivations for the course, our experiences to date, and our plans for future iterations and opportunities for expansion.**

Keywords—Human-Computer Interaction, Gerontology, Digital Literacy, Service Learning

I. Introduction

As society in the United States and elsewhere in the developed world adapts to new uses and forms of computing, many of our elderly citizens are being left out. The movement toward digital technology has much to offer the elderly: a wealth of news and health information and the ability to stay in touch with distant friends and family, to name a few. But with digital literacy moving from an attractive option to a necessity, many seniors – especially those on fixed incomes and with limited access to current technology – are experiencing frustration and helplessness. It is not only a valuable opportunity but a moral imperative for students in computing disciplines to be aware of the challenges facing this important but overlooked constituency.

We have piloted a course that combines research in usability and digital literacy for the elderly with a community outreach program at the local public library. Our multidisciplinary graduate-level course investigates aspects of software design for an aging population. In their new role as tutors for the elderly, our students are placed in a position to question their implicit assumptions about use of technology.

The design and execution of this course could be characterized as a pilot or pre-study that aims to understand how the seemingly disparate activities of teaching, learning, research, and community outreach can be effectively combined. Results from this course could be used to evaluate the feasibility of partnering with community organizations to assist the elderly, assessment procedures in the classroom, new research methods developed by the students, and the development of future courses. This paper discusses our goals and motivations for the course, our experiences to date, and our plans for future iterations and opportunities for expansion.

II. Motivation

Senior citizens comprise the largest and fastest growing demographic in the digital divide. By the year 2050, the population of older Americans is projected to be 88.5 million, 20.2% of the total population [1]. At the same time, the pace of new technology adoption is accelerating. Seniors are suddenly forced to use computers to perform routine tasks that were previously paper-based, such as filing tax returns, using coupons, or changing their address. Most seniors do not have computers, have never used computers, or have only used computers at work. Even those with computer skills are often frustrated when they find that standards and norms have shifted since their last experience with computers, rendering their hard-earned skills worthless.

Our desire to create this course derives in part from the particular character of our local area and our university. Michigan Tech, located in the far northwest corner of the U.S. State of Michigan, near the shore of Lake Superior, is a research intensive university focused on technology, engineering, and scientific degree programs. Its international, high-technology atmosphere is in stark contrast to the experience of residents outside the university. County residents over age 65 constitute 15.2% of the 2011 population. Many of their relatives live far away, and those who stay struggle to get by in an economically depressed area with few jobs outside the university. Because of the larger than average number of elders without family support, many of whom are below the poverty limit, there is a strong need for help with digital literacy in this community.

As a pilot offering, the designers of this course seek to combine research and meaningful study of usability and digital literacy with a service learning component that supports the needs of the elderly. The service learning component of our course precipitates some unlikely pairings: on one hand, local residents with long family ties to the area and varying levels of technological literacy; on the other hand, graduate student tutors from around the globe, with extensive interest and

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experience in technology. These encounters are designed to help tomorrow's technologists understand the situation of the elderly and to foster consciousness as they create software for an aging population. Furthermore, through our community service activities we aim to ease elders' transition to a computer-based society.

III. Course Creation and structure

Software for Senior Citizens is a multidisciplinary course investigating aspects of software design for and use by an aging population. The course combines graduate-level readings and discussions with hands-on projects involving seniors from weekly help sessions at the public library. Students learn about the context that older users operate in (e.g. their attitudes, skills physical barriers) and engage in some design activity aimed at providing a better experience.

Our course leverages a successful outreach effort that we have continued since 2011 [2]. Students at our university have been meeting weekly at the local public library with community members, most of them 60 years of age or older. This series of meetings, called "Online at the Library", provides one-on-one tutoring for people with questions about digital technology. Some participants are ordinary people who may have never used a computer but suddenly find themselves required to conduct online banking transactions or update electronic retirement information. Others may have used computers but have fallen out of practice. Still others need help transferring skills from PCs to new mobile devices. Most of them struggle with things that those among the techno-literati find simple.

In creating the course, we follow a long tradition of service learning in university courses, and two efforts in particular to introduce students in computing disciplines to the context of elderly computer use. Pace University's undergraduate Intergenerational Computing course offers instruction in technology and gerontology theory and service learning involving personal tutoring at elderly residence facilities [3]. In a software design course at Iowa State University, students meet with real elderly users and design products based on their interactions [4]. The reports on these efforts have inspired us to combine the threads of theory, training, service learning and research into a single course.

IV. In the classroom

Two of the three weekly contact hours for the course take place at the university. Classroom activities include discussion of readings and activities to increase awareness and train students in research techniques.

Understanding the problem. Our initial readings delve into the demographics of an aging population and the physical, cognitive and social barriers faced by the elderly [5][6]. Of particular interest is the concept of lag: the lack of congruence between individual and environment that lies at the heart of many challenges for the elderly [7]. This theoretical construction has helped us to frame the particular concerns we have witnessed at our help sessions. Readings from literacy studies also helped to frame elderly computing skills as a literacy problem [8][9]. Identifying different levels of literacy, beyond the mechanical notion of functional literacy to higher levels of critical and rhetorical literacy, has allowed us to think of teaching digital literacy as something broader and more exciting than training of rote procedures [10]. Finally, readings on design for elderly use have provoked discussion of personal experiences with effective and flawed interface design [11][12].

Building empathy. Getting students to envision themselves as elders themselves is an important component of the course. Through a generous loan from the Ford Motor Company, students have taken turns wearing a "Third Age Suit", designed to constrain movement and obscure senses to simulate the effects of aging [13]. Experiences during the service learning sessions also bring to life the realities of aging; student experiences are shared during classroom sessions and on the course blog.

Figure 1: Wearing the Third Age Suit

Practicing methods. One course is not enough to cover the wide variety of analysis techniques available to designers. Students have discussed and practiced the "think aloud" approach to activity analysis [14] and ethnographic observation [15]. Students have also practiced user task analysis on common computer tasks, in an effort to understand their own approaches to accomplishing tasks online [16]. In their summary statements posted on the blog, students reflected on the difference between their own "digital native" behavior and that of the elders they had encountered at the library:

"I observed ____ using Amazon... I really liked how she scanned the screen in a circle around the streaming content, looking for affordances that would help her with her task. This was an obvious contrast to the way seniors try to read the screen; left to right, top to bottom. It seems seniors either try to read everything in a linear fashion, or freeze up and read nothing because of information overload."

"On Facebook, I was the user and ____ observed. I found Facebook difficult to setup. It was hard to find settings, especially privacy settings, to setup the account in the way I wanted. Facebook is completely open by default and I wanted to lock it down and then open up features I wanted as I discovered I need them. It was a very frustrating and time consuming experience (it took over an hour to create an account) I can't imagine a senior attempting to setup an account."

V. ONLINE AT THE LIBRARY

In the experiential component of the course, students help community members with real computing needs. In conjunction with the public library, we offer weekly computer help sessions open to anyone in the community (Fig. 2). Students in our class act as individual tutors, teaching elders how to use the Internet to keep in touch with people, share pictures and letters, find information, and much more. Participants are welcome to bring their laptop computers if they choose, or they may use the library's computers. People may attend as many of the sessions as they wish. Our students reflect on each week's tutoring session through a class blog and in-class discussions.

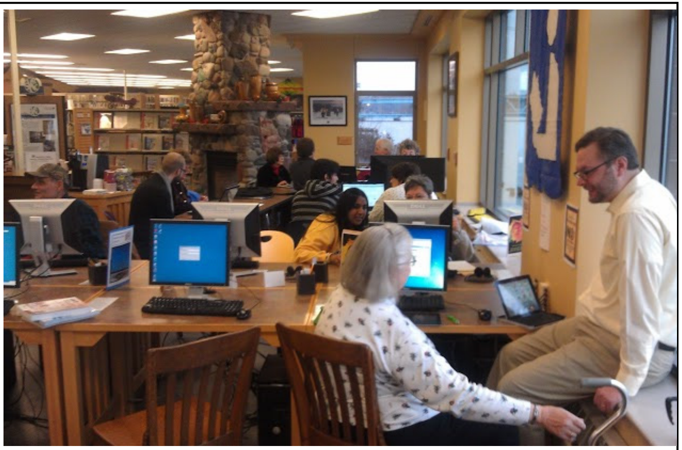

Figure 2: Online at the Library

While helping community members, students began to catalog common tasks that require assistance: sending pictures in email, bookmarking web pages, browsing the web, searching for people or information, paying bills online, using antivirus software, removing viruses or malware. Our course blog has been an effective repository of stories illustrating some of the problems seniors encounter while using computers:

Connecting to the Network. "I helped a gentleman get on the library network. Generally, when someone is unable to connect to the internet on a laptop, the first thing I look for is a switch or button on the sides of the laptop that can switch-off the wireless. These buttons are put there so you can turn-off wireless on a plane, or in a hospital, or just to conserve battery. In this case, there was a button on his keyboard, above the function keys, that toggled wireless."

Cursor Related Difficulties. "The woman I was working with [couldn't figure out] how to get the video started. I know that in many cases, there is a 'play' icon that appears superimposed on the video image - that is an affordance that draws the user toward mousing over the video. But in this case, there was nothing! It made me think about how mouse-over has quietly become a new standard behavior: if you can see something on the screen that you want to interact with, but you're not exactly sure what it is or what you can do with it, mouse over it."

Double Scrollbars are Confusing. "One elder spent 3 minutes looking for the Gmail send-button because it had scrolled out of view due to the size of the email he was sending, and Gmail uses a double vertical scroll bar, an inner one on the message, an outer one on the work page that includes 'send' buttons. This is ridiculously confusing, even to people who use it all the time." Classroom time is an opportunity to explore interface issues like this in depth (Figure 3).

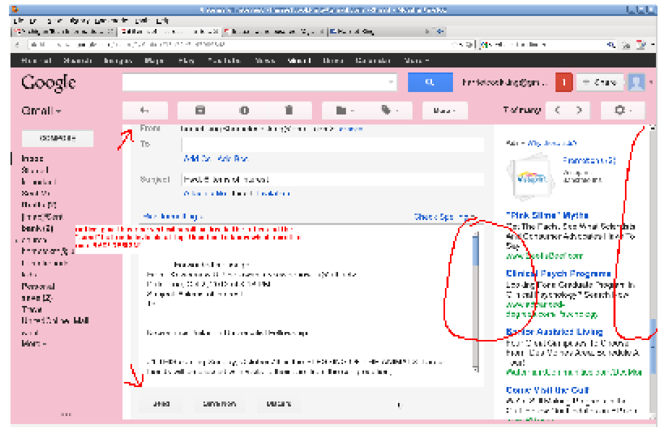

Figure 3: Discussing the double scrollbar problem in class

Students were reflective in their observations and often frank and even critical of themselves:

"What did you notice today at tutoring? Is it more about teaching or about what design we see that is annoying? I was bossy and made ___ practice attaching photos to her email. I told another that google maps directions are not helpful if she already knows a good local route, but at least I showed her how it would be helpful if she had no idea how to get somewhere."

"I helped ____ change his desktop picture and I bit my tongue when he picked something 'ugly'. So that was a small small small success on my personal growth."

"I'm afraid I was not in a great place this morning, having had to get up and into work very early to handle a problem with a live system. So I was tired, stressed, and irritable when I arrived at the library."

Students had fun working with the elders:

"Today I helped ____ learn about using Google products. That is to say we played the whole time."

"Today I helped a few different people and had a great time. One wanted to start learning excel, not sure I helped her that much. Another was very high frustration but seemed happy when she realized that things were not broken and it was not going to be hard to use her new system. Another wanted me to help her husband and I hope I did. Then I helped someone at the end and we learned together. A good tutoring day! Yay!"

Elders often come with focused, sophisticated questions:

"Then she asked about a more advanced topic. How does one insert a picture into a document. So I showed her how to do that from the insert tab. Then she wanted to know how to resize the image without distorting it. So we talked about selecting the image and using the handles to change its shape or to rotate it."

"____ had arranged his spreadsheet like you would arrange a set of papers on your desk. There were multiple tables laid side-by-side, but the rows of the tables didn't match up with one another. So when it came time to sort the entries in one of the tables, it was a nightmare. I carefully put each table into a separate worksheet (I'll admit, I did some steering on his laptop), then showed him how he could get to the various tables by clicking on the tabs. He's going to need some practice getting used to that – unless he understands tab navigation, he's going to wonder where those other tables went."

VI. RESEARCH PROJECTS

The tutoring experience at the library forms the basis for student-conducted research addressing technical, and social issues connected to the digital divide. These projects offer students the opportunity to pursue their interest in this area beyond the bounds of our course. We received IRB approval for including our library attendees as subjects in research projects. In their projects, students have investigated a range of topics: receptiveness to Twitter; effect of visual clutter on elders' ability to navigate unfamiliar websites; patterns of communication between tutor and student in the help sessions; use of user interface gestures by the elderly between different device platforms.

Are tablets the answer? One undergraduate student enrolled in the course wanted to find out why modern interfaces are difficult for elders to learn and use. Based on observations at the library of seniors using desktop computers, he concluded that there are three main aspects of user interfaces that posed the largest barriers: *mouse* (finding and manipulating the cursor, distinguishing between cursor and caret, distinguishing between click and double click, distinguishing between left and right click, selecting data), *windows* (finding the active window, moving between windows), and *files* (understanding the file hierarchy, locating files).

The student was interested in exploring the new paradigm of tablet computing as a potential solution for these problems. He led a group of library attendees through a series of tasks on an iPad. He concluded that the tablet paradigm eliminated the problems that seniors had using windows because only one application is active at a time. Likewise, because the iPad hides the file system, seniors did not experience any problems finding files. Although the touch-screen interface solves many of the mouse-related problems, it introduces some new problems: double tap and tap-hold confused seniors, and none of the seniors were able to copy-and-paste.

Communication patterns. A Ph.D. student in the course studied the patterns of communication exhibited between the seniors and tutors during help sessions at the library [17]. Her work consisted of data gathering at the help sessions and rhetorical analysis of the interactions between tutors and elders (Fig. 4).

Her observations revealed a range of strategies that tutors use in explaining and training. While the elderly attendees generally had few planned questions, running through activities together, with the "prop" of the computer artifact, elicited questions. Direction was more commonly used than demonstration, but when the latter is necessary, tutors tend to use "think aloud" to expose their mental model. Tutoring is tactical in nature, and often the methods of instruction must change in the moment – for instance, when tutors did not know a solution immediately, they frequently switched to an "explore together" pattern.

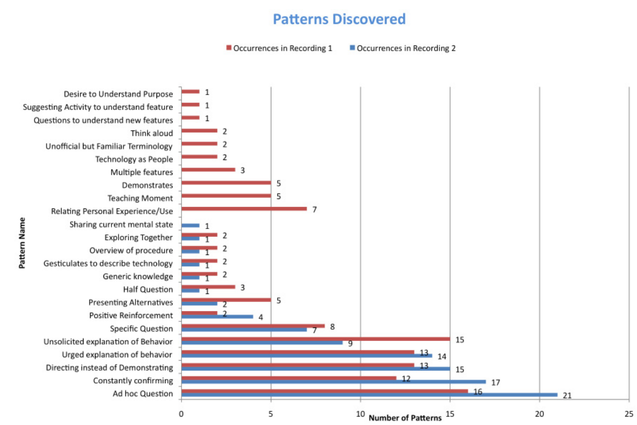

Figure 4: Communication pattern analysis

Lessons from our elders. After the end of the course, a number of the students collaborated on a conference paper detailing our findings, in the context of "lessons learned" for technology designers [18]. The main findings are summarized below:

- *Anxiety stifles exploration*. Stories from mass media provide unrealistic models of threats. Fears of losing data or compromising secret information reduce the kind of free-form exploration that students in the course use to learn about new interfaces.
- *Details obscure abstraction*. With the advent of multiple types of computing platform – tablets and smartphones, in addition to traditional personal computers – elders can get lost in the details of a particular device and fail to see the commonality between them. This is particularly problematic when addressing cloud-based services.
- *Lag complicates adoption*. Slow changes to infrastructure in our rural area puts elders at a disadvantage. Arcane and ever-changing vocabulary keeps elders in the dark, and their hard-earned computer knowledge depreciates rapidly with today's rate of technological change.

VII. WORLD USABILITY DAY

Students in the class participated in World Usability Day (November 8, 2012) by hosting an event on campus. The goal of the event was to raise awareness of the usability issues faced by the elderly.

We began the day by meeting with interested seniors to make signs for a march across campus (Figure 5). Seniors made signs indicating how they felt about technology, the questions they had about computers, or what they had learned from the students. Their slogans echo the concerns and frustrations we encounter at our help sessions: "I need computer – Computer no need me"; "How do you turn it on?"; "Device not Recognized"; "Files everywhere and yet I cannot find it!" Students and elders marched onto campus where we were stopped by the police! After we explained that we were non-violent and that this was an official, scheduled event, we were allowed to continue. This excited some of the senior citizens and we heard stories of their participation in protest marches while in college.

Figure 5: Seniors marching for World Usability Day

After the march, there was a poster session for students' research projects and a discussion forum. Seniors and students participated in an open forum, discussing their experiences working with each other to learn how to use computers.

VIII. FUTURE WORK

Our pilot of this course produced a rich discourse, both in class and online, a broad array of creative research projects, and assistance to the outreach program at the library. It should be noted that the class size was small - only five students - and that only Computer Science was represented. The structure of the course is well suited for interdisciplinary study, and we hope to bring a broader group of students together for the next offering of the course. Students in our Technical Communication and Cognitive Science programs would be particularly well suited for the course. We also plan to explore the option of scaling the course up to serve a larger body of students. Furthermore, we hope that by reporting on this course, we can help others develop similar programs in their communities.

ACKNOWLEDGMENTS

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Internal Combustion Engine's Throttle Control as a Motivational Theme for Teaching Microprocessors Systems Lab Classes

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***Abstract*—The increased fuel economy and driveability of modern internal combustion engine vehicles (ICEVs) are the result of the application of advanced digital electronics to control the operation of the internal combustion engine (ICE). Microprocessors (and microcontrollers) play a key role in the engine control, by precisely controlling the amount of both air and fuel admitted into the cylinders. Air intake is controlled by utilizing a throttle valve equipped with a motor and gear mechanism as actuator, and a sensor enabling the measurement of the angular position of the blades. This paperwork presents a lab setup that allows students to control the throttle position using a microcontroller that runs a program developed by them. A commercial throttle body has been employed, whereas a power amplifier and a microcontroller board have been hand assembled to complete the experimental setup. This setup, while based in a high-tech, microprocessor-based solution for a real-world, engine operation optimization problem, has the potential to engage students around a hands-on multidisciplinary lab activity and ignite their interest in learning fundamental and advanced topics of microprocessors systems.**

Keywords—electronic throttle control; ICE control; chopper power amplifiers; hands-on education; laboratory experiences

I. Introduction

Contemporary society has been to a considerable extent shaped by transportation means and, in special, by individual transportation vehicles. The role played by internal combustion engine vehicles, and accordingly by carmakers, along with road and fuel infrastructure creation and operation is of paramount importance to modern industrial society. The whole car business encompasses a huge amount of employees and creates considerable wealth.

ICEVs have been experiencing a steady technological improvement since the beginning more than a century ago. Microprocessors along with sensors and actuators play a key role in permitting the fuel efficiency and driveability achieved by modern automobiles. Though tens and tens of microprocessors can be found in contemporary cars to carry out a myriad of different functions, hereafter our focus is on the microprocessor system used to control the vehicle's engine, the so-called engine control unit (ECU).

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As we will see in the rest of this paper, microprocessors lab classes can be created that explore the microprocessor use in the control loops of ICEs. In particular, we will present and discuss an experiment using a microprocessor to control the position of a throttle valve according to an input signal representing the driver's desire for power. Given the ubiquity of cars and their fetish ("I drive, therefore I am."), we postulate that this type of lab activity can be motivational for engineering students and help to ignite their enthusiasm to learn basic and advanced topics on microprocessors systems. Relying strongly on hands-on approach to teach microprocessors systems is widely recognized as an effective pedagogy [1]-[6].

II. Electronic Fuel Injection (EFI)

A. Cylinder and Basic Elements

A great step towards the increase in fuel efficiency and engine performance, which also led to the generation of lower amount of pollutants escaping the gas pipe, was the replacement of carburetors by electronic-controlled fuel injection [7]. The latter control technology builds on technologies such as microprocessors, accurate air intake mass measurement and control, exhaust gases' oxygen sensor, and precise control of fuel injection using solenoid-operated nozzles (Fig. 1).

As a general rule, EFI control aims at maintaining the

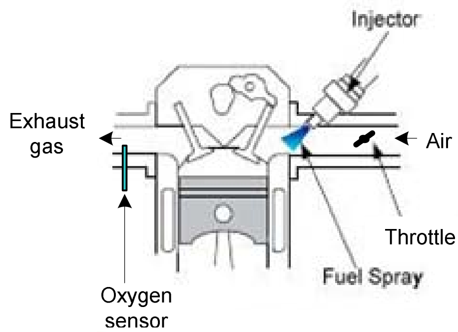

Fig. 1. Sketch of a cylinder of an internal combustion engine.

stoichiometric air/fuel ratio, the so-called lambda parameter, equal to unity. This could be achieved thanks to the microprocessor technology. The ECU receives information with the driver's need for power, which is conveyed by a gas pedal sensor (Fig. 2), and calculates (and controls) the amount of air and fuel to be burnt inside the cylinders, all in real-time.

B. *Throttle Body*

The ECU controls the amount of air entering the cylinders by controlling the position of the throttle's blade [8]. Therefore, the air control throttle is de facto a fundamental block of EFI. The throttle body is composed of a dc-motor which turns the valve's axis position by means of two cascade rack and pinion gears, against the forces of a planar, spiral, high-stiffness restoring spring and the air pressure on the throttle's blades (Fig. 3). A potentiometer whose sliding lead is connected to the valve's axis enables measurement of the valve's axis position.

III. MICROCONTROLLER-BASED THROTTLE CONTROLLER

A. *Overview*

Fig. 6 shows the block diagram for the microcontroller-based throttle controller. The control block itself is fully embedded in the 8-bit microcontroller (PIC18F4550-I/P from Microchip Inc.). Two channels of the 10-bit analog-to-digital converter (ADC) are used to read the gas pedal sensor (GPS) and the throttle position sensor (TPS). Indeed, the GPS establishes the set point for the controller and in this project was substituted by joystick potentiometer. The error ε is obtained by a simple subtraction between the two last values of GPS and TPS. The control algorithm's job is to null the error as fast as possible, with minimum overshoot, which are somewhat conflicting requirements.

The control algorithm main task consists in appropriately updating the duty cycle δ for the pulse width modulator (PWM), this also an internal microcontroller peripheral.

The throttle body is the plant to be controlled. Assuming the time constant of the mechanical unit (spring and inertia of valve, motor and gears) is much higher than that of the dc motor electrical circuit (dictated ultimately by coil inductance and resistance), the plant can be suitably regarded as a typical second-order system.

To convert the duty cycle signal δ into power, the 12-V voltage-output chopper amplifier sketched in Fig. 4 is deployed. Notice the simple interface connecting the microcontroller's PWM output to the chopper amplifier. Recall that the dc motor torque is proportional to the motor current. In turn, the motor current is proportional to the input voltage integral. In other words, the motor torque is in direct relation with the duty cycle δ. Therefore, as illustrated in Fig. 5, different duty cycles lead to different motor currents (mean value of motor voltage) and hence to different torques.

Throttle equilibrium position θ is dictated by motor toque T_m, amplified by the gears' radii ratios, and spring stiffness and perturbation torque due principally to the air pressure exerted on the blades. Coulomb friction has also an impact on the dynamic response of the entire system. The throttle position θ

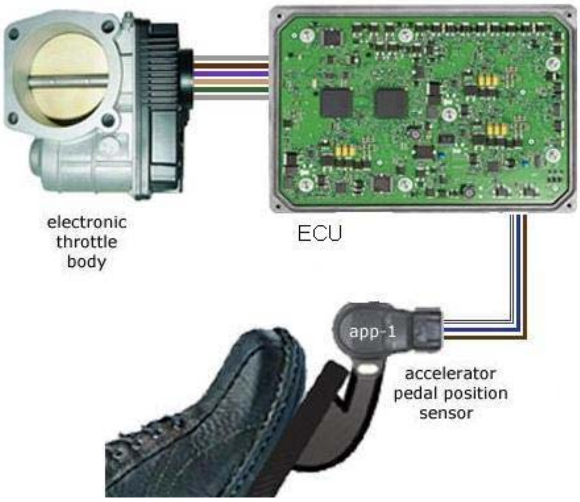

Fig. 2. ECU, gas pedal, and throttle body.

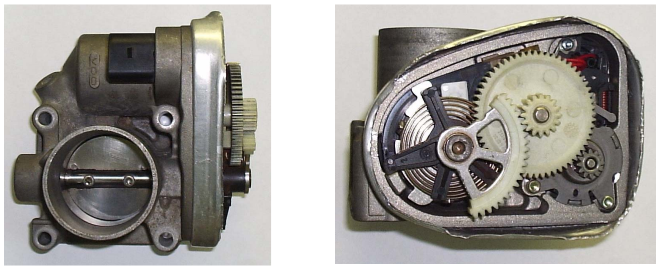

Fig. 3. Pictures of an open commercial throttle body.

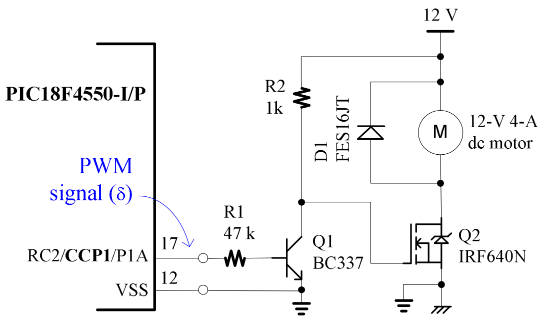

Fig. 4. Chopper-type power amplifier and interface to microcontroller.

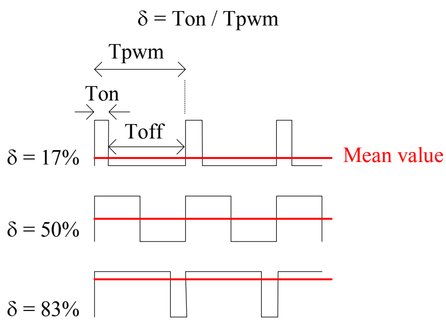

Fig. 5. PWM duty cycle δ is software controlled.

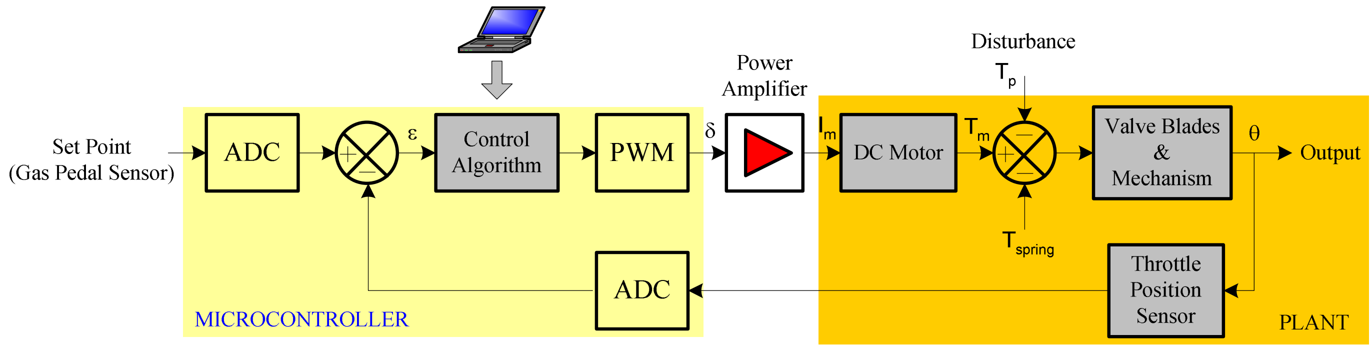

Fig. 6. Block diagram for the throttle position controller.

is sensed by a linear rotary potentiometer embedded into the throttle body. Circuit is omitted here for simplicity.

B. Control Strategy

Once the hardware is ready, several different control strategies might be put into action. Due to the fact that our students have had a mandatory course on classical control theory the year before they engaged in the microprocessors systems course, it was quite direct the adoption of classical proportional, integral and derivative (PID) control strategy in this lab design. Fig. 7 presents the flowchart for the implemented control strategy. Before beginning the control loop, values for the proportional, integral and derivative gains have to be chosen. Also, one must define the PWM frequency and initial values for the duty cycle δ and the error ε. Despite the existence of practical methods to establish the values for the aforementioned gains, e.g. Ziegler-Nichols' method, it seems interesting that students can play with these parameters in order to develop a feeling about their impact on the controller's performance and stability.

The error derivative is taken as the difference between the current value for ε and that calculated during the preceding iteration. Obtaining the error integral is a bit more laborious, since one needs to store several samples for the error ε, each of which corresponds to the error value gathered during an earlier sampling interval. In this lab design, we adopted six consecutive error values and calculated the error integral as a simple summation of these values. This could be easily done by creating a vector with six elements and replacing the oldest element (i.e. the oldest error value) as a new error was calculated. At program start, this vector had all elements zeroed. All programs were written in C language.

IV. Experimental Results and Discussion

Fig. 8 shows a picture of the final experimental assembly. For the sake of simplicity, the microcontroller programmer and the personal computer containing the integrated development environment (IDE) were not included.

Many experiments were realized with the working throttle body under control of programs downloaded to the microcontroller board. Gains for the proportional (K_p), integral (K_i) and derivative (K_d) terms were chosen at will and subsequently the system's step response was recorded and analyzed. Fig. 9 presents the result of such an experiment. One can easily observe that the throttle angular position follows

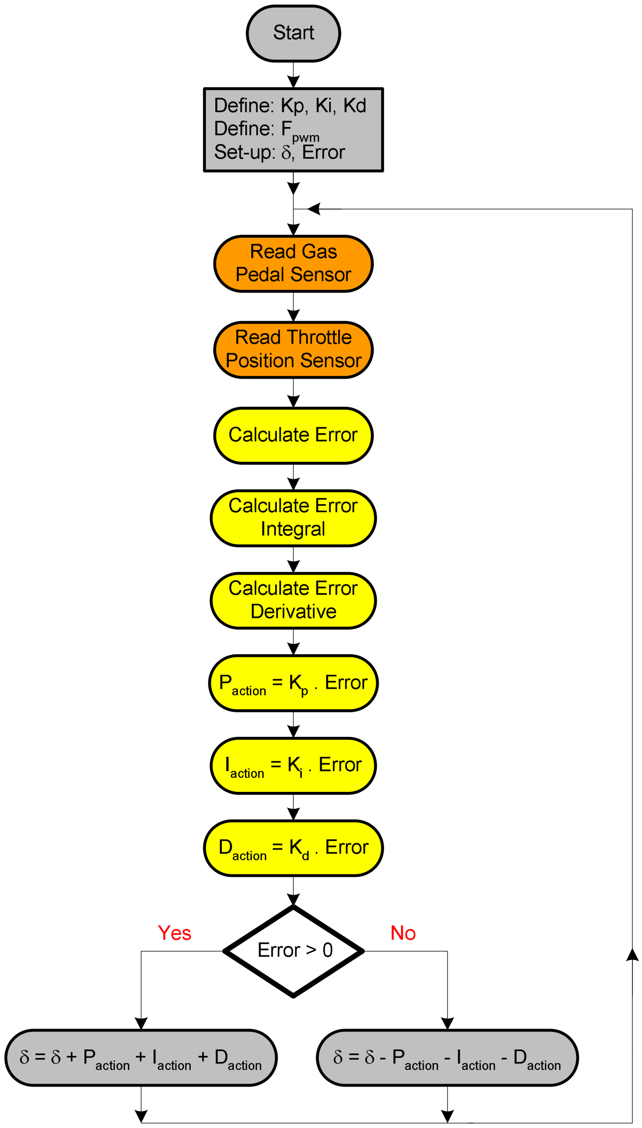

Fig. 7. Flowchart for the implemented PID control strategy.

pretty well the gas pedal signal. Recall that a joystick plays the role of the GPS in this setup. The step response's waveform makes it clear that the system exhibits a considerable overshoot. Students must be aware of this system behavior and discuss about the dominating factors, when it comes to overshoot control. Debating about possible improvements and tradeoffs are of utmost importance for students to develop critical thinking skills.

To better illustrate the system ability to follow the input signal, an experiment was carried out wherein the control system's input and output signals were overlapped on the oscilloscope screen. As clearly depicted in Fig. 10, the plant's output follows the input signal quite well. Perhaps, one should make it clear at this point that in ICEVs the throttle valve position is not to follow the gas pedal signal. Instead, its position is determined by the ECU in a manner that leads to stoichiometric fuel/air ratio. On the other hand, students must acknowledge the fundamental tests to be carried out with the throttle position control system that ultimately guarantees the valve angular position will suitably obey the commands issued by the ECU.

The signals shown in Fig. 11 are to highlight the real-time updating of the PWM's duty cycle as changes in the throttle position occur. Here students can observe the real-time correction action of the closed-loop control system. They are stimulated to use their fingers to force the blades out of its equilibrium position, i.e. artificially introducing a perturbation into the system, just to observe the fast change in duty cycle values provided by the control program in its struggle to keep the error as small as possible.

Microprocessors systems course (MPS) is a mandatory subject at our university. It lasts two terms and consists of 3 hours of theory and two of lab weekly. Electrical engineering students are allowed to get enrolled in this course after they have successfully attended digital electronics course (DE). By far, besides having attended the DE course, the students enrolled in MPS have already succeeded in linear control systems course and analog electronics course. These students are in their fourth academic year, in an undergraduation course that extends for five years. Regarding classes, the last year's workload is relatively light, for the students have to fully dedicate three days a week to their internships at industry.

Lab classes of MPS are run typically with groups of 10 students. The year this lab design happened, a team of four students was assigned the task of designing part of the hardware and software for the microcontroller-based throttle controller. We have used project-based learning (PBL) as instructional pedagogy, concerning the laboratory classes during the second semester of the aforementioned course. The students faced tough problems regarding time management and sharing the tasks among them. Also, the team found quite difficult to decipher on its own the innards of the microcontroller's PWM, a fundamental structure for the implementation of the control strategy. Yet another peripheral that took so much time for students to tame was the ADC. Unfortunately, the industrial-grade C-language compiler utilized was plagued with a terrible error in the built-in library function to read the ADC: the compiler documentation states

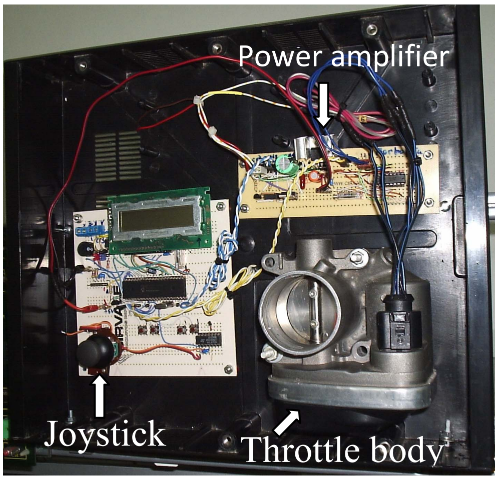

Fig. 8. Microcontroller board, chopper amplifier and throttle body.

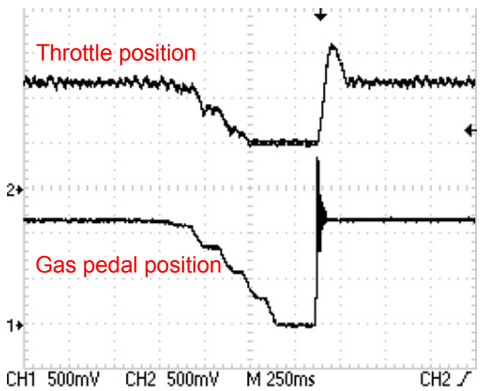

Fig. 9. Gas pedal sensor signal and throttle position sensor signal.

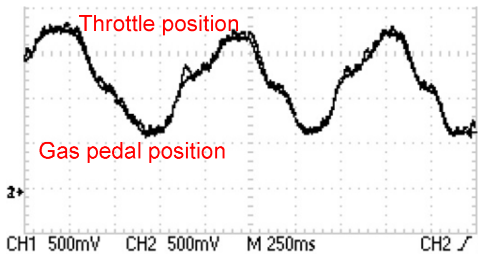

Fig. 10. Overlapped pedal sensor signal and throttle position signal.

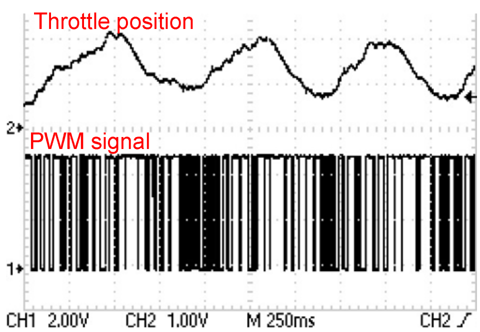

Fig. 11. Throttle position sensor signal and corresponding microcontroller-generated PWM signal.

that this function returns an integer number. Nonetheless, the ADC returned wrong data as revealed by tests deploying known input voltage values. Correct values might only be read when using float type variable. This type of problem is quite difficult to be tackled by students, since they are fully confident about the tools (e.g. IDE, measuring instruments, power supplies and so on) they are using. As a result, it took a long time for students to get suspicious about the compiler and look for help.

V. Conclusion

Modern ICEVs are equipped with state-of-the-art digital technology to control the amount of fuel and air to be mixed and burnt inside the cylinders. Also, the spark ignition is under ECU control. The overall goal is fuel economy, driveability, and emission of smaller quantities of pollutants. In a nutshell, what is sought is the optimization of engine operation under rough and varying environmental conditions. To do that, the ECU counts on sensors and actuators, such as the sensor for oxygen concentration in the exhaust gas and the sensor for the angular position of the throttle valve. Key actuators are the throttle valve, to control the amount of air intake into the cylinder, and the solenoid-operated nozzles, to inject known amounts of fuel into the cylinders. This paper dealt with the development of a microcontroller-based throttle controller by a team of students of the fourth year of the electrical engineering undergraduation course at our university. The project was assigned to students so that they could work on it during their weekly hours of microprocessor systems lab classes.

Initially planned to run under pure project-based learning (PBL) instructional pedagogy, it turned out that difficulties faced by students were so intense that they were poised to fail in fulfilling project goals. Students faced huge difficulty in translating their knowledge of linear control theory into the practical application they were assigned with. In particular, though they had had a year-long course on linear control, they could not manage to apply their skills on analyzing control system using their transfer functions and Matlab-like environments to the development of the throttle position controller. For instance, they were unable to discuss about the appropriate sampling frequency for the controller. This fact reminds us that bridging the gap between theory and practice will always be highly challenging for both students and faculty. Lab classes of modern control systems rely heavily on such computer programs as Matlab®/Simulink® and Labview®. These are powerful tools that accelerate product development and scientific research. Today these tools are a must in scientific and high-tech industries. However, for they hide hardware and software details, a glory for scientists and engineers who can now concentration on the problem solution architecture and algorithms, they go precisely in the opposite direction, when it comes to teaching solutions using microprocessors/microcontrollers. Here, details are of paramount importance and can only be grasped by directly struggling with them, as advocated by active learning pedagogies.

Furthermore, students encountered tough difficulties in understanding the innards of microcontroller peripherals such as the ADC and PWM. Seemingly a more effective approach would be the adoption of these fundamental microcontroller peripherals in the lectures on microprocessors systems. Nowadays, these topics are treated in a very general purpose way, i.e. students are taught general principles about ADC and so on, which does not help them when they have a specific microcontroller at hand.

With a much frequent helping hand of instructor, the team could see the throttle controller operating nicely. However, given the high degree of instructor interference during the project development, it is more correct to think of the instructional pedagogy as a blend of PBL and traditional one.

The ubiquity of ICEVs in modern societies along with the lure of youth for these machines underpinned our decision to introduce car technology as a motivating theme to teach microprocessors lab classes. Despite the difficulties cited above, we strongly support the idea that a blend of PBL and traditional instructional pedagogies, along with ICEV-inspired applications, can be much effective in igniting students' interest in learning microprocessors systems more profoundly. And this, beyond doubt, can ease their future migration to industry.

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Using Scrum to Teach Software Engineering:

a case study

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***Abstract*— The diffusion of agile methodologies in software development makes them more mature for corporative environment. However, teaching agile methodologies on the academic environment poses many difficulties and limitations. This paper describes a case study where an innovative approach for teaching software development technologies was adopted. In this approach, the entire course was designed to fit Scrum's principles, so that the students could apply them as they were learning it. Also, the course's main project was to be developed in sprints, as proposed in Scrum. After almost two years using this approach, in this paper we describe our experience and perform a critical analysis. We observed some positive points, such as the practical nature of learning by example, and a better preparation of the students regarding agile methodologies. As negative points, we highlight the impossibility of delivering complete products in earlier sprints, and some interaction and collaboration difficulties. The main conclusion of this study is that, for the approach to work in our academic scenario, a modified version of the Scrum methodology was necessary.**

Keywords—agile methodologies, software engineering, academic teaching, SCRUM

I. Introduction

The software market demands readiness for unexpected and quick changes, and the earlier software engineering methodologies did not seem to be appropriate for many practitioners. Agile methodologies, such as Scrum [1], are a response to this demand. As a direct consequence of this evolution, there is an increasing need to place more emphasis on teaching Scrum in order to prepare students for their professional careers [2].

It is a known fact that teaching software engineering cannot be restricted to presenting concepts and methodologies as abstract ideas. It requires the integration of applied methodology and theory into the practice of software development, otherwise students may fail to develop a deep understanding or appreciation of the most important ideas [3]. For this reason, most software engineering courses have a large project, meant to be its final piece, also known as capstone project. Mahnic presents a discussion about the use of agile methods in capstone projects, based on different literature reviews [2]. While there are many successful stories that favor agile methodologies in these scenarios, Mahnic argues that there are some reports indicating that a more traditional, disciplined process paradigm would be more suitable for the still inexperienced students.

We were facing the same dilemma in our university. We have a two-year lato sensu (specialization) graduate course in software development, which has been offered since 2003. As the final part of this course, students must develop a large project to put into practice the concepts they learn. Until recently, they followed a traditional process, moving from requirements to the finished software product in a single iteration. However, this model was causing problems, mainly because of the lack of proper time management. Due to different factors, such as limited availability of the students and a long wait until they reached enough maturity to start developing the project, the delivery of unfinished and/or poor quality projects was very frequent.

An agile methodology seemed to be a perfect solution, as it is a structured process, but that supports both creativity and productivity in a team project. It also allows for flexible, self-controlled time and task management that enables students to react on the varying workload in their jobs [4]. So, as pointed out by Schneider and Johnston [5], we asked ourselves: should we try to change the scenario, and introduce the practices of agile methodologies in software development education?

We decided to follow this path, by adopting a Scrum-based approach to teach software development technologies and software engineering concepts. In the approach, some Scrum practices, such as iterative and incremental development based on sprints, were integrated into the academic environment, so that the learning itself could happen in an iterative and incremental way. To fit this format, the entire course had to be reorganized so that the disciplines could deliver the necessary contents for the sprints to succeed.

In this paper we present the approach in details, and also perform a critical analysis after two years of experience with it. We highlight the main positive and negative points, and try to make suggestions to improve it in the future.

The remainder of this paper is organized as follows. Section II presents the background and scenario of the study. Section III presents the sprint planning for this course. In Section IV we present our critical analysis and suggestions for the second version of the course. Finally, in section V we present some concluding remarks and future work.

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II. BACKGROUND

The initiative described in this paper was conceived in the context of a lato sensu (specialization) graduate course, in the area of software development for the Web, offered at UFSCar – Federal University of São Carlos – SP – Brazil, since 2003. In this course, students learn different software development techniques and concepts, such as programming, modeling, database design, human-computer interaction, web development and project management. The course has also a practical component, in the form of a mid-size software project, where the students can put most of the theory in practice. The course project was supposed to be developed in parallel with the theoretical activities, in groups of six or less students.

But since the beginning of the offering, we observed that many projects reached the end of the course as incomplete, or with fundamental flaws that could not be corrected in time. We identified two main possible causes for this problem. The **first** one is the fact that most students have a limited availability because they have jobs and/or work in different areas. They typically have 6-8 hours per week to work on practical assignments, and this was causing many delays.

A **second** possible cause is the fact that many students seeking this degree have little or no knowledge in computer sciences, while others have practical knowledge, but never got a bachelor or engineer's degree. We typically have 20% of the students without knowledge in software engineering and 30% of the students working in other areas. As a result, the classes normally start with a very heterogeneous distribution in terms of academic formation and practical background. Many students do not reach a degree of knowledge that is sufficient for the project to start until much later in the course. So the project normally started only after one year or more.

After many discussions, the course organizers came to the conclusion that the solution to this problem was not to change the course duration – 444 hours distributed over two years – but to better distribute theoretical and practical effort.

Together with this observation, there was the fact that agile methodologies were already included in the course program, as a subject related to project management. But it was being taught in an abstract way, leading some students to wrong conclusions or even boredom.

As a response to these two problems, the course was reorganized to employ the concepts and principles of agile methodologies. Because it follows the agile ideology [1], even though it is not specifically tailored for teaching, Scrum was adopted as the model for the iterative approach to be followed during the course.

First, it was established that the project was to be developed iteratively and incrementally. At short periods of time, or sprints, students should deliver parts of the system, until it is complete. In parallel, the theoretical disciplines of the course were reorganized to deliver the necessary content for each one of these sprints to succeed.

The expectation behind this proposal was that students could start development earlier, and have less risk of delivering an incomplete project in the end. It would also make them practice agile development in a mid-size project, reducing the gap between theoretical software engineering teaching and practical agile concepts.

Next section presents the detailed course setup and description of the course project, according to the agile approach.

III. COURSE PROJECT

Initially, it was established that the course disciplines would be divided according to their applicability in the project. For this reason, the course started with an overview of Scrum, basic programming, requirements and analysis. More advanced contents, such as database design and programming frameworks, were to be introduced later, and so on. This was done for the theoretical part of the course, which resulted in four phases, described next.

The **first phase** had an estimated duration of 3 months, and consisted in an introductory phase. It was also called "pre-Scrum" phase, and was dedicated to the activities that are not related to actual development. In this period, there were teaching activities about the development process, environment preparation and basic programming. The disciplines that were part of this phase were:

- Agile software development: studies about the software development methodology that would be used in the projects. In this course, Scrum was adopted;
- Free software development platforms: preparation of the environment to be used in the project. In this case, the students would have to work with CentOS [6], PostgreSQL [7] database and Java IDEs NetBeans [8]; and
- Java certification: a basic java discipline, intended to help students get acquainted with the language that should be used to develop the projects.

The **second phase,** which had duration of 4-5 months, involved the actual usage of the agile methodology. In this phase, the disciplines focused on requirements, analysis and design. The goal was to enable the analysis and design of the project to be developed. But since the students should already be developing part of their projects, some software development techniques were explored, such as web development, mobile computing, and database activities. This would allow them to deliver a few parts of the software that involved only basic programming. Other parts of the project, that required advanced knowledge on database persistence or a more complex framework, would be introduced later.

In the **third phase**, with duration of 5-6 months, there were the disciplines that would provide most of the content of the course. Here the focus was on giving a complete coverage of most recent web development topics, such as human-computer interaction, object-relational persistence frameworks, service-oriented architecture, reuse-driven development, test-driven development, among others. The content of this phase was intended to be used by the students during most of the part when developing their projects.

In the **fourth and final phase**, which was supposed to last 2 months, the disciplines involved advanced topics, to close the theoretical part of the course. Project management, advanced development topics, such as data warehouse and optimization, and even scientific methodology, helped to give students a better understanding of which topics could be further explored later in their career.

These four phases characterize the theoretical part of the course; however they were not applied in a sequential way. Since we were following an iterative process based on Scrum, the actual division of activities was different. The course was organized around the project, and thus it was divided into eight sprints of three months each. At the end of each sprint, students were supposed to deliver part of their projects, as working software.

To support these deliveries, the disciplines had to be arranged to provide students with the necessary knowledge in each sprint, in order to allow a logical evolution from sprint 1 to 8. So, early sprints have more focus on disciplines from the phase one of the theoretical part of the course. And late sprints have more focus on the disciplines from phase four.

There had to be some repetitions, as some disciplines had too much content. In these cases where the same discipline appears in more than one sprint, only part of the content was given at each time. For example, the "agile software development" discipline appears in six sprints, each time introducing new concepts, starting with basic concepts and ending with practical examples and guidelines. "Object-relational patterns and frameworks" is another example, appearing in three sprints, basic concepts in the first and

TABLE I. BASIC COURSE SCHEDULE

Sprint	Disciplines	Sample deliverables of one of the groups
Pre-Scrum	- Agile software development - Free software development platforms - Java certification	None
1	- Web programming - Pattern-based software modeling - User interface design and evaluation for the web - Object-relational patterns and frameworks - Agile software development - Database design	- Class models - Database models - Basic CRUD operations for users - System authentication
2	- Pattern-based software modeling - User interface design and evaluation for the web - Object-relational patterns and frameworks - Database design - Mobile computing - Agile software development	- Advanced CRUD (different user types) - Community creation - Update in the system layout - Update in the documentation
3	- Mobile computing - Web development frameworks - Object-relational patterns and frameworks - Agile software development	- Profile visualization - Profile data update - Sharing of public messages - Timeline visualization - Pending issues in authentication
4	- Service-oriented architecture and web services - Reuse-driven software development - Scientific methodology - Agile software development	- Design for mobile devices - Login/logout for Mobile - Information visualization - Multiple timeline visualization - Basic CRUD for other information - Message posting - Project mockup
5	- Test-driven development - Service-oriented architecture and web services - Reuse-driven software development - Scientific methodology	- Technical issues - Visual adjustments in the interface
6	- Reuse-driven software development - Performance optimization of Relational DBMS - Images and visual effects in web applications - Software development topics - Agile software development	- Image posting - Contact acceptance - Search for contacts and communities - Inclusion of contacts and communities - Community visualization and adding
7	- Data warehouse - Scientific methodology - Reuse-driven software development	- Video posting - Invitation/inclusion of people in communities - Administrative interface - Access privilege control - Community reports
8	- Project management in agile software development - Scientific methodology	- Technical issues

practical knowledge in the end.

Although it may seem that these sprints take longer than most sprints in industrial projects, which typically last between 2-3 weeks, in terms of work hours the duration is approximately the same, because students were supposed to work 8-10 hours per week on the course project.

Table I shows the basic course schedule, together with an example of the deliverables that one of the groups should provide at the end of each sprint. The deliverables refer to a system to help in the organization of scientific events, which was the domain of their project. In the next section more details about the project and the deliverables are presented.

The students must complete a mid-size software project as part of their course. In our approach, this should be done iteratively, to reduce the risk of incomplete projects in the end. So, the students had to plan what should be delivered, in term of user stories [9,10], at the end of each sprint. Due to the limitations of the academic environment, in comparison with an industrial project, in our approach students were allowed to deliver incomplete products in some sprints. In other cases, students could plan to deliver only enhancements or adjustments, instead of a product, in a sprint. Table I shows some examples of these cases in sprints 5 and 8. But every sprint should include some form of deliverable.

There was a product owner (PO) [9,10] assigned to each team of six students. The PO would be responsible for the definition of the stories and for following the results of the development. As this was also an exercise of Scrum itself, students had to practice the role of Scrum Master [9,10]. So, in each sprint, a different member of the team should act as Scrum Master, to put in practice the different concepts of the method and also learn his/her responsibilities.

Another important point of the project setup was the definition of the domain. We have observed that, in this course, the groups almost always follow a pattern: normally, students are professionals working on the software market, with little time to develop the activities. They also normally live in a distance from each other – only a few groups are composed of people living in the same city. The different areas in which they work also caused a great degree of heterogeneity and a knowledge gap between the members of a group.

To minimize the negative impact of these factors, we defined that all groups, without exception, should work on one out of two possible projects. Half of the groups would develop project A, and the other half would develop project B. With a regular class size of 35 students, this results in six teams with 5-6 students.

Two teachers would play the role of PO, one for each project. They were supposed to help during the planning meetings and give technical support regarding the development technologies and/or correct application of Scrum principles.

Control during the process would be performed with the help of an on-line sheet. In this sheet, students and teachers should include and maintain all the necessary information to allow a proper management of the development in each sprint.

Basically, when planning a sprint, the students would insert the stories in the sheet, together with the activities to be performed. With all activities available on-line, each member perform it. The Scrum Master (of that particular sprint) was responsible for maintaining the sheet, and also making sure the others keep it updated, so that he/she could follow the burndown chart [9,10]. In this sheet, the chart was automatically updated each time an activity was marked as completed. The following information was part of the sheet:

- **Product backlog**: list of stories of the system, with a detailed description and the acceptance criteria;
- **Sprint**: stories of the current sprint and the tasks needed to finish them;
- **Kanban**: repeats the tasks from the "sprint" part, and includes a status column ("to do", "blocked", "doing" and "done") and a task finish date column. Fig. 1 shows an example of this part of the sheet;
- **Burndown data**: based on the tasks table of the kanban sheet, this part keeps a comparison between the planned dates and the actual dates; and
- **Burndown chart**: graphical visualization of the burndown

fx Create the service to list the friendship requests

	A	B	C	D	E
1	To Do	Blocked	In Progress	Done	Finished
2				Create the friend search tool	6/26/12
3				Create the result screen for the friend search	6/26/12
4				Analysis of the Mobile interface	6/27/12
5				Analysis of the Mobile interface	6/27/12
6	Create the web service for friend search				
7				Timeline development for the mobile	6/26/12
8				Create a tool for adding friends	6/27/12
9				Create tool to aprove or deny friends pending requests	6/27/12
10	Create a mock for the services and upload on the university server				
11				Create the service to list the friendship requests	6/14/12
12				Create the service to aswer the friendships pending requests	6/14/12
13				Create the service for adding friends	6/15/12
14				Create service to deny the friends requests	6/15/12

Fig. 1. Example of a kanban sheet

data. Fig. 2 shows an example of this part of the sheet .

Fig. 2. Example of a Burndown Chart

IV. CRITICAL ANALYSIS

In general, the approach was successful, as both of its goals were achieved:

1. All groups were able to deliver the complete project in the end of the course; and

2. Students managed to put some of the agile principles in practice, using them as they were learning them. This resulted in a better learning of agile concepts.

There were also some additional positive observations. In our case, both teachers acting as POs had previous experience with Scrum in practical scenarios, which has proven to be essential to provide a good alignment between the course content and the principles of agile development. The presence of these teachers as POs, and their constant availability, was also a positive result, since it allowed students to clear their doubts without taking too much time. The fact that the POs were teachers, specialized in Scrum and technical development concepts, and not business experts, did not result in a negative influence. This happened because the projects involved a domain which they were actually very familiar with – scientific events. The rotation of the Scrum Master role was also benefitial, allowing each student to play this part at least one time.

However, we observed many problems with the approach, and we believe these could be addressed to provide even better results in the future.

A first problem relates to the gradual evolution of the learning process in a normal course, and its contrast with the incremental and iterative approach proposed by most agile methods. There is a natural incompatibility between these two approaches, because each sprint represents a small, but complete, development iteration. This means that, in each sprint, the development team must perform activities that are related to almost all software engineering disciplines, even if only a little part of them at a time. Although we attempted to introduce these disciplines at the same time, much content was only really assimilated by students after two or three sprints, after the discipline was finished.

This explains why most groups were unable to deliver complete software in earlier sprints, because they simply did not have enough knowledge to implement a complete piece of software. For example, service-oriented architecture is only introduced in sprint 4, so it was impossible for some groups to implement a distributed part of the software in sprints 1, 2 and 3. More basic concepts, such as object-relational frameworks, were introduced only in the final stage of sprint 1. Some framework concepts were left to sprints 2 and 3, so many stories could not be completely implemented in these sprints.

When interviewed by us, some of the students reported this exact problem. Many complained about the mandatory deliveries in the early sprints, arguing that they still had not learnt the necessary concepts to implement what was being planned. Those ended up delivering incomplete software or software with conceptual errors. Of course, there were those students that already had the necessary knowledge, because they already work with development, but this is far from ideal.

A second problem we observed relates to inspection and self-management, two central aspects of Scrum [9,10]. Students reported that, because they are not physically close to each other, and because many of them had other time-consuming activities, some of the interaction tasks required for control in Scrum were not properly executed, or not executed at all. One example is the interaction between the Scrum Master and the rest of the team, which turned out to be very difficult under these conditions. The physical distance and the lack of responsibility and discipline of the other members of the team made it nearly impossible for the Scrum Master to control task execution in a continuous fashion. This is a serious flaw, because personal interactions is a strong principle of Scrum and agile methods in general.

Another issue is that, because there were only two possible projects, shared by all groups, there was always some kind of comparison happening between the students. Some felt pressured to keep up with the most experienced students, while others, less experienced students, felt intimidated by the top groups, becoming even frustrated in some cases.

We do not see any ideal solution for the first two issues, as we consider them to be innate to this particular academic environment. It is not possible, for example, to obligate students to be physically present at the university all the time, since this is a postgraduate course, and most students have their regular jobs. However, we did identify some improvement possibilities, that we intend to test in a future version of the course. These are described next.

A. Changes in the second version of the course

A first change relates to the definition of the POs. In the first version, two teachers acted as POs for all groups. This was not seen as a negative point in the first version, but only because the projects involved a domain the teachers were familiar with. As we wanted to change the domains, we decided to use actual business experts as POs. We also defined that they should not be familiar with technical details. The idea is to make the students experience what it feels like to deal with potentially real customers, having to work harder to establish the communication and capture the PO's knowledge.

A second change is that, differently from the first version, where there were only two projects from which students could choose, in this second version there were more options, allowing each group to work in a different project. This should reduce the comparison effect we observed earlier.

Another change in this second version is related to corrections and improvements made in the software, from one sprint to another. In the first version of the course, we observed that many groups were spending time in one sprint to correct mistakes made in the previous one. This happened because of the irregular learning curve discussed in previous section. In this version, we made it possible for students to include these corrections and improvements as valid deliverables. So, instead of delivering one complete piece of software in each sprint, a group was allowed to deliver an incomplete, or erroneous part of software, in one sprint, and plan its correction in a future sprint.

The changes described here are being currently tested, in a second offering of the Scrum-based version of the course. We expect to observe improvements related to some of the issues described in the previous section.

V. CONCLUDING REMARKS AND FUTURE WORK

Although we observed many problems and issues, the merging between teaching and an agile process has proven to benefitial to students. It leveraged the overall experience, from simpler theoretical classes, to a richer practical activity revolving around actual development, simulating the real challenges of this dynamic environment. Students were forced to not only understand the concepts and principles of agile development, but put them in practice and feel the difficulties faced by practitioners. In particular, they had to deal with technical challenges, process enactment challenges, personal interaction and inter-team relationship.

We perceived that some aspects of the methodology, such as scoping and delivery restrictions, had to be adapted to make the experience viable in an academic environment. Some of these adaptations were aldeady made during this first experience, while others are being tested in a second version. In either case, the adaptative nature of the course made this experiment possible.

Regarding the difficulties and problems that were observed, we conclude that some can not be easily solved, such as those related to the physical distance between the students and their lack of time and dedication. For others, we are currently experimenting some changes, as described in previous section, and we expect good results. Feedback from the teachers and the students will enlighten our path, and possibly raise new issues.

Besides these changes we already described, future work should deal with:

- Better distribution of the disciplines alongside the sprints, to provide a closer alignment with the deliverables. Perhaps there should also be some kind of guidance during the initial planning, in order to help students to start with simpler stories;
- Better choice of projects, to only include those that are amenable to a more logical division from simpler functionality to a more complex one; and
- Self-management formalization, to help Scrum Masters to deal with their teams. Currently, it is up to the team to define how they should be managed. However, this has proven to be problematic, because of the distance between its members. A more formal process, requiring more rigid control, would force students to have discipline and an active participation, specially in process control. Even if it goes against the agile principles, we believe this could be benefitial in this particular environment.

The experience, although in its first version and with glitches and corrections to be made, forcing students to not only understand the concepts wrapped up the process, but also to apply them and feel the difficulties faced by professionals who choose to use the method, as both procedural and planning relationship with the team.

It is felt that some aspects of the methodology, such as the closing of scope and delivery restrictions, sometimes must be adapted so that it becomes feasible to use the method in practice academic environment. The vision of the labor market and experience in agile methodologies presented by those involved was importance to design and optimized coordination of the course. Some strategies may not be considered agile, as the time between sprints and little interaction between the team members. The time between sprints is necessary because the teams need learn how to do and do it. The increase of interaction between the team members can be made and we have recommendations how to solve it in the next experience.

In the next experience some points will be analyzed to reduce the difficulty required to develop the full functionality in the sprints with only part of knowledge, requiring only the scope that has already been taught. The process for the development of Sprint requires weekly meetings replacing the daily meetings of the original conception of Scrum. The meetings will relate the status of the worksheets and they will show the progress of activities in parallel. These points will be not abandoned and they are essential for the correct handling of the use case, where someone can perform a checkpoint of these activities during the sprints, assessing whether the performance is occurring in the team. However, attention must be given up lest they undermine the progress of activities and the motivation of participants with a big load evaluation.

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A retrospective study of a personal energy audit assignment in a renewable energy sources course

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***Abstract*— A retrospective study was conducted on analyzing student performances on the personal energy audit assignment in the renewable energy sources course. We analyzed student scores from 2006, 2009, and 2012 years respectively and categorized them by declared major. In this assignment, we asked our students to calculate the amount of energy that they consumed in one week of their life in college and identify the activities that consumed the largest amount of energy. We also asked them if they would consider any habit changes after completing this assignment. The goal of this assignment was to introduce non-science and engineering students to the concepts of energy, power, electricity, heat, temperature, first and second laws of thermodynamics, embedded energy and world energy consumption. The most common categories included; energy consumed in heating up water, transportation, and electricity. Additionally, on calculating energy used by electricity, we asked the students to confirm their calculations by reading labels and using Kill-a-Watt reading devices. In total, the scores of more than 500 students were evaluated. We found that the average of the scores increased by 19% between 2006 and 2012, and by 14% between 2009 and 2012. Since we used a similar rubric for grading, this shows that the students were able to perform better as we provided more step-by-step instructions, and streamlined the lectures on basic physics and energy concepts in the first three weeks of the course. Moreover, we grouped the student's scores by their declared major. The four categories were engineering, social sciences, natural sciences, and undecided/other majors. We found that in 2006 the students with social science majors on average received the highest scores and in 2009 the students with natural science majors received the highest scores. Interestingly, the students with engineering majors showed the highest improvement in their scores between 2006 and 2012. The paper provides analysis of the student performances on this assignment and the overall effectiveness of this assignment.**

Keywords— personal energy audit

I. INTRODUCTION

While our nation faces the challenge of meeting the demand of growing energy consumption, personal energy audits are coming more and more common in residential and commercial sectors. In 2010, together, these two sectors consumed 41.2% of energy in the United States[1]. Currently, the important concepts of saving energy at home and at school are taught as early starting the third grade through the 12th grade and in college[2]. Concepts of energy management, solid waste and recycling are part of the curriculum starting in kindergarden through the 12th grade in high school[3]. Popular teaching methods include classroom activities and hands-on experiments. Home energy efficiency kits have been developed for students to take home, to facilitate discussions between students and their parents on various ways of saving energy. Typically such kits consist of incandescent light bulb, compact fluorescent light bulb, kill-a-watt meter, light meter, Teflon tape, low flow showerhead, kitchen sink aerator, thermometers, night light, radiation cans, humidity pens, and other related materials[4].

The use of SmartMeter technology is expanding dramatically in California. Pacific Gas and Electric Company (PG&E), provides energy services to 15 million people across 70,000 square miles in California, deployed 9 million advanced meters across the state. SmartMeters provide meter reads that include hourly intervals for electricity consumption and daily intervals for gas consumption. The energy use information is available online. Additionally, customers can also compare their home energy usage to other homes in the area as well as to weather patterns[5]. Last year, the National Energy Education Development Project in collaboration with PG&E launched a new SmartMeter curriculum module for students in grades six through eight that reinforces the need to conserve natural resources[6]. Information provided by Smart Meters can be used directly in student's personal energy audit assignments.

While conservation of energy is becoming more popular in K-12 curriculum, energy audits assignments are becoming a standard at college or four year institution courses on renewable energies and energy efficiencies.

At the University of California at Santa Cruz, the Renewable Energy Sources course is a theory based course with 19 lectures and eight hands-on laboratory experiments[7-9]. It is a 10 week course that meets general education requirements. The course has been offered every spring quarter since 2006. The course is designed for engineering and non-engineering undergraduate students and does not require any advanced mathematics or physics background. A sample list of lecture topics by instructors and guest lecturers include but are not limited to;

- World energy overview
- Energy basics, temperature and heat
- First and second laws of thermodynamics
- Solar energy
- Bioenergy
- Wind energy
- Ocean power
- Geothermal energy
- Social aspects of renewable energy (guest lecture)
- Nuclear energy (guest lecture)
- Local efforts on harvesting renewable energy (guest lecture)

This year, the eight hands-on laboratory experiments demonstrate the principals of the following; solar pathfinder, flywheel, wind turbine, hydroelectric, thermoelectric, hydrogen fuel cell car, greenhouse and solar power concentrators.

Additionally, the course involves required reading assignments, four written homework assignments, a midterm, a personal energy audit, a final exam and a final project proposal. Additional information and details about this course can be found at www.soe.ucsc.edu/courses/ee80j/.

II. Personal ENergy Audit Assignment

Around the third week of lectures, students receive a 20 minute lecture which outlines the requirements of the personal energy assignment. In this assignment, students are asked to conduct a personal energy audit to calculate the amount of consumed energy in one week of their life in college and to deliver their findings in the form of a report. The lecture also provides brief step-by-step instructions on how to calculate energy consumption of the most popular activities [10].

We ask the students to write their reports while following the report format shown below,

- Abstract
- Introduction (should include information about the student)
- Methods
    - List of energy services and sources
    - Transportation
    - Hot water consumption
    - Electricity usage (Watt-hours/week)
        - Calculated from labels
        - Measured with "Kill a Watt" meter
            - When appliances are on
            - When appliances are off
        - Verified through PG&E smart metering
        - Other
- Results
- Discussion (list of questions to answer)
    - Look for peaks of energy consumption, what do they consist of? What appliances were on during those particular hours?
    - How did your energy consumption change with the weather?
    - How did your home energy consumption compare to other homes in that area?
    - Which energy services are the biggest energy users?
    - How would you expect energy use for each service to change throughout the year?
    - Any surprises or noteworthy points?
    - From working on this project, would you now consider alternative energy sources for particular services?
    - From the calculations above, suggest a replacement for one of the high energy appliances? How much would it offset your energy consumption by?
    - Would you now consider a habit or lifestyle change?
    - Compare your results to the average American and European citizens.
- Conclusions

III. Results

At the end of the 2012 quarter, we asked every student in our class to complete a questionnaire which we asked a series of questions about the course. One of the questions asked was if the course had made the students more aware of energy use and its impacts. Another question was more specific to the energy audit assignment, which asked if the students had changed some of their personal energy use habits as a result of this course. We asked the students to rate their responses using the Likert scale. The results of our findings are presented in Table I. Seventy six percent of the students strongly agreed or agreed that this course made the students be more aware of energy use and its impacts. Almost sixty percent of the students have changed some of their personal energy habits as a result of taking this course.

TABLE I. Eng of Quarter Questionnaire, Spring 2012

Questions	***Strongly Agree***	***Agree***	***Neutral***	***Disagree***	***Strongly Disagree***
This course has made me more aware of energy use and its impacts.	30%	46%	18%	4%	0%
I have changed some of my personal energy use habits as a result of taking this course.	20%	39%	29%	7%	3%

Over the last six years, we improved our lecture instructions and the details of the assignment in order to show improvement in our instruction over the last 6 years. We conducted a retrospective study where we looked at the student's scores for the energy audit assignment when the course was taught in 2006, 2009 and 2012 (every 3 years). In total, the scores of more than 500 students were evaluated. We found that the average of the scores increased by 19% between 2006 and 2012 and by 14% between 2009 and 2012. Since we used a similar rubric for grading, this shows that the students were able to perform better as we provided more step-by-step instructions and streamlined the lectures on basic physics and energy concepts in the first three weeks of the class.

Additionally, we grouped the student's scores by their declared major. The four categories were engineering, social sciences, natural sciences and undeclared/undecided/other majors. We found that in 2006 the students with social science majors on average received the highest scores and in 2009 the students with natural science majors received the highest scores. Interestingly, the students with engineering majors showed the highest improvement in their scores between 2006 and 2012. Fig.1 contains the results of our findings.

Moreover, we looked at the performance of the students based on their grade level; freshmen, sophomores, juniors and seniors (students in their fourth year or higher). We found that sophomores received the highest scores in 2006 and 2012 while seniors received the highest scores in 2009. The highest improvement in scores between 2006 and 2012 was among juniors and the highest improvement between 2009 and 2012 was among freshmen. Lastly, we sorted the student's scores based on the student's gender. It was found that the male student population had the highest improvement from 2006 to 2012 and 2009 to 2012, while the female students received on average higher scores in 2006 and 2009. Fig. 2 and 3 contain the results of our findings respectively.

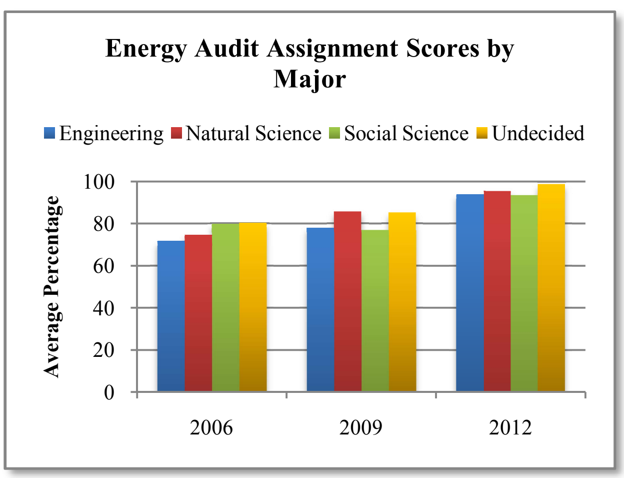

Fig. 1. Average Energy Audit Assignment Scores by Student's Major

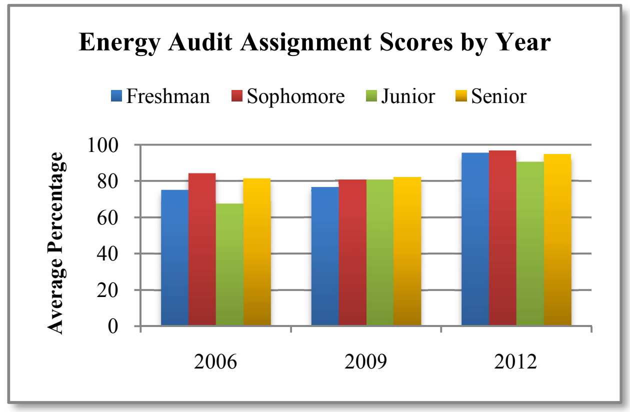

Fig. 2. Average Energy Audit Assignment Scores by Student's Year at the University. Note: Seniors are fourth year or higher.

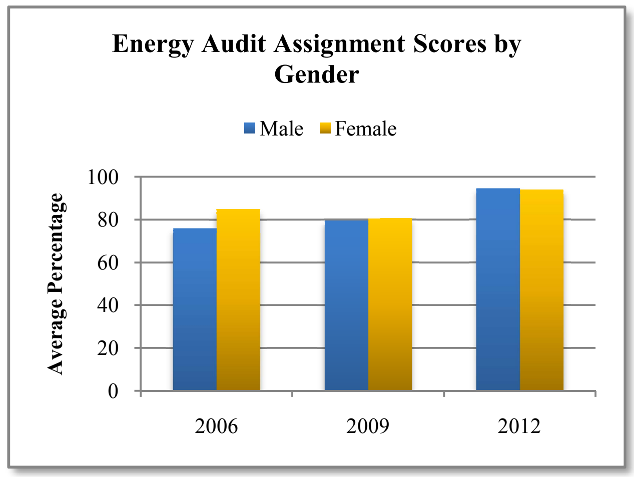

Fig. 3. Average Energy Audit Assignment Scores by Student's Gender.

IV. Long Term Follow Up

For long term follow up, we contacted our alumni students who took our renewable energy sources course exactly five years ago. At that time, our class enrollment was 139 students. Using social media, we were able to locate 75 of those students to whom we sent invitations to participate in an online survey in December 2012. We received responses from 27 students. Below is the summary of our findings;

- 93% of our students agreed or strongly agreed that our course significantly broadened their knowledge of renewable energies, energy conversion, energy storage, or clean energy technologies.
- 93% of our students recommend for other universities and colleges around the country to implement such a course into their institutions.
- 89% of our students agreed or strongly agreed that our course was a valuable course of their curriculum at UCSC.
- 89% of our students agreed or strongly agreed that our course sparked their interest in learning more about topics related to renewable energies.
- 74% of our students indicated that they have experienced a few habit changes since completing the personal energy audit assignment as part of this course.

- 93% of our students indicated that if they were to pass by a newspaper stand and to catch a glance of a title on the front page of a newspaper, “San Francisco voted to be powered by 100% renewable energy” they would read at least part of the article.

The outcome of this survey shows a great interest among our students in the environment in which they live in and the energies that power it.

ACKNOWLEDGMENT

Authors would like thank past and present students of our Renewable Energy Sources course. Additionally, the authors would like to acknowledge the financial support from NSF/DUE 1023054 Engaged Interdisciplinary Leaning in Sustainability grant.

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A hands-on laboratory experiment on concentrating solar power in a renewable energy sources course

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Abstract*— At Hartnell Community College in Salinas, California, a renewable energy and energy efficiency course is a theory based course with several hands-on laboratory experiments. The course is designed for engineering and non-engineering students who are looking to transfer to a 4 year institution. Similar courses at 4 year universities, usually meet general education requirements. This course does not require any advanced mathematics or physics background. In order to enhance student learning in this course, we offered an additional hands-on laboratory experiment on concentrating solar power. The laboratory kit consisted of affordable and widely available materials that included 24 telescoping mirrors, stands, steel cup, thermometer, timer, and a cup of water. We asked the students to design, assemble, and test a central receiver concentrator with the goal to boil water contained in a steel cup. Upon achieving this goal, students were then asked to calculate the efficiency, define losses, and recommend ways of increasing efficiencies and therefore improving their systems through. The design challenge for the students is to determine the optimum position for the mirrors. Additionally, we asked the students to comment on the following; the effects of the time of the day and weather conditions, direct commercial applications, the process of generating electricity from solar concentrators. In order to record the level of improvement, each student was given the same questionnaire before and after completing the laboratory experiment. Upon grading the questionnaires, our assessment showed a 30% average on pre questionnaires scores and a 73% average on post questionnaire scores, suggesting a 43% improvement. This paper presents the results of our findings on performance improvements in further detail.

***Keywords*— concentrating solar power, laboratory experiment, solar concentrators, questionnaires.**

I. INTRODUCTION

A solar concentrator is considered one of the cleanest technologies for harvesting renewable power. There are several ways of concentrating solar power. The most popular methods are through using one or the combination of one of the following:

- A parabolic trough concentrator is a solar thermal energy collector. It is constructed as a long parabolic mirror with a tube running its length at the focal point. The sunlight is reflected by the mirror and concentrated on the tube. It usually rotates to track the sun that moves across the sky.
- A central receiver concentrator also known as central tower concentrator is also a solar thermal energy collector. In such design, a tower is used to receive the focused sunlight from an array of flat, movable heliostats (or mirrors).
- A parabolic dish concentrator is also a solar thermal energy collector. In this design, one or more parabolic dishes are used to concentrate solar energy on a single focal point. It is considered one of the most powerful types of collectors. [1]

For the purpose of this laboratory experiment, the authors chose to focus their attention on a central tower concentrator system. Recently, these types of systems have received more interest on a large scale. Typically, large scale systems of this kind cover several square kilometers, consisting of thousands of heliostats, and one central tower.

In the United States, several power plants of this kind are in production in the Mojave Desert, California. The first prototype was completed during the 1980s, it is capable of generating 10 MW of power. Fig. 1 demonstrates a photograph of this power plant on the left [2]. At the same time, internationally, PS10 and PS20 solar power towers were completed in 2006 and 2009, generating 11 and 20 MW of power respectively, providing energy for over 10,000 homes in the city of Seville, Spain[3]. Fig. 1 shows a photograph of the PS20 power tower on the right.

Fig. 1. Barstow central receiver system (left). SP20 central power tower in Seville, Spain (right).

II. METHODS

The goals of this laboratory experiment were to illustrate the principles of concentrating solar energy, to familiarize students with relevant technologies, and for students to gain knowledge and skills in calculating efficiencies.

To achieve these goals, we introduced a miniature version of a central power concentrator system that mimics the insights of a large scale system. Next, we asked the students to design, assemble, and test a central receiver concentrator with the goal to boil water contained in a steel cup. Upon achieving this goal, students were then asked to calculate the efficiency, define losses, and recommend ways of improving their systems.

The students were encouraged to work in groups of no more than three students. The laboratory was approximately 90 minutes. Each individual student was provided with a paper based laboratory write-up and each group was given a laboratory kit consisting of discrete components. Each laboratory kit consisted of 24 telescoping mirrors, a stand, a steel cup, 6 oz. of water, a thermometer, and a stop watch. The telescoping mirrors, steel cup, thermometer, and stop watch are affordable and commercially available instruments. The steel cup was previously welded to the extendable arm of one of the original telescoping mirrors. The stand was custom made to provide support for the 24 mirrors and the steel cup with support.

Next, the students were asked to read the laboratory instructions, follow directions, conduct the laboratory experiment, and fill in the required information while showing their calculations. The students were then asked to follow the instructor outside to collect the needed data. Below is the list of 13 steps summarizing the laboratory instructions. Additionally, the students were provided with formulas needed for the calculation of efficiency.

Laboratory Instructions

Due to the large diversity of student backgrounds, we provided more detailed instructions than if it was all engineering students.

1 Using the data published by the National Renewable Energy Laboratory in Colorado, determine the amount of solar energy available at your location today. Calculate the solar power density available to this location per day.

2 With your group partners, discuss possible configurations of harvesting solar power using the 24 telescoping mirrors. Your goal is to build an energy harvesting device that brings a cup of water to boil in the least amount of time and therefore achieving the highest efficiency possible.

3 Choose one mirror configuration that you and your partners agree would achieve the highest efficiency and discuss it with your instructor.

4 Proceed to the outside location with your instructor.

5 Place the stand in the desired location. Next, position your lab components in the following order; cup holder with a mounted cup, water, thermometer, telescoping mirrors. DO NOT TOUCH THE CUP AND THERMOMETER ONCE THE FIRST TELESCOPING MIRROR IS IN PLACE. SERIOUS BURNS MAY OCCUR.

6 Record the temperature of water and time periodically (every 30 seconds or 1 min).

7 Once the desired temperature of the water is achieved, disassemble your device by first removing the mirrors, letting the steel cup cool off for several minutes. Next, remove the cup holder with a cup and finally pour out the water in a safe location.

8 Please return to your classroom.

9 Calculate the amount of energy needed to raise the given amount of water by certain number of degrees Celsius.

10 Calculate the amount of power that was put into the system to raise the temperature of water.

11 Estimate the circular area (in meters2) of the solar concentrator that you built. You can do so by estimating the radius and calculating the area.

12 Calculate the power density of your device.

13 Lastly, calculate the efficiency of your system.

Discussion Questions

- Why do you think the efficiency of your system is so low? Define at least three losses in your system.
- Taking the losses into consideration, identify at least three ways of improving the efficiency of your system.
- If you and your partners had another chance at conducting the same experiment, what would you have done differently from the beginning?
- What effects do the time of day and weather have on this experiment?
- Brainstorm several direct commercial applications of the solar concentrator.
- Develop a scheme to generate electricity from a solar concentrator.

III. RESULTS

A total of 14 students participated conducting this experiment. The class consisted of eleven males and three females, nine 1st year, three 2nd year, two 3rd year students, ten declared engineering majors, two social science majors, and two undecided majors.

All students were able to complete this laboratory experiment successfully in a given period of time. Several groups modified their design and techniques during mirror configuration and assembly processes. Fig. 2 shows photographs of students assembling their set-ups.

Fig. 2. The students are gathering data from their central tower concentrating laboratory set-ups.

IV. STUDENT ASSESSMENT

In order to test the acquired knowledge, each student was required to complete a questionnaire before and after the experiment. The questionnaires were called, pre and post questionnaires respectively. The pre and post questionnaires consisted of ten identical questions with five multiple choice answers with the last question being “I don’t know” on the pre questionnaire and “I still don’t know” on the post questionnaire. The list below contains questions from the pre questionnaire. Each questionnaire was graded on a scale of one to ten, where each score represented a number of correct answers.

Pre Questionnaire

Due to diverse academic backgrounds, the questions were chosen to access the base line knowledge of the subject area prior to the experiment as well as test knowledge gained after the experiment.

1 In the last decade, what was the fastest growing renewable power technology worldwide?

a Wind Turbines
b Photovoltaics
c Fuel-Cells
d Electric Vehicles
e I don't know

2 How long have solar concentrating devices been around?

a a few years
b a few decades
c a few hundreds of years
d a few thousands of years
e I don't know

3 How much power (over one year) are we capable of harvesting in California using photovoltaic systems alone?

a a kilowatt
b a MegaWatt
c a GigaWatt
d a TeraWatt
e I don't know

4 What is a heliostat?

a photovoltaic cell
b a photovoltaic array
c a solar dish
d a mirror
e I don't know

5 In the winter time, how many hours during the day do we receive 70% of sunlight?

a 8 hours
b 7 hours
c 6 hours
d 5 hours
e I don't know

6 If a solar concentrating device has a circular area with radius of 10 cm. What is the area of such device?

a 20 cm
b 60 cm^2
c 100 cm^2
d 300 cm^2
e I don't know

7 In Arizona, on average, 7 kWh/m^2 of solar energy density is available a day. If a solar concentrating device has an area of 2 m^2, how much energy is acquired by such device.

a 3.5 kWh
b 7 kWh
c 14 kWh
d 28 kWh
e I don't know

8 If you have a device that consumes 100 Joules of energy in 10 seconds. How much power does it consume?

a 10 Watts
b 100 Watts
c 1000 Watts
d 10000 Watts
e I don't know

9 If a kitchen kettle raises the temperature of 300 gr of water from 20°C to 60°C? How much energy does it consume in doing so? (please neglect all losses) (specific heat constant is 4.186 Joules/gr °C).

a 1.2 kJ
b 2.5 kJ
c 25 kJ
d 50 kJ
e I don't know

10 If a solar concentrating device is exposed to 1000 Watts of power per day and it harvests 200 Watts of power on daily basis, what is the efficiency of this device?

a 10%
b 20%
c 50%
d 100%
e I don't know

Upon grading the questionnaires, our assessment showed a 30% average on pre questionnaires scores and a 73% average on post questionnaire scores, suggesting a 43% improvement. Additionally, the students answered on average 2.5 questions as "I don't know". After completing the laboratory experiment, the students answered on average 0.8 questions as "I still don't know" suggesting 17% improvement.

V. Conclusion and Future Work

Overall, the students in the class showed improvement in learning and understanding concepts about concentrating solar energy. Our future plans include transferring paper based laboratory write-ups and assessment to computer based interactive applications. Additionally, one way of expanding this laboratory experiment is by adding a Sterling engine kit that would convert heat into rotational energy as part of this experiment. Fig.3 demonstrates potential addition. Other potential additions could include a variety of thermoelectric devices.

Fig. 3. Sterling engine powered by solar energy. The design challenge for the students is to determine the optimum position for the mirrors.

Acknowledgment

The authors would like to thank the students for their participation and interest in conducting this laboratory experiment. Additionally, the authors would like to acknowledge financial support from the NSF-ATE program 1104311.

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Design, Construction, and Testing of an Electric Machine Test-bed for Use in Laboratory and Research Education

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***Abstract*—Research and education into various methods of improving energy efficiency for electrical devices has become increasingly important to meet future energy needs. Because of this need, an electrical machine test-bed was designed and built in collaboration with a senior design team for the purpose of furthering research and education in the area of power electronics and motor drives. Both the engineering education and research capabilities aspects of this test-bed have an important role in educating engineers with skills to quickly contribute to the power and energy related industry. This paper will discuss the design, construction, and testing of a research quality electric machine dynamometer and test-bed for use in undergraduate and graduate (UG/Grad) education, as well as for research into power electronics and motor control .**

Keywords—electrical machine; dynamometer; test-bed; engineering education; power electronics

I. Introduction

Dynamometer systems are used extensively in testing and verification procedures in various applications relating to automotive, industrial, and manufacturing fields. The advantages of using a dynamometer are to simulate a wide range of loads a system may experience, precise controllability, and unit testing prior to the unit under test reaching the customer. Electrical machine drive systems are used invarying degrees of dynamometer systems for both research and design, and for product validation. In order to investigate some of the latest technology and control techniques for electric machine drives applications, an electrical machine test-bed was designed and built with the purpose for both research into these topics and to compliment undergraduate laboratory course in power electronics and motor drives.

Fig. 1. Testbed Infrastructure Control Cabinet

II. Architecture and Design

The electric machine test-bed is a collection of various commercially available and custom made components. It is designed to enable a wide variety of electric machine configurations and applications, as it provides a platform for testing of innumerous projects. The current configuration of the test-bed features two identical 20 HP ABB induction machines in a back-to-back testing configuration. The “dynamometer” is controlled via an ABB (full 4-quadrant) variable frequency drive. The “prime mover” machine is driven from a custom IGBT inverter and is controlled via a dSPACE embedded controller. A Himmelstein compact a compact digital torque meter measures both shaft speed and shaft torque. The power wiring of the test-bed is controlled by a Motor Controller and Safety System Enclosure (MCSSE), shown in Fig. 1. The MCSSE includes a standalone PLC system that controls the power flow throughout the system. The test-bed machine mounting tables were built in modular fashion to accommodate various machine types and size.

While designing the dynamometer test-bed, safety was a top concern. The test cell safety layout is shown in Fig. 2 and shows two zones of safety; the green zone and red zone. These zones are a mental construct used to indicate to the test cell user where the areas of concerns are located. There are no physical barriers, or markings, in the test cell to differentiate the zones. The green zone has virtually no added risk or safety concerns, whereas the red zone requires greater caution. The “green zone” is the intended area for the operator to be during any testing or computer use and has no greater risk due to the test cell components. The “red zone” has significantly greater risk of injury because of the test-bed table, cables and cable trays, and the exposed test cell electrical components; such as the inverter, dc power supply, transformer, dynamometer, and enclosure. These devices have adequate guarding to protect from injury, however the risk is greater around these components. To protect the torque sensor cables, a cable tray was placed on the floor below the workbench. The users should observe caution when working around the workbench. The workbench also has several electrical components that could cause risk of injury and the user should be cautious when working around this. For the mentioned reasons the “red zone” is determined to have an increased risk and increased user caution.

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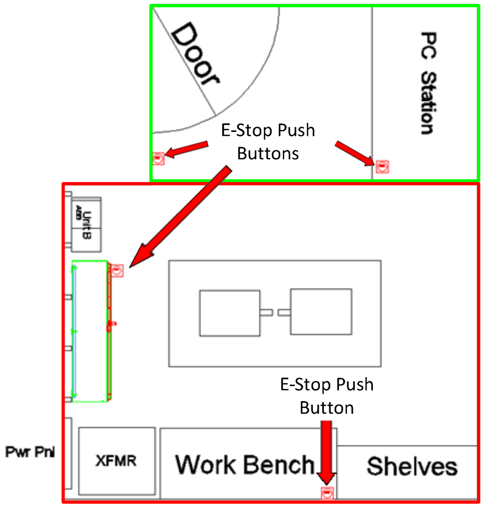

Fig. 3. Testbed Floor Layout

Throughout the entire test cell system there are several varying power supplies with the majority of power supplies powering the inverter controls and control devices including 5 VDC and 15 VDC powers supplies to power the signal isolation and interface board. The MCSSE has only two external power sources, the "Main Power" source (MPS) (208 VAC 3ph) and the "Control Power" source (CPS) (120 VAC 1ph). Table I lists all of the electrical energy levels present in the system and the rated maximum current carrying (fused limited) ability of the circuit.

TABLE II. TEST CELL ELECTRICAL POWER OPERATION LEVELS

Name	Voltage	Max Current	Description
Main Power[a]	208 V_{AC} 3ph	50 A_{rms}	Line feeds to Motors
Motor 1	208 V_{AC} 3ph	50 A_{rms}	Load feeds for Motor1 (Prime Mover)
Motor 2	480 V_{AC} 3ph	30 A_{rms}	Load feeds for Motor2 (Absorber)
Control Power[a]	120 V_{AC} 1ph	10 A_{rms}	Micrologix, Aux Fans, DC Power Supply
Control System	24 V_{DC}	10 A_{dc}	Test cell I/O, Stop PB, safety relay

[a.] denotes external power source

A. Electrical Power Stage Design

The test-bed architecture was design for two electric machines "back to back" testing. A one-line schematic is shown in Fig. 4 for the current system configuration. This system configuration allows a lower amount of energy supplied from the building infrastructure. At full load, the energy flow is in a clockwise direction and only the losses in the system are needed from the building power system. The "back to back" testing configuration consists of two identical induction machines that are mechanically coupled together via flexible motor couplings and torque sensor. There is only one source of electrical energy for the electrical machines, a 208 VAC 50 Amp 3 phase receptacle, which is supplied from a power panel from the building infrastructure. This source would supply two "loads"; the magna dc power supply/inverter and an ABB frequency drive. The Magma dc power supply powers the APS inverter which supplies power, decoupled frequency, to the "Prime Mover" electrical machine, M1. Because the frequency drive operates at a different voltage than the main source power a transformer is needed. The frequency drive would then supply the "Absorber" electrical machine, M2.

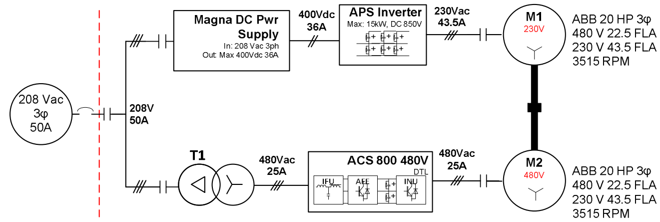

Fig. 4. One Line Testbed Circuit

B. Control Stage Design

The control state consist primarily of a custom design MCSSE that houses all of the test cell infrastructure controller hardware. The MCSSE includes five 60 A contactors that can control the flow of electrical energy in the test cell. The contactors are controlled via a Allen-Bradley Micrologix controller and a Allen-Bradley safety relay. The safety relay monitors the emergency stop push-buttons using two different electrical circuits for redundancy. If one of the contacts on the ESPB happens to malfunction, the safety relay will detect this and remove the electrical power to the outputs of the Micrologix, therefore opening the contactors, and removing the main power source to the electrical machines. If the safety relay does not detect an issue, the Micrologix controller has control on turning the contactors on and off, based on its user defined program. The advantages of having both devices controlling the contactor operation, is the reliability of the safety relay and functionality of the being able to program using the Micrologix.

The control stage power is derived from a separate power source than that of the electrical power stage. This allows the control stage to operate independent of the power stage being energized. This was a specific design choice to allow for commissioning and troubleshooting purposes. This design choice minimizes the exposure to high voltage and power wiring, when working with solely a control system issue. The power and control stage system level electrical schematics were developed and the MCSSE layout was design specifically to keep the high voltage ac power separate from the low voltage dc safety system power. Fig. 5 shows the MCSSE with the enclosure doors open. The green box indicates the low voltage dc wiring. This is done to minimize any induced voltage on the dc Safety System control circuits which may cause undesired behavior. The presence of the low voltage ac (120 VAC single phase) is necessary to power the dc power supply, Micrologix controller, enclosure ventilation fan, and the inverter heat sink fan, it is located inside the green box (upper right hand corner). This location was chosen to minimize any induced voltage on the low voltage dc circuits.

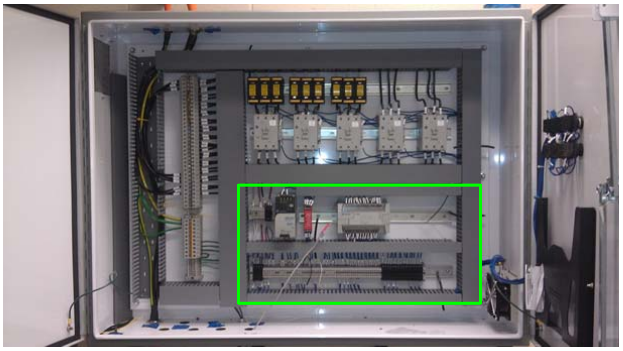

Fig. 5. Testbed Infrastructure Control Panel Layout

C. Test-bed Modularity

The test-bed system was design and built to be able to incorporate various application and configurations. It's designed is only constrained by the voltage and current levels off 600 V and 60 A respectively. The test-bed electrical machine table, shown in Fig. 6, was design with industry standard "T-slots" for mounting that are spaced with several mounting widths for various electrical machine sizes. The tabletop is also made considerably wider that the current induction machines, to allow for future expansions. The Micrologix controller was also purchase to allow for future expansion of I/O channels and possible future implementation of a Human-Machine interface touch panel.

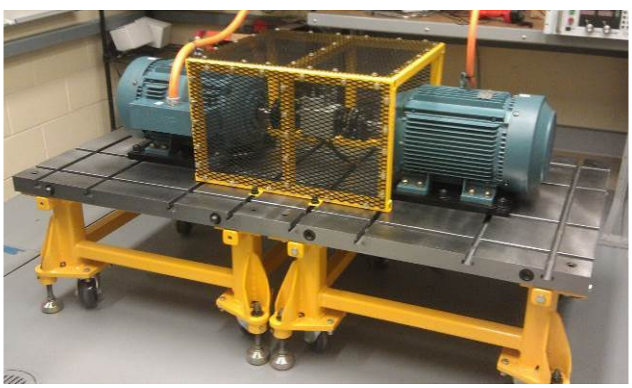

Fig. 6. Dynamometer Test Bed Table

III. Component Discussion

The test-bed is primarily comprised of off-the-shelf commercial products. The components are integrated together to form a functional electric machine dynamometer test-bed. The one-line system is classified into two distinct portions; the "prime mover" and dynamometer. TABLE III lists the different subsystems within the testbed as seen in Fig. 7. The top branch of the circuit, or prime mover, consists of the subsystems A and B. The lower branch of the one-line diagram is classified as the dynamometer and consists of subsystems E through F.

TABLE III. Test cell Major Components

Abbr. Letter	Component Name
A	Dc Power Supply
B	Dc-AC Inverter
C	Induction Machines
D	Motor Coupling Assembly
E	Isolation Transformer
F	Variable Frequency Drive
G	Controller Station
H	Control Signal Isolation and Interface

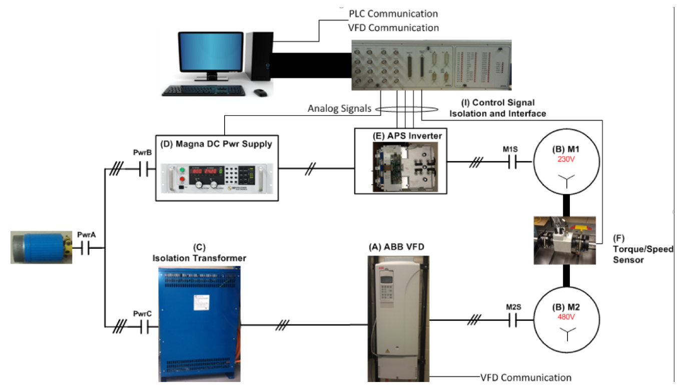

Fig. 7. Test-bed System and Component Integration Overview

A. Prime Mover Components

The "prime mover" components consist of the dc power supply and inverter. These two components allow for control over Motor 1 via the dSPACE embedded controller. The dc power supply converts the three phase voltage supplied by the building infrastructure into a dc potential, which then feeds the 3 level inverter. The inverter uses common control switching techniques such as volts per hertz, field oriented control, and direct torque control to send the appropriate voltage and current waveforms to Motor 1.

The dc power supply is manufactured by Magna-Power Electronics and is available in a variety of input and output configurations. The model used in test-bed is a TSA400-36 and has a 240 volt, 3 phase input. Its nominal output power is 15 kW with a max dc output of 400 V and 36 A. It has three modes of operation; Normal, constant voltage, or constant current. For the "Normal" mode the TS series power supplies can be configure for control by rotary mode input, local sensing, internal control, and external control. With this configuration, the operator can select either a constant voltage or a constant current output using the front panel controls. The mode is determined by the limits of the voltage or current settings. During operation whichever limit is lower for that particular operating point it will determine the operation mode, either constant voltage or constant current, that will be governing the control. For the test-bed application the dc power supply is configured to be constant voltage control by setting the current limit to the maximum value. The embedded controller then sends an analog signal to the power supply governing the dc output voltage. However one major drawback is the dc power supplies inability to sink current and absorb power from the electric machine.

The inverter can be configured as either dc to dc power converter or a dc to ac single/three phase inverter. It main function is to power and control the "prime mover" machine. The unit is manufactured by Applied Power Systems, Inc. The inverter, part number IAP75T120, is a standard IGBT sixpack configuration consisting of 6 IGBT arranged in 3 phases, each containing two IGBTs. The inverter can accept up to a 850 Vdc input, operates at switching frequencies up to 20 kHz, and has a maximum phase current of 75 A. It features built protection systems for output over-current, input over-voltage, heatsink over-temperature, control under-voltage, and short circuit protection. It also features opto-isolated (fiber-optic) gate drive and fault signal output for electrical isolation and noise immunity.

B. Dynomometer Components

The dynamometer components consist of the isolation transformer, variable frequency drive, and the second induction machine, Motor 2. The variable frequency drive (VFD), was donated from ABB Automation and Power based out of New Berlin, Wisconsin. It is intended to provide the load torque in the dynamometer system. It is an ultra-low harmonic (ULH) VFD, which minimizes the amount of harmonics injected from the grid or power supply. The VFD features insulated gate bipolar transistor (IGBT) controlling the supply side of the drive line connections to the dc link, known as an active front end (AFE). This is in contrast to the conventional diode bridge used in other VFD systems [1]. The AFE permits the ABB VFD to control the line current to sinusoidal waveform and the built in harmonic mitigation eliminates the need for additional, expensive equipment like transformers or line reactors. The AFE also ensures that the drives meet the harmonic distortion standards set by the IEEE 519 1992 standard. The ABB VFD also features Direct Torque Control, and open-loop dynamic speed-control with accuracy matching ac drives using closed loop flux vector control, Start-up Assistant estimates motor parameters by the user entering nameplate info, and Adaptive Programming.

The isolation transformer is needed because of the different potentials between the building supplied voltage level (208 Vac) and the required input voltage of the VFD (380-500 Vac). The transformer was purchase to be configured as a 30 kVA step-up, step-down, or isolation transformer. The ability to use the transformer in any one of these three configurations allows for future flexibility and varying electric machine voltage potentials while added only approximately 25 % more in purchase costs.

C. Electric Machine and Coupling Components

The electric machines used in the current configuration are 20 HP dual winding induction machines; wired for 230 VAC or 480 VAC. They have a rated frequency of 60 Hz, rated speed of 3515 RPM, and a full load current of 22.5 A/45.0 A depending on their wiring configuration. Unfortunately there was no documentation for this donated equipment, so only nameplate information is available. Further machine values and parameters are discussed in section IV.

The motor coupling assembly is comprised of a torque sensor and two flexible coupling units as shown in Fig. 8. The assembly is a "mechanically floating" system. This means there is no support to the sensor holding off the test bed. Excluding the shafts, the only means of mechanical connection is strap (cable) used to mechanically "ground" and keep the sensor from spinning with motion of the shafts. The only force the mechanical "grounding" strap would need to provide is the frictional bearing force of the sensor.

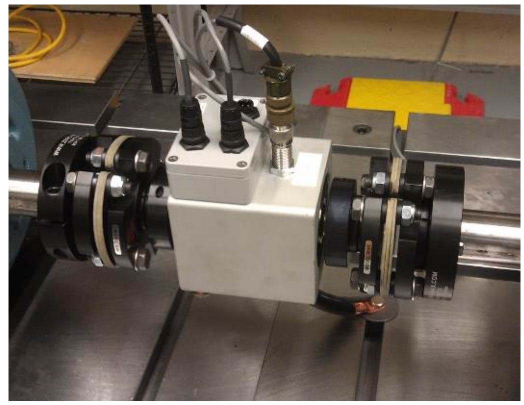

Fig. 8. Torque Sensor and Flexible Coupling

The torque sensor is commercially available unit purchased from S. Himmelstein and Company, which specializes in torque sensors of all type. It has a max continuous torque rating of 113 Nm and 226 Nm overload rating. It provides both shaft torque and speed information to the embedded controller from an external signal condition unit purchased with the sensor.

The torque sensor used is in conjunction with flexible couplings manufactured by Zero-Max. Theses couplings are intend to minimize any misalignment in the horizontal direction which would translate to axially torque that could possible damage the torque sensor. The flexibility comes from the composite discs that are a "clover" shape and are made of laminated, flexible sheets. The same flexible coupling units can be order with a variety of input and output shaft sizes, lending it to be appropriate with future configuration flexibility.

D. Test-bed Operational Controls

The current test-bed operation control is comprised of three independent interfaces. The inverter embedded controller, which sends the control signals to the inverter unit, is an ACE 1104 unit supplied from dSPACE. This system was chosen for its known behavior in laboratory classes and its relative ease of use. This controller features two digital signal processors (DSP). The "primary" DSP performs the control algorithm execution therefore performing the majority of the calculations, and executes at a rate of about 100 µs. The other DSP, or "Slave" DSP, controls the switching action sent to the inverter via pulse width modulation (PWM). The slave DSP can operate at switching frequencies in excess of 100 kHz. The DS1104 and breakout box features 8 ADC analog inputs (4 multiplexed, 4 parallel), 20 digital input/output (I/O), 8 channel DAC analog outputs, two DSP, serial communication port, and digital incremental encoder interface.

The VFD has several options for user control input such as front panel keypad, and using a fieldbus adaptor that can communicate on various industry communication protocols. For the test-bed configuration, the VFD communicates via Modbus RTU receiving its commands using LabVIEW from the test-bed computer. This configuration allows the VFD to be controlled through the common test-bed computer. From the user station, the VFD can be turned on/off, reference torque, and reference speed can be commanded.

The test cell infrastructure controls was designed to be a standalone system, independent of the VFD and inverter control systems. The test-bed infrastructure controls what power stage components are supplied the primary 3 phase power from the main power source. The test cell infrastructure controls consist of the power wiring, fuses, contactors, and a programmable logic controller (PLC). Based upon the user provided control inputs, the PLC decides the states of the outputs. Example of these control inputs are contactors, the safety relay, start/stop pushbuttons, fans, and indicator lights. The outputs of the system are the 3 phase power contactors as well as a few indicating lights. The high level control scheme of the test cell safety system puts the system in one of five states; "Ready", "Enabled", "Powered", "ON" and "Fault". These states dictate what, if any, combination of contactors and indicating lights are on.

IV. System Parameterization and Performance

To utilize this system as an educational platform, its behavior must be observed and quantified. There are several unknown areas, component efficiency, system response, and electric machine parameters that needed to be understood and characterized. These areas include induction machine parameter estimation, component operation efficiency, and system response data.

To employ any type of modern electric machine control techniques such as FOC or DTC [2]-[3], the induction machine parameters needed to be determined. Precisely knowing these parameters allows for accurately modeling and designing the control algorithms is used to command the system. The method used to derive the equivalent electrical machine parameters listed in TABLE V. Several tests were performed to estimate the parameters of the ABB 20 HP induction machines; No-load and blocked rotor tests. These tests were conducted according to [4]. The no-load test obtains the number of pole pairs by comparing ratio of the electrical frequency over the mechanical frequency are various values, up to rated speed. In addition the machine was operated at rated voltage and rated speed, and the data in TABLE IV was obtained.

TABLE IV. No-Load Test Data

L-L Voltage (Vrms)	Line Current (Irms)	Freq. (Hz)	Speed (RPM)	Real Power (W)	Apparent Power (VA)
220.04	7.463	60.044	3590	723	2808

TABLE V. Machine Parameter Estimation Symbols

Symbol	Name	Value	Unit
R_s	Stator Resistance	150	mΩ
R_r	Rotor Resistance	2.977	mΩ
L_{ls}	Stator Leakage Inductance	303.57	μH
L_{lr}	Rotor Leakage Inductance	202.38	μH
L_m	Magnetizing Inductance	42.7712	mH
N_p	Number of Pole Pairs	1	--
J	Moment of Inertia	0.0526	Kg-m^2

The block rotor test involves a rotor blocking device that prohibits the rotor to spin. Since no commercially available device was available for the induction machines used, a custom rotor blocking fixture was designed and built. The blocked rotor test applies 25% rated frequency and rated line current. For this particular system the current test was about 90% of rated current due the lack of current source ability of the dc power supply. The blocked rotor data was collected as shown in TABLE VI.

TABLE VI. Blocked Rotor Test Data Values

L-L Voltage (Vrms)	Line Current (Irms)	Freq. (Hz)	Speed (RPM)	Real Power (W)	Apparent Power (VA)
16.68	40.301	15	0	719	1148

V. Benefits

The test-bed was built to meet the demand for an easily configurable platform to further research in the areas of power electronics, motor drives, and electric vehicle propulsion systems. Hence, it was built to be flexible in order to adapt to a variety of areas and be easily transformed to any future research or educational need.

A. Direct Project Interaction

The test-bed was built with a relatively low cost which was accomplished by incorporating the design and construction tasks into graduate and undergraduate students' project work. By integrating senior design, faculty funded project and industrial partnership, the overall project cost was reduced, while increasing the direct student exposure to concepts they usually have no hands-on. Our industry partner ABB Inc. Medium Voltage Drives, Research and Development group donated several key components used in the test-bed.

The project team consisted of a graduate student and three undergraduate students. The team was led by the graduate student doing research in the areas of motor drives and electric machines. The undergraduate students received Capstone Senior Design credits for this project. The team members received numerous benefits from involvement with this type of capstone project that they would not get in a traditional senior design project. The first major benefit was working on a real collaborative multi-disciplinary project among faculty, undergraduate and graduate students. They also learned how to work with real system design requirements. Students were also exposed to industry tool such as CAD design and layout, dSPACE embedded controller, National Instruments LabVIEW VFD control, PLC programming, Allen-Bradley Micrologix Program, communication (ModBus) integration, sensor integration, fault detection, OSHA safety standards. The senior design students will be able to apply in their career the technical knowledge from the use of the development tools they were exposed to during all phases of the project as well as some experience with complex system level problem solving.

B. *Research Potential*

There are many research topics that the test-bed is intended to be utilized. These topics include electric drive systems, electric or hybrid-electric vehicles propulsion, power electronic converter principals and topologies, and ac micro-grids components. Investigation into high performance machine control algorithms is a clear example of research opportunity. The initial test-bed system was characterized using a lower performance control algorithm, slip control. A higher performance induction machine control algorithms allow for a starting point in the machines controls research. This research topic is applicable to industrial companies in Variable Frequency Control of electric machines. Some applications are for Pump stations for both mining properties and municipals, fan control systems for HVAC.

The test-bed would also serve to investigate areas in an electric vehicle propulsion system. The prime mover described in Section III.A would be used to emulate an electric vehicle propulsion system. The current AC machine topology (asynchronous 3 phase induction machine) is the propulsion system for the Tesla Roadster [5]. Another electric propulsion topology utilizes an AC synchronous machine, specifically AC permanent magnet, is currently used in the Chevrolet Volt [6] and Nissan Leaf [7] propulsion systems. Given the modularity design of the testbed system, it could easy be modified to replace the prime mover machine with an AC permanent machine and emulate this propulsion topology.

The current system configuration has some limitations, specifically two quadrant machine operation. For full vehicle simulation the dc power supply would need to be replaced by a battery pack, because the current dc power supplies inability to sink current. If propulsion only drive cycle scenario, no regenerative braking conditions, a simulated battery voltage/current profile from the output of the dc power supply could be emulated. The current inductions machines could be used as common electric machine types for automotive propulsion systems or they would either be replaced with differing machines, as needed by the EV propulsion system architecture.

To utilize the test cell for a three phase ac MicroGrid, it would need to be modified according to the combination source and load desired. Minimal testbed hardware configuration would need to be changed, however the test cell infrastructure controller scheme would require substantial development, most notably if the test cell was not used as a machine type load. This changed relates to the order and timing of the contactors that control the power flow in Fig. 4.

The test-bed can be configured for an typical industrial motor drive type application by replace the dc power supply with a 3 phase hex-bridge converter to converter the 3 phase line voltage to a dc bus voltage. This approach is known as an Active Front End (AFE) and is common in most modern motor drive systems. The AFE configuration allows for increase input power quality [8]. This would require a slight hardware configuration change however the control scheme and system signal would need to be altered significantly. Using an AFE over the current DC power supply would also have the added benefit of allow for current sinking ability and regenerative braking applications.

C. *Undergraduate Laboratory Experiences*

The incorporation of this test-bed into the curriculum of the power electronics and motor drives laboratory was one of the main objectives of the test-bed. The motor drives lecture and lab introduces engineering students to various types of electric machines and their control algorithms. Fig. 9 illustrates the actual academic bench top system. This bench top system has the same flexibility of changing to various machines types, both AC and DC. The advantage to this bench top system is the safety in size and reduced complexity. With this bench top system students study the major machine topologies such as DC machines, AC synchronous machines (permanent magnet), and AC asynchronous machines (induction).

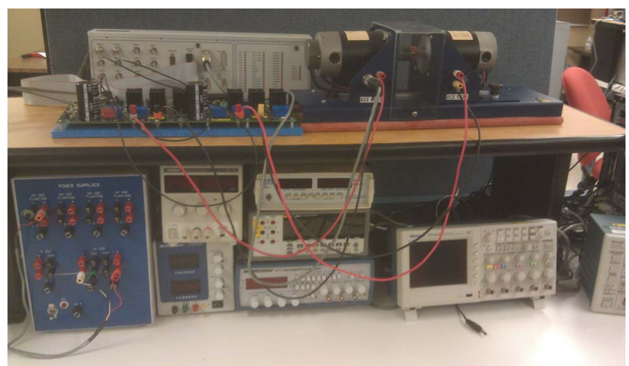

Fig. 9. Academic Motor Drive System

One common topology used throughout industry is the induction machine. The motor drives lab focuses several weeks on this particular machine, where students characterize its behavior. However, the system which students perform their experiments is significantly different in power level and setup compared to an actual test electric machine testbed seen in industry. This is done to reduce the risk and complexity the students would experience and allow them to place focus to fundamental concepts.

The different level of complexity can be easily observed by comparing the electric machine test-bed (shown in Fig. 1, Fig. 5, and Fig. 6) to the academic bench top system (shown in Fig. 9). Even though the reduced complexity is beneficial for the students start learning these topics, many students commented that they do not know how the academic systems correlates to system they will see in an industrial setting. Exposure to the test-bed gives students an example of an industrial type setup. To reduce the complexity and safety the bench top system is at a very low power level and uses measurement data from the power electronic converter board. Using these on board sensor circuits is not as accurate or consistent as separate measurement equipment. While this simplified method of data collection works for the educational objectives, it leaves a gap between how similar tasks are executed in industry. The test-bed also exposes students to industry quality data acquisition and measurement devices. The test-bed equipment consists of Yokogawa power analyzer, LEM current sensors, Himmelstein torque/speed sensor, APS power converters, ABB variable frequency drive, and Tektronix Mixed Domain Oscilloscope with smart voltage and current probes. This equipment exposes engineering students to the types of power and data acquisition device they will encounter in their engineering career.

This test-bed serves as an excellent platform to introduce students to industrial grade dynamometer systems and measurements devices. It relates the concepts the students are learning in the classroom to an actual industrial system. It also introduces students to think about subsystems within a more complex test-bed and how these subsystems interrelate to each other, which is crucial for systems engineers [9]. During the last lab experiment for the motor drive class, students solely focused on the electric machine test-bed system. Basics of energy flow and conversion principals are discussed in relation to their newly gain knowledge of motor drive concepts, obtained during the semester recitations and lab. Students also performed the same system performance test outlined in Section IV. This allowed them to see and interact with typical industrial type equipment.

The power electronics lecture and lab introduces engineering students to different types of electric energy conversion principals and topologies, and their control systems. Starting in Fall 2013 to the test-bed will be used to demonstrate some of the difficult topics including dc to ac conversion, Pulse Width Modulation, and power filtering. The test-bed will be used to discuss on how these topics interrelate within a system. Similarly to the topics discussed in a previous motor drives course, the test-bed will be used to focus an entire lab session to discuss the energy conversion process. These concepts are demonstrated and discussed using the inverter feeding electric energy to prime mover electric machine. In addition, students can see a direct use of the topics taught in lecture in a typical industrial application. In addition, the various electrical energy voltage and domains (discussed in Section II) will be presented demonstrating how these individual topics interrelated within the test-bed.

VI. CONCLUSIONS

A research quality test-bed was designed and constructed with emphasis placed on flexibility and integrated modular systems. This allows to easy adaption to future projects and research topics. The test-bed was also tested to demonstrate its functionality and to define a baseline for its operation. Its dynamic and steady state characteristics where also defined along with the characterization of the current induction machines. We discussed the use of the test-bed in various research areas that could be utilized based on current configuration or with some modifications. In addition to serve for research purposes, the test-bed is a very useful platform for engineering education in power electronics and motor drives, exposing students to industry typical applications and configurations.

ACKNOWLEDGEMENTS

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Using Matlab's Simscape Modeling Environment as a Simulation Tool in Power Electronics and Electrical Machines Courses

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***Abstract*— In this paper the use of MATLAB, and in particular Simscape, will be discussed as a simulation tool to model multi-domain physical systems in power electronics and electrical machines courses. The overall system response (both static and dynamic) of power electronics and electrical machine circuits are demonstrated and emphasized using Simscape language. Including Simscape in the curriculum reinforces conceptual ideas presented in lectures, as it increases students' focus on conceptual material, and their familiarity to modeling systems using MATLAB/Simulink.**

Keywords—power electronics; motor drive systems; engineering education; MATLAB/Simulink/Simscape environment.

I. Introduction

Electrical energy conversion has become ubiquitous in modern electronic devices, and in turn, creates a need to educate electrical engineering students in the fields of power electronics and motor drives. These fields are complex and involve other electrical engineering areas such as basic electronics, power systems, signal processing, and control systems. In addition to this wide breath of knowledge, students must also grasp the concepts of static versus dynamic nature of these systems. In the traditional lecture format, concepts are presented for both power electronics and electrical machines in a static nature, where the dynamics of the mathematical relations are ignored to reduce the complexity of the problems. This traditional approach works for student to learn the basic concepts. However, with the current computation and technological progress, simulation of these systems has become easily obtainable in a classroom environment with minimal computation requirements. The use of simulation in a classroom environment greatly improves the understanding behavior of more complex systems that cannot be simplified. Formulating control algorithms for these systems is also desired, in addition to observing their impact in the system behavior, which can be very difficult for undergraduate students to understand in a mathematical state space modeling approach. The use of simulation packages, such as MATLAB/Simulink/Simscape, reduces the complexity of the control algorithm implementation and observation of the system behavior.

In addition to help students to better understand complex systems, scientific computing and simulation are valuable skills for engineering students entering the workforce[1]. Both skills have several benefits to students. The first major benefit is the visualization and reinforcement of basic concepts and system behavior. The second major benefit is the exposure to a modeling and simulation environment that may be useful in future engineering tasks. The use of simulation in complex systems, such as power electronics classes have proven as a beneficial educating tool as discussed in [2] and [3]. By incorporating an easily understandable simulation environment into the traditional lecture material, students can visualize the dynamics and static response without the need to understand the complicated underlying mathematical relationships.

The assessment methodologies for this course uses indirect and direct measurements to assess the applicable ABET a-k criteria [4]. The assessment results indicate that the use of the Simscape simulation package increased students' focus on conceptual material and their familiarity to modeling systems using MATLAB/Simulink. The results also indicate improvements in the student comprehension of key concepts, and increased students' confidence to start their careers in the industry.

II. Matlab and Simscape Background

MATLAB has long been a tool both engineers and scientist used for numerical computations. Its native environment is based on the C programming language, however, it has a graphic editor, Simulink, which allows for multi-domain simulation environments. An additional toolbox for Simulink known as Simscape provides the fundamental building blocks to create simulation in common physical domains such as electrical hydraulic, pneumatic, among others. In addition to providing base building blocks, Simscape allows users to create their own custom defined blocks. These custom defined blocks are programmed similarly to MATLAB language.

Simscape is a physical modeling language that is designed to emulate physical systems appearance. It is similar in form to electrical circuits simulation in SPICE simulation package. Its main advantage is the integration of a common engineering tool, MATLAB/Simulink. It also has the ability to be used in conjunction with multi-domain environments. The ability to model various domains (electrical, mechanical, thermal, etc.) is an incredible power for teaching material involving several different domains. One example is a course taught in the Electrical Engineering department in the area of Electrical Machinery and Drives. The topics covered in the course combines both electrical and mechanical domains in one simulation environment, Simulink, as demonstrated in Fig. 1. This figure illustrates the multi-domain capability of Simulink and Simscape by using basic blocks available in the Simscape

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basic library to construct a Class E Chopper drive coupled to a permanent magnet dc machine (PMDC). The mechanical load simulated is a fixed torque application. The components shown in the blue and red box, respectively, denote the defined electrical and mechanical domains. This multi-domain simulation is executed in one single environment allowing undergraduate students to have easy visualization of the system level response.

version. The foundational library includes basic elements that cover multi-domain simulation listed in TABLE II. The foundational library contains all the necessary components for basic demonstration of the fundamental concepts to undergraduate students. Simulations can easily be constructed without the need for additional toolboxes to be purchased and therefore lowering the additional cost if students choose to purchase the student version of MATLAB/Simulink. This was

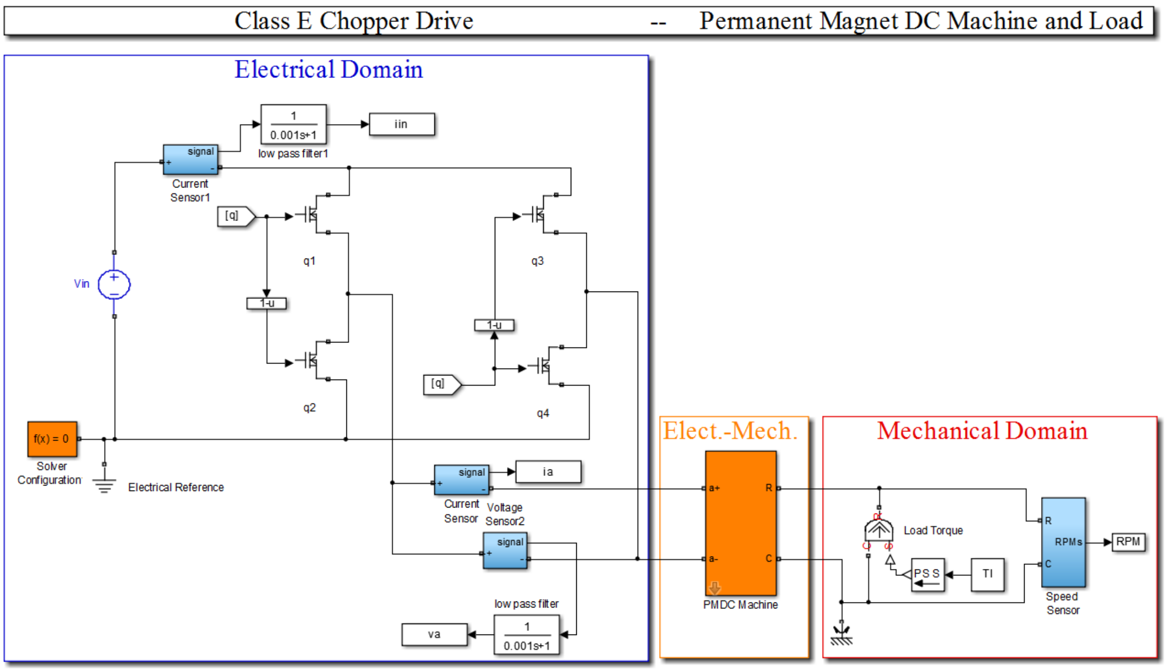


Fig. 1. Multi-Domain Simulation Environment

The simulation shown in Fig. 1 was developed using the Simscape foundation library set. Simscape consist of several additional toolboxes, as shown in TABLE I, which can be purchase with Simulink. The additional block sets are populated with common components for a specific engineering field. An example is the SimPower Systems toolbox which contains component ranging for various ideal electrical sources, electric machine models, power electronics elements, and passive elements. The major drawback, and reason for not incorporating the additional Simscape Library toolbox, was the additional cost to students. Each one of the additional block sets can be purchased separately as required by the simulation application.

TABLE I. ADDITIONAL SIMSCAPE LIBRARY BLOCKSETS

Name	Modeling Domain
Foundation	Basic Blockset (multi-domain)
SimDriveLine	Mechainical Driveline Simulation
SimElectroncis	Electrical Circuit Simulation
SimHydraulics	Hyrdaulic Systems Simulation
SimPowerSystems	Electrical Power Sytems Simulation
Utilities	--

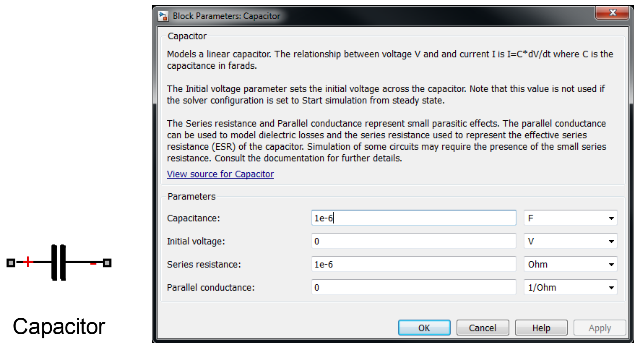
The foundational library block set was used exclusively in lecture material, to minimize the cost for students and institutions, with the purchase price of $39.00 for the student

an important point in our decision to use this simulation package since both power electronics and motor drives courses have distant learning students which may not be able to take advantage of the university site license.

TABLE II. SIMSCAPE FOUNDATIONAL LIBRARY BLOCKSET

Name	Modeling Domain Units
Hydraulic	Pressure, Flow
Magnetic	Flux, Magneto-Motive Force
Mechincal	Force, Torque (Linear, Rotational)
Physical Signals	Dicrete, Delays, Linear, Non-Linear
Pneumatic	Mass/Heat Flow, Pressure and Temperature
Thermal	Heat Flow, Temperature

The Simscape foundation library is based on an open model structure that allows the user to view and edit the model code behind the block. In other available Simulink block libraries the model may be described in the documentation, but is not accessible to the user which often leads to a “black box” impression for students. With Simscape, an instructor or student can dig underneath every box to revel the model code. The Simscape block code is not typical MATLAB code. In fact, it is a separate language based on a causal differential-algebraic relationships. For example, the graphical model of a capacitor is shown in Fig. 2.(a) and the parameters are shown in Fig. 2.(b). There is a hyperlink in the parameter dialog for each foundation library model that opens the Simscape language editor. A simplified version of the code for a capacitor is shown in Fig. 3. This electrical model block has single port with a defined voltage across the terminals and the currents through the device. The model equations in Fig. 3 define the voltage and current relationship. This code can then be copied, modified and re-compiled to create user defined models and libraries.



(a) (b)

Fig. 2. Simscape Block Parameter Example

```
component capacitor < foundation.electrical.branch
% Capacitor

  parameters
    c  = { 1e-6, 'F' };    % Capacitance
    v0 = { 0, 'V' };       % Initial voltage
    r  = { 1e-6, 'Ohm' }; % Series resistance
    g  = { 0, '1/Ohm' };   % Parallel conductance
  end

  variables
    vc = { 0, 'V' }; % Internal variable for
voltage across capacitor term
  end

  equations
    v == i*r + vc;
    i == c*vc.der + g*vc;
  end

end
```

Fig. 3. Simscape Programming Language

It is important to note that only blocks from the Simscape Blockset library can be connected to Simcape blocks. Special converter utility blocks are required to convert Simcape variables and states from Simscape sensor blocks to what are called “Physical Signal” data types with associated units. To convert from this physical signal to a normal unit less Simulink data type, a second conversion block is required.

Some of the benefits of MATLAB, in addition to the multi-domain capability, are the strong engineering industry presence, and extensive help and example files available to students on-line. Simscape also has the flexibility of user component and subsystem development and customization. An example of this is demonstrated in Fig. 1. The PMDC is a custom made subsystem that models the physical behavior of PMDC machine. The subsystem is masked, meaning that only the parameters of the model are display when opening the subsystem, as shown in Fig. 4. This is helpful to make the simulation code modular and easier for students to absorb. The actual model component can be viewed by “looking under the mask” via the right-click menu in Simulink, as seen in Fig. 5. Custom Simscape blocks can also be defined by the user in the native Simscape language.

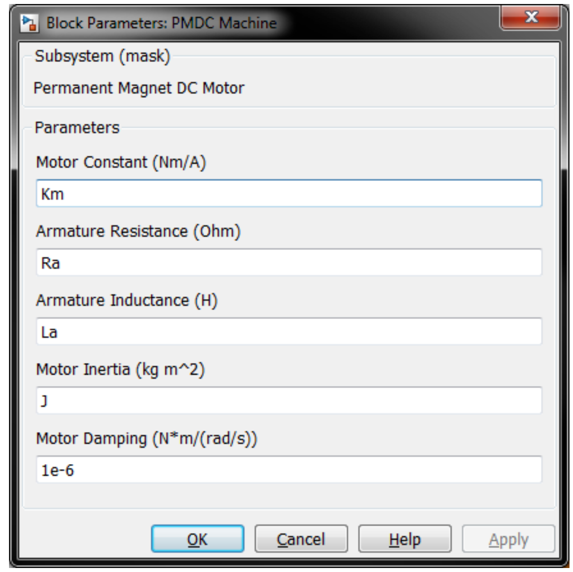


Fig. 4. PMDC Blocked Parameters

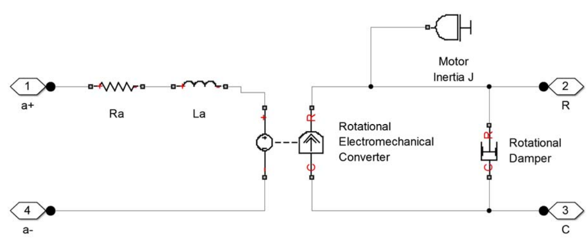


Fig. 5. PMDC Simscape Component Model

III. SIMULATION INTERGRATED INTO LECTURE

The approach used in both Power Electronics and Electric Machines lecture courses, with optional lab, was to create dynamic simulation examples using the Simscape basic building blocks. The examples compliment the previously developed material, which generally were static, steady state, response. The same static, steady state, relationship were presented and discussed; in addition, we use simulation to demonstrate both the static steady-state response and dynamic response.

A. Simulation Implemenation

A typically lecture would contain one or two simulation examples. These examples would first be discussed in a static sense with the general mathematical relationship presented. One of the early examples presented in the power electronics lecture was a boost converter. The boost converter is a DC-DC converter where the output is greater than or equal to the input as shown in Fig. 6. The static steady-steady average value mathematical relationship is shown in (1). This relationship is ideal, meaning no losses are modeled, and predicts the output voltage based on the input voltage and duty cycle, D_1; where the duty cycle has a value rang of 0 to 1 and is typically represented in the percent form. The relationship in (1) predicts that the output voltage will be that input voltage, given a duty cycle value of zero. With a duty cycle of 1 the output voltage is predicted to be infinite, however, this response is not practical. In a real circuit, each circuit component (inductor, capacitance, switching devices, and wires) has parasitic components that limit the range of predictable output to approximately 80 %. Above 80 %, the model is significantly different than the actual response and is no longer valid. Fig. 7 demonstrates the normalized steady state response. Both the ideal and non-ideal behavior are discussed in the lecture with emphasis placed on students' understanding the appropriate application of each.

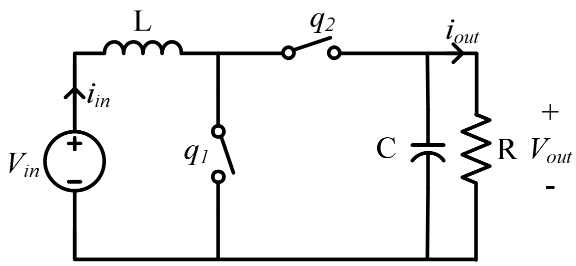


Fig. 6. Boost Converter Circuit Diagram

$$V_{\text{out}} = \frac{1}{1-D_1} V_{\text{in}} \tag{1}$$

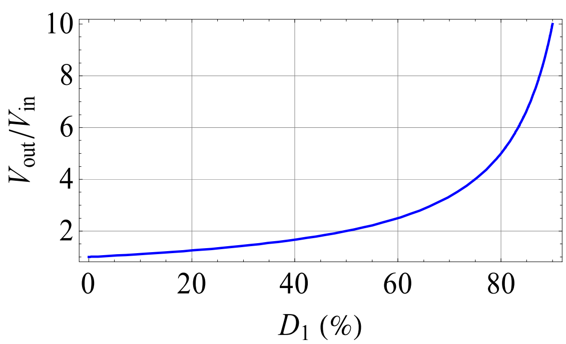


Fig. 7. Boost Converter Normalized Output

After understanding this basic relationship and behavior, the students are then presented with a functional simulation comprised of both the dynamic systems response from the initial conditions and steady-state (static) response. The first connection presented in lecture is the "hand worked" steady state solution and the steady state simulation response comparing similarities and differences. For a brief example consider(1) with D_1 of 50 %. The normalized output is twice the input. The circuit is then simulated using Simscape as shown in Fig. 8, and confirmed by the state-state solution, shown in Fig. 9. This response shows the approximate steady-state solution to be 20 V, or twice the input voltage of 10 V. The slight difference in the simulated output voltage is due the component models having very low, but not zero, parasitic values. The dynamic response shown in Fig. 9 demonstrates a startup condition where the initial value of the inductor current and capacitor voltage is zero. These initial conditions can be easily changed through the Simscape block parameters dialog box.

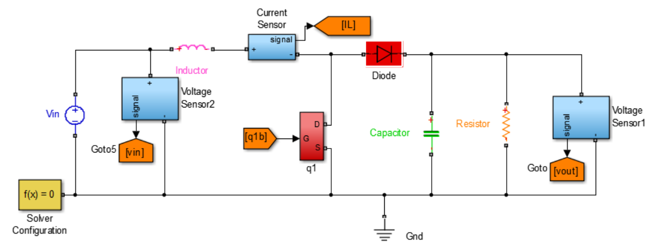


Fig. 8. Boost Converter Simulation Circuit

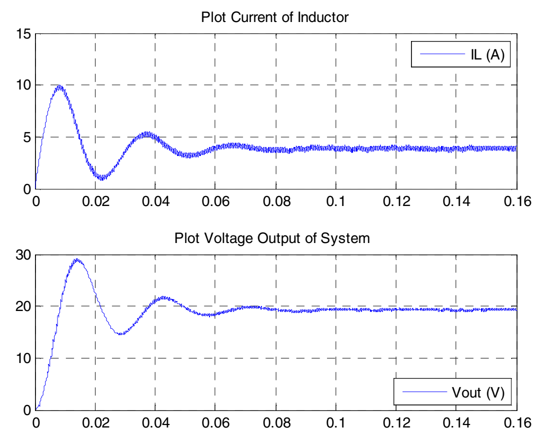


Fig. 9. Boost Converter Response with 10 V Input and 50 % DC

When comparing Fig. 6 and Fig. 8, the actual circuit and simulation look similar. This approach of using a simulation environment that emulates the physical system is a crucial concept that allows the minimal amount of student modeling ability while retaining the feature of visualized system response. This shifts the focus away from the simulation topics and emphasis is placed on obtaining system response. This approach was widely found in literature, including [5] and [6]. One relevant note is that the refereed authors' had different opinions on the MATLAB/Simulink effectiveness as research tool. For instance, in [5] the authors stated MATLAB to "lack some the basic modern object oriented and high-level programming language features".

Given continuity to the objective of having students focusing their attention on the -main concepts and not on the simulation environment, operational Simscape simulations were presented in the lectures. Basic circuit analysis was presented, where the static response values where calculated and confirmed with the simulation results. The dynamic response was also discussed, specifically with relation to the initial conditions (assumptions). These initial conditions were changed to demonstrating the effect on the transient response.

An example can be seen when comparing Fig. 9 and Fig. 10. The boost converter system response shown in Fig. 9 demonstrated the "start-up response" if the two energy storage elements (inductor and capacitor) in the converter are uncharged. Fig. 10 shows the "start-up response" when these two element have some initial energy stored when the input is applied. The initial conditions used for this example were 20 V on the capacitor and 5 A in the inductor. Both Fig. 9 and Fig. 10 show the same type of behavior. The simulation starts at the initial condition and eventually settle to the approximately the same steady-state average values of 19.5 V measured across the output and 4 A through the inductor.

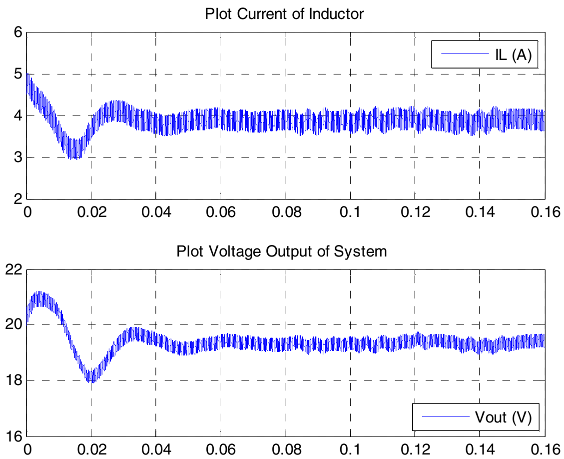


Fig. 10. Boost Converter Response with non-zero Initial Conditions

Some of the key concepts essential for students to understand power electronic converters are differences and similarities of the average mode model and the switching mode model. Many modern power supplies use a switch mode topology for energy conversion and therefore have a specified ripple in their output voltage and current. A switch mode power supply (SMPS) is an electric device that efficiency converts electrical energy from one form or potential to another, through switching between different energy storage elements. This switch action causes an inherent ripple in the output waveforms however the ripple is a very small percentage of the average value of the output. The difference can be seen when viewing Fig. 11, which demonstrates the steady state average mode model and switching model in the same graph. Both model responses are presented together in the same response graph. Typically, students are first presented with the average mode model where the switching action and behavior is then super imposed onto the average mode response. However, with demonstration utilizing Simscape both model can be discussed and understood together. The "live" nature of easily integrated simulated models allows students to make observations and predictions about changing circuit parameters and how the changes may affect circuit behavior. This "predict and see approach" is reinforced in lecture where the students are asked to predict a given changed to the circuit. An example of this would be to predict how the output waveform would differ if the capacitor was doubled. A brief discussion would then take place in lecture, the simulation would quickly be executed, and the output observed. The relatively easy nature of Simscape allows the focus of the discussion to be placed on the lecture topic and not on the simulation environment.

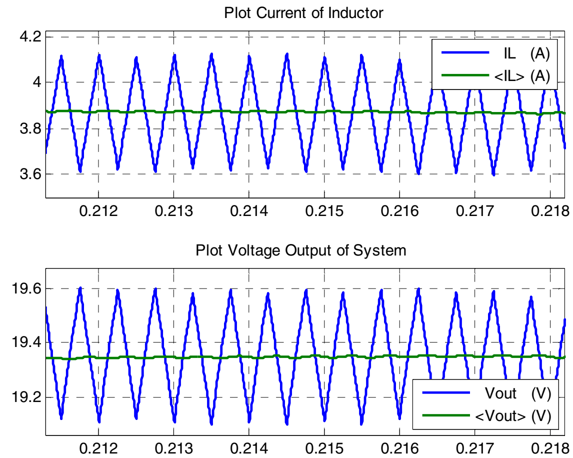


Fig. 11. Boost Converter Steady-State Switching Response

After the lecture, students were asked to answer homework questions comprising of both basic concepts topics (handwork problems) and a simulation component. The simulation components were a slight variation of the simulation example presented in lecture, again, to allow students to focus their attention on the conceptual ideas and less focus on the simulation environment.

B. *Typical Examples*

In each class over 25 examples were presented and available for students to experiment with. General topic areas for Power Electronics and Motor Drives are listed in TABLE III and TABLE IV respectively.

TABLE III. GENERAL LISTING OF CONVERTER EXAMPLES PROVIDED IN POWER ELECTRONICS

Topic Area	Name	Topic Area	Name
Basic	Resistor and Inductor Load	DC/DC	Push-Pull
DC/DC	Buck Converter	AC/DC	Rectifier (Full & Half)
DC/DC	Boost Converter	AC/DC	Charge Pumper
DC/DC	Buck-Boost Converter	DC/AC	Voltage Source Inverter
DC/DC	Flyback	DC/AC	PWM Inverter

These examples are provided to the students to experiment and learn. It is also strongly encourage for students to adapt the simulation model to a different application. All examples include an initialization and plotting script. This gives the students exposure to model parameterization and numerous post processing functions in MATLAB.

TABLE IV. SIMULATION EXAMPLES PROVIDED IN MOTOR DRIVES

Topic Area	Name	Topic Area	Name
Basic	Passive Load Modeling	Machines	PMDC Machine
Pwr Elec.	DC-DC Converter	Machines	PMAC Machine
Pwr Elec.	DC-AC Inverter	Machines	Induction Machine
Load	Hoist Load Modeling	Application	HEV Model

IV. BENEFITS

Historically, power electronics and electric machines undergraduate courses have had laboratory components where the student had exposure to hardware and dynamic responses of the systems. However, in recent years there has been a movement for more on-line courses, including power electronics and motor drives. To compensate for the lack of a laboratory experience for distance learning students, the use of MATLAB/Simulink/Simscape have been added to these courses. With the modeling and simulation assignments students are able to visualize the dynamic response of the system without the need for advanced material in dynamic modeling that is not appropriate for an undergraduate course. This simulation approach first reinforces the basic concepts and give another perspective to allow for great student retention. It has also been a proven methodology for greater student learning as discussed [2] and[7].

The use of MATLAB/Simulink/Simscape exposes, or reinforces undergraduate students with a very common industry tool, enhancing their skill set and employability as an engineer. It has the added benefit of relatively low curve for students, and for instructor development, when compared to various other methods of simulation incorporated into power electronics courses such as Java [8]. Simscape allows for user defined component development, however, the majority of power electronics and motor drives topics are easily simulated with the pre-defined components included in the foundational library.

V. OUTCOMES AND ASSESSMENT

Assessment of student outcomes is important for any engineering programs as a feedback element for course improvement and as a requirement for ABET accreditation of these programs. The ABET-EAC defines outcomes as “what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program.” The ABET Criteria 3 – Program Outcomes [4] requires that engineering programs must demonstrate outcomes (a-k), and includes: (a) an ability to apply knowledge of mathematics, science and engineering; (e) an ability to identify, formulate, and solve engineering problems; (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. The new methodologies that we used in the two courses discussed in this paper successfully satisfy the applicable ABET a-k criteria 3. The use of MATLAB 's Simscape modeling environment as a simulation tool in power electronics and electrical machines courses particularly satisfy criteria 3-k. The criteria 3-k has been interpreted as an ability to use and to learn appropriate software programs and computer simulation tools, as well as capability to collect engineering data using modern instruments..The assessment methodologies to document the achievement of this outcome for the courses discussed in this paper used indirect and direct measurements. The direct measurements included graded assignments and class exams. The indirect measurements included surveys and end of semester instructor evaluation. The performance indicator that we used here are in line with performance indicators for criteria 3-k as in [9]. The surveys results are discussed below. The assessment results indicate that the use of the Simscape simulation package increased students’ focus on conceptual material and their familiarity to modeling systems using MATLAB/Simulink. The results also indicate improvements in the student comprehension of key concepts, and increased students’ confidence to start their careers in the industry.

Surveys were given to the students of the power electronics and motor drives courses to assess their experience and perception of the modeling and simulation tools used in the courses. The results are summarized in TABLE V and TABLE VI in the percent of the students that responded. The column headings indicate Strongly Agree, Agree, Disagree, and Strongly Disagree from left to right respectively.

TABLE V. POWER ELECTRONIC STUDENT SURVEY DATA RESULTS

Question	SA	A	D	SD
“Prior simulation abilites are proficient”	6	44	13	13
“Believe added simulation skills will be benefical”	41	48	9	0
“Enhance employability”	55	34	6	0
“Simulation significantly helped understanding of core concepts”	58	41	0	0

TABLE VI. MOTOR DRIVES STUDENT SURVEY DATA RESULTS

Question	SA	A	D	SD
“Prior simulation abilites are proficient”	4	35	52	9
“Believe added simulation skills will be benefical”	39	54	7	2
“Enhance employability”	48	46	4	2

In the motor drives course, 54 students responded to the survey and 43 students responded to the survey in the power electronics course. To the question “Prior to entering this class, would you rate your modeling and simulation abilities proficient?” the responses from the motor drives course demonstrated that they students believe they were below the curve in ability. The responses to this question was also comparable in the power electronics class. While most students (92%) have used MATLAB in a previous course, 79% had never used Simulink or Simscape. However, 96% of the students agreed or strongly agreed that MATLAB/Simulink/Simscape is an important engineering tool. In addition, 94% of respondents agreed that their experience in MATLAB/Simulink/Simscape has enhanced their employability. Over 90% of the students also mentioned that Simscape toolbox had a relatively low learning curve, and all the students agreed that the modeling and simulation portion of the course helped them to understand the course concepts. In the surveys the students were also asked to "describe if the use simulation has helped or hindered their comprehension of the course material". The majority of students (57%) indicated that the simulation has helped them. Some of these students commented on the learning curve and simulation issues they experienced but ultimately believed the simulation help with the course concepts comprehension. Those who explicitly stated that the simulation content hindered (30%), felt the extra time and effort to learn this new language was not worth the benefit to see the system dynamics and behavior.

A common point of contention with the students was when experiencing issues with the simulation files, which required a significant amount of time to investigate the issue. This was unexpected - because of two facts: first, the students were senior level with "prior" knowledge and experience with MATLAB in several classes. Second, students were provided with working simulations during lecture. They only had to slightly modify the parameters values and re-run. The intent behind this approach was not to have student focusing their time on model development. However, this caused the un-intended consequence of students' inability to recognize the appropriate steps that were needed to understand and modify the simulation file for proper execution. Increasing student competency in the basic course concepts with minimal impact to the students' time was the main objective. Closing the assessment loop and finding ways to improve future teaching offerings of these courses based on prior student feedback is one easy methodology to achieve our main objective [10]. Based on the students' feedback, the following actions will be taken to lower the simulation workload on students in future course offerings:

1. Supplemental MATLAB/Simulink lectures will be prepared. This will help students who do not have the basic MATLAB language skills when entering the course.
2. Require initial basic simulations files to be developed solely by the students. This will increase the students understanding of the simulation process and avoid the basic simulation issues encountered previously.
3. Reduce the number of occurrences of simulations in each homework assignment. Typical homework examples consist of 2-3 simulation questions. By reducing to 1-2 questions student continue to get the exposure of simulation while lower the overall workload on simulation.

VI. Conclusions

A new simulation approach was used to further reinforce concepts in power electronics and motor drives courses. By utilizing a widely used engineering tool MATLAB/Simulink/Simscape, students obtained simulation and modeling exposure that will enhance their employability as future engineers. Simscape allowed for relatively low learning and development curves for students and instructor, respectively.

As an extension of MATLAB Simscape can utilize a large user examples and help info database making the adaption of simulation environment to various engineering domains. This multi-domain capability allows for simulation of the power electronic and motor drives systems with realistic loads, while minimizing the difficulty of model multi-domain systems. The students were provided with simulation examples coupled with a minimal amount of simulation information to learn, which allowed them to focus on the core lecture material, rather than the simulation environment itself. Assessment results indicated improvements in the students' comprehension of key concepts, and increased students' confidence to start their careers in the industry.

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Energy Efficiency: Teaching for Accreditation, Ethics, and Technology

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***Abstract*— Increased energy demand in IT is growing rapidly as the world becomes more industrialized. Projections show that IT growth will continue to increase, with annual network growth at 45%. Increasing worldwide energy demands results in an increase in both costs and climate change.**

Using the energy efficiency topic, we address 5+ ABET learning outcomes, including ethics and local/global impact. One learning goal of this section is for students to learn what constitutes sound ethical reasoning and what does not (e.g. egoism). Another goal is to categorize the social implications of the technology into spheres of concern (local/national/global) and basic ethical theories (virtue/deontology/consequentialism). One of the best ways to teach ethics is to engage the students in identifying the ethical perspectives in use. We have created a table of justifications for energy efficiency and categorized them by ethical theory. Our main source for these reasons is *Hot, Flat, and Crowded*, by Thomas L. Friedman. For homework, students write a paper that includes both a technical and societal/ethical component to it.

Keywords—Education; Energy efficiency; Ethics; Sustainability; Green computing.

I. INTRODUCTION

Data centers require 40 times the energy requirements of a regular office [3]. Projections show that IT growth will continue to increase, with annual network growth at 45%. With improved technology this growth can be reduced, with estimations for savings ranging to 55% overall energy and 80% in infrastructure [1]

Green computing is in its infancy, but there are three good reasons to start teaching it now. The two obvious reasons are energy efficiency (cost containment) and the environment. However a third benefit is that this topic helps to achieve ABET program learning outcomes, including the difficult ones of analyzing ethical/social issues and local/global impact of computing, and continuing professional development.

Research on energy efficiency is not yet mature, but there are many papers on engineering energy efficiency (e.g., [4-8]). However, papers on teaching energy efficiency in a computer science or computer engineering curriculum are rarer. One CS text, *A Gift of Fire* [10], does include a case study: "Modeling Climate", which briefly discusses climate simulations, but does not delve into energy efficiency.

Mann et al. [19] develop a framework for Computing Education for Sustainability, and evaluate resources for teaching. They define two philosophical goals: "Does the resource reinforce computing as a pathway or tool for achieving sustainable practices? Does the resource implicitly or explicitly define sustainability in a way the student can understand?" We agree and try to meet both requirements. In addition, we meet their required areas of "Curriculum integration" and "Linking and Connecting" (i.e. to world issues).

Talebi and Way [20] discuss technologies that can be taught in the classroom. They suggest: turn off equipment, power saving modes, eliminating phantom loads, extending computer lifecycle by upgrading with efficient components, purchasing energy efficient equipment (Energy Star), and using alternative power sources. They also suggest the use of Kill-a-Watt and 'Watts Up?' energy measurement devices, and provide sample results for desktop versus laptop. They do not discuss ethics as part of their learning goals.

Cai [21] points out ABET has called for a shift towards sustainability education in engineering disciplines, and sustainability is attracting the attention of students around the world. (Approx. 2/3 of CS faculty agree [12].) Cai has developed a course that is half about Green Computing and half about Network Services, at Michigan Technological University. It includes topics of: general concepts, virtualization technology, data centers, power-aware computing, smart power management, electronic waste, and regulatory compliance. The course was well received by mostly IT majors, with a high rating of 4.7 out of 5.

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We propose combining the teaching of energy efficiency and ethics. The paper "Computing for the Social Good" [11] reminds us that ACM CS-2008 computer science curriculum recommends a single course on professional, ethical, and societal issues, plus complementary modules that integrate these topics into technical courses. After surveying computing departments, they summarize that "the survey shows that there is still much uncertainty in what social issues include, how they relate to computing, what pedagogies to use, and where and when they can best be presented." We believe that integrating ethics and energy efficiency serves as an excellent 'complementary module' that can serve as an introduction or development of ethical thought and an intriguing research area within technology.

The CS ethics text, *Ethics for the Information Age* [13], presents a number of ethical classifications, including 'ethical egoism', Kantism (i.e., Deontological), and Utility. We present a simplified version of Egoism, Deontological, Consequentialism (or specifically Utility), and Virtue, and apply it toward Energy Efficiency in this paper.

This paper first introduces how we teach and have taught this module, as well as related accreditation issues. Next, we review ethic theory, and apply it toward societal reasons for energy efficiency. Technical vocabulary is introduced in lecture to help students to understand technical papers. Finally, we discuss our results in the classroom as lessons learned and a conclusion.

II. MODULE OVERVIEW

The energy efficiency module is introduced as a later module in a 3-credit hour CS 355 Computer Architecture course, offered once yearly to Computer Science undergraduates who have completed CS 245 Assembly Language. CS 355 covers processor and memory design, but also applied topics: hardware security and energy efficiency.

Energy Efficiency is a 3-hour module towards the end of the semester. It includes a lecture, an active-learning exercise with Kill-a-Watt [23], and a homework writing and presentation assignment. The two-hour lecture reviews ethical theory, societal reasons for energy efficiency, and technical aspects of energy efficiency. The technology aspect of energy efficiency topic is lightly-covered because students will get into technical depth in their papers/presentations. The lecture materials are discussed later in the paper.

During the homework assignment, students write a paper that includes a social/ethical/business and technical component. Students also do presentations on their papers (with time allocated according to class size).

Student assessment includes evaluation of the student paper, and questions related to ethical and social impacts on an exam.

The first semester this was taught, students were enthusiastic about the topic, and most papers and presentations were very good and interesting. However, it was observed that the non-technical ethical and social aspects of the papers were weak, particularly in comparison to the technical aspects. Thus, the ethical aspect of the course was strengthened with help from a Philosophy professor (author 2), who teaches ethics. This paper presents results from a more mature ethics component related to energy efficiency.

III. ACCREDITATION

Whether or not the department is ABET-accredited, any accreditation agency is interested in program and course learning outcomes, preferably taught at multiple levels in the curriculum. ABET has proposed student outcomes, which are demonstrated by mapping the outcomes to courses. This topic meets many student outcomes, including some of the difficult ones for computer science: local-global issues, ethics, and continuing professional development. The full text for each addressed ABET student outcome is provided first, in bold.

(a) An ability to apply knowledge of computing and mathematics appropriate to the discipline

This lecture and written assignment emphasize knowledge of computing hardware, affecting processors or computing equipment, network equipment, and data centers. The emphasis is on computer or data center architectural design, power consumption and computer life cycles.

(e) An understanding of professional, ethical, *legal, security and* social issues and responsibilities

An introduction to ethics and social issues is provided in the lecture. Students are expected to categorize potential justifications within one or more ethical theories. In addition they must discuss ethical and social issues within a written paper (and possibly presentation).

(f) An ability to communicate effectively with a range of audiences

Students write a research paper on a selected topic, and then present on it. Required components of the research paper and presentation include: a literature review and brief description of proposed technologies, an analysis of the usefulness of the proposed technologies, and an analysis of the ethical and local-global impact of implementing the technology. These aspects require students to research, analyze, write, and present.

If teams present a summary of their work, then teamwork (another ABET outcome) is also part of the assignment.

(g) An ability to analyze the local and global impact of computing on individuals, organizations, and society

Energy efficiency mainly impacts economics and the environment, but both can have an effect locally, nationally, and globally. Students must analyze the societal impact of their topic in their paper and presentation.

(h) Recognition of the need for and an ability to engage in continuing professional development

Energy efficiency and green computing is a new technology. As such, it is rapidly evolving and unstable. It would be difficult for an instructor, who does not do research in this area, to become or stay current in the technology. Therefore, having students write and present a literature review in a selected topic introduces students to learning about technologies on their own. The instructor learns as well from reading the reports and seeing the presentations. The instructor can point out that since this research is rapidly evolving, this is an example of a need for continual professional development in the field.

(i) An ability to use current techniques, skills, and tools necessary for computing practice.

This is a minor learning outcome, compared to the others. Students learn to use Kill-a-Watt to learn about electricity, and use Excel to learn to produce graphs and work with equations.

While not all ABET student outcomes are addressed as part of this assignment (or should be), we have shown that six are addressed. However, these goals should not be addressed in only one place in the curriculum. Whether for ABET or HLC (Higher Learning Commission) accreditation, another recommendation is that learning goals are not pooled in one course, but reinforced at three levels: introduction, development or reinforcement, and mastery. For us, these learning goals serve at the introduction, development, or reinforcement levels.

IV. ETHICS AND SOCIETAL IMPACT

The first part of the lecture is on ethics and the societal impact of climate change. One learning goal of this section is for students to learn what constitutes sound ethical reasoning and what does not (e.g. egoism). Another goal is to categorize the social implications of the technology into spheres of concern (local/national/global) and basic ethical theories (virtue/deontology/consequentialism). After a theoretical introduction to ethics, the lecture discusses ethical theories in relation to green computing.

A. Ethics and Social Impact Classifications

By the definition of ethics, one must be careful that the conversation not become about self-interested impacts. For instance, we might note that using lead to create circuit boards introduces a deadly toxin to our water supply; I drink from that water supply; therefore, I don't want to use lead to create circuit boards. This is both reasonable and practical but not clearly ethical. Kant points out that people do not need an incentive to act in their own interest, since they do so naturally [16]. Therefore, we can never be certain of the motivation of a person who acts in a way that benefits herself; she might be acting ethically but she might also be acting just to save her own skin.

We classify ethical ways of thinking three ways: Virtue Ethics, Deontology, and Consequentialism. For contrast, we also present Egoism. Thus, the four categories are identified as follows:

1) Egoism

Right action is determined by what is in the individual's self-interest. An egoist would justify energy efficiency by saying, "an efficient design will allow me to make buckets of money." This justification sits on Lawrence Kohlberg's lowest stage of ethical development [14]. Because self-interest thinking can actually lead people to break society's rules and norms we wish to move students away from this way of thinking.

2) Virtue Ethics – Aristotle [15]

Right action is that which promotes human flourishing. A Virtue Ethicist would justify efficiency by saying "that is what a good engineer does." To flourish we must strive for excellence at our telos (end). One might challenge the student towards this way of thinking by asking "In the best world, what would your design look like?" Further telos-oriented questions might include: Would your role model approve of this design? Or, very specifically: would the person of good character exploit workers in a foreign country in order to make products affordable in the US? Would a good engineer design a product that uses as much power as it can draw or would he strive for efficiency?

3) Deontology – Immanuel Kant [16]

Right action is that which is done from duty. A Deontologist would justify efficiency by saying, "it is my duty to be efficient." To determine duty one must ask "can my rule of action be universalized without contradiction?" Often this is recognized as "do unto others as you would have them do unto you." One might encourage the student to ponder the Deontological view by asking "would everyone be able to employ a design like this one?"

To explain further, Kant prohibits actions if they produce a contradiction when implemented in a universalized way. For example, lying is self-contradictory: the point of a lie is to pass off untruth as truth; if we universalize lying so that everyone lies then no one will accept our untruths as truth; so, lying, when universalized, contradicts itself. Friedman's point about limited world resources is useful here: can every nation on the planet use as much power as the United States?

4) Consequentialism – John Stuart Mill [17]

Right action is that which creates the greatest happiness. A Utilitarian would justify energy efficiency by saying, "it will allow the most number of people to have access to and to utilize our products." Being careful to not confuse happiness with momentary pleasure, one might stimulate thinking in the student towards the Utilitarian view by asking "Will this produce more happiness than the alternatives?"

Although Consequentialism is easy to grasp and agree with, it is hard to live by. From experience, students balk at the idea that they might be required to sacrifice some of their own happiness in order to increase the happiness of others. There is no tenable argument that can show that my happiness is worth more than your happiness. Thus, a Utilitarian must accept that her happiness is not more important than anyone else's. So, even though iPhones have made hundreds of thousands of Americans happy, we might still be morally prohibited from buying them, if tens of thousands of Chinese that are employed to make them are more unhappy than the happiness we Americans receive.

5) Local/National/Global Impact

The learning objective is the identification and discussion of issues at each sphere of influence. The spheres are defined below:

Local: Has an impact within a participating local organization or within the region.

National: Has an impact at the national level, e.g., through increased economic (or other) measures: GNP, increased competitiveness, cleaner environment.

Global: Has an impact outside the nation: impacts one or more external nations or world conditions (e.g., energy, poverty, environment, world peace.)

B. Applying Ethical Theory to Energy Efficiency

One of the best ways to teach ethics is not only to provide the theory, but to engage the students in identifying the ethical perspectives in use. One excellent source for ethics related to climate change is *Hot, Flat, and Crowded* [2], by Thomas L. Friedman (best-selling author of *The World is Flat*). This book covers the expected growth of energy consumption, the problem of climate change, and potential technological directions and political issues. We have taken Friedman's justifications for energy efficiency, and created a table categorizing the reasons by ethical theory and geographical impact. Because of its length, this table: Table 1: Ethical Reasons for Energy Efficiency, is currently located as an appendix to the paper.

In lecture, the instructor discusses the justifications for energy efficiency before categorizing into ethical theories. The lecture also provides students with ideas for social/ethical topics that they could write on. One of the most impressive issues Friedman discusses is that until recently there were two energy hogs: America and Europe. Now with India and China emerging, there are four. As other heavily-populated regions further develop, there will be the equivalent of 9 'Americomes' consuming fossil fuel power. Friedman shows how this growth affects five major issues: energy and natural resources, petrodictatorship, climate change, energy poverty, and biodiversity loss [2]. These social issues related to energy use include traditional conservative issues: oil production helps to fund Muslim extremists, and desert war conditions requires massive air conditioning, leading to trucking of petrol across unfriendly terrain. However, the book has a very holistic view that also describes how petrol has led to less freedom in the middle-east.

V. TEACHING ENERGY EFFICIENCY

The technical part of the lecture introduces some concepts of energy efficiency in processors and data centers. The goal is to discuss vocabulary and core concepts to help students in understanding their readings. The first aspect is to show that IT can benefit from energy efficiency, through recent and projected energy usage statistics [4, 6]. To sum up projections, computers have become more energy efficient, but demand is increasing. For example, network traffic volume is expected to increase 190 times between 2006 and 2026 [6]. Recent estimates indicate that up to 40% of data center costs are for air conditioning [7].

The lecture then demonstrates the power usage of a number of recent processors [22], and describes how the factors affecting power consumption relate:

$$\text{Power} = \text{CapacitiveLoad} \;\; x \;\; V^2 \; x \;\; \text{Freq} \qquad (1)$$

Computers and networking devices can be made more efficient, through dynamic power scaling, including adaptive rates, and low power idle [4,5]. Important vocabulary includes:

- Sustainability: Minimizes environmental impact, including greenhouse gas emissions, use of raw materials, and hazardous waste. [19].
- ICT (Information & Communication Technology)
- DVFS (Dynamic Voltage and Frequency Scaling)
- Leakage: Power loss within a chip, often thermally-induced.
- PUE (Power Usage Effectiveness): Total_Power/Computer_Power
- ECRvL (Energy Consumption in Relation to Variable Load)

Some discussion of novel but maybe controversial techniques may also be discussed. Energy can be reduced using alternative techniques such as an air economizer, which uses colder outside air to assist in air conditioning. Chillers are tubes which carry colder water to where they are needed. Also, running the room temperature higher but within computer specifications may be useful if leakage does not result in greater energy loss [8]. Alternatively, turning some computers off during slow periods and improving airflow can reduce electrical costs. Green actions also include using computers longer, recycling, and reselling the computers.

To prepare computer science students for the active learning lab, the lecture reviews Ohm's law, and definitions for voltage, current, and resistance. Then the instructor shows how to calculate kilowatt hours, greenhouse gas emissions, and electrical costs, producing annual statistics, using a downloadable Excel spreadsheet. A one-hour active learning Kill-a-Watt exercise has students measuring the volts, amps, watts, frequency (etc.) to contrast a desktop with a laptop computer. They enter the results into an Excel spreadsheet, and produce a graph. The spreadsheet includes automatic equations to calculate expected annual electrical costs and greenhouse gas emissions. The following two equations show how to calculate kilowatt hours, and pounds of carbon dioxide, as a function of kilowatt hours [9]:

$$\text{KWH}=[\text{Watt} * 24 \text{ (hrs/day)} * 365 \text{ (days/year)}]/1\text{K} \quad (1)$$

$$\text{Pound}_{CO2} = 1.75 * \text{KWhour} \quad (2)$$

Thus, the active learning activity gives them experience with electricity measurement and Microsoft Excel. Following this brief introduction, students choose their own topics to look up and research.

After the ethics and energy efficiency lecture, students write a paper by researching an aspect of energy efficiency, related to computers. Students were allowed to pick any topic they wanted from the five categories: 1) data center efficiency; 2-3) Computer and network efficiency; 4) Smart grid/Smart home; 5) Green IT lifecycle (procurement, disposal). The instructor discouraged students from selecting computer efficiency, since a first view of these papers indicated that they involved advanced electrical engineering. However, upon further analysis, it was determined that some papers are readable by undergraduate computer scientists.

The student paper was required to include the following sections, with the following findings:

Motivation (Society/Ethics): Students were to define their goal or preferred impact of lower energy consumption and the societal and/or ethical implications. Students were then to discuss the business, political, or societal effects of the technology. This could relate to local versus international issues, or barriers to implementation. This 20-point topic asks students to perform a literature review using 2-3 non-technical sources on the societal effects of their chosen topic.

Technology: This section is divided into *Technology Vocabulary* (10 points) and *Technology Description* (30 points). The Vocabulary section encourages students to look up words as part of continuing professional development. The hope was that students would not be afraid of papers they did not at first understand.

For Technology Description, students were to describe three to four methods of energy efficiency using professional technology and other references. Most students did well. However, some student papers defined, but did not describe the technology. Thus, lower ratings were given when there was no demonstration of good technical understanding.

Evaluation: In this 10-point section, students were to describe the tradeoff of one versus the other technology technique, possibly in relation to societal or business impacts. Mature answers gave thoughtful and creative answers or considerations, beyond the obvious.

Conclusion: Students were to summarize the contribution of their paper, describing the 'take-home message'.

References: Students were to list each reference used in the paper, properly reference material in their text, and provide the diverse reference material. References needed to be from professional (IEEE/ACM), non-technical (environmental, business), and web sources. Non-technical references ensure that a holistic/multiple perspectives are considered. Reference material is requested to verify information and ensure no cheating. Proper referencing is worth 10 points.

Writing: Students were also evaluated on their writing. Good grammar and spelling, and adherence to the paper outline provided full points for this 20-point section.

VI. LESSONS LEARNED

Lecture. During Year 2 lecture, social arguments were presented and discussion ensued over the proper ethical category. In a short time, students could accurately discern the proper ethical categories. Table 1 was provided to students for study purposes.

Papers/Presentations. In Year 1 (before the ethics/social emphasis) students covered the technology aspect reasonably well in papers and presentations, but it was clear that there was no systematized evaluation of ethics or local/global issues. Also, students used only technical references.

In Year 2, papers were required to include 2+ non-technical references that considered social aspects of energy efficiency, and 68% of students complied. Students' Motivation section often included social aspects that included government statistics or a story/example of the issue in society. This made their Motivation more powerful and believable. However, only 14% of students discussed any ethical categories in their paper, and of those, most only mentioned Egoism (!) In Year 3 the paper outline will clearly state that students must discuss the ethical category of their arguments.

Each student did a 5-10 minute presentation on their paper. (In Year 2 they could present on either hardware security or energy efficiency.) In spite of the redundancy for certain topics, there was rarely overlap, and all talks were interesting. Presentation grades tended to mirror paper grades. It was useful for students to learn from the other students' presentations.

Exams. In Year 1, the exam study sheet and exam required ethical discussion about energy efficiency. Students appeared to do well with that question. In Year 2, students needed to describe two techniques to achieve energy efficiency in processors, and define and apply ethical categories. The specific exam question was to apply the four ethical categories to hardware security. Here, the percentage of students correctly defining two or all four ethical categories was 42% each. For the processor efficiency questions, the percentage of students getting a 0, 1, or 2+ points was 25%, 25% and 50%, respectively.

Teacher evaluations for this course for both years were at or higher than average for the department and the instructor. Lecture and spreadsheet materials are available by contacting the author.

VII. CONCLUSION

Energy efficiency is an advanced, interesting, and practical topic in computer architecture. The topic can be used to achieve some difficult ABET learning outcomes.

This paper focused on an integrated method that introduces ethics, local/global issues, communication, technology, and continuing professional development. We provide a table of reasons for energy efficiency categorized by ethical theory. The teaching of ethics and local/global aspects and the paper writing assignment helps students to observe, contemplate, and categorize ethics related to technology.

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TABLE I. ETHICAL REASONS FOR ENERGY EFFICIENCY

	Reasons for Energy Efficiency	Local/ National /Global	Examples for Ethical Categories
1	*Americans live beyond our means*. Americans buy goods from China, and China buys U.S. treasury bills. This enables Americans to buy more Chinese goods. These goods require energy to produce and ship. (Ch. 1[2])	N,G	Egoism: As an American, it is bad for me that China owns most of our debt. Virtue: This is bad because the person of good character wouldn't be in debt. Utilitarianism: This may lower worldwide happiness, due to the unsustainability of environmental destruction and (possibly) the exploitation of low-wage Chinese workers.
2	*Provide Sustainability*: "If we want to maintain our technological, economic, and moral leadership, and a habitable planet, rich with flora and fauna, leopards and lions, and human communities that can grow in a sustainable way – things will have to change around here, and fast." (Ch. 2-3 [2])	L,N,G	Egoism: "If WE want to maintain OUR leadership… and a habitable planet…" This focuses on our benefit only. Virtue: "…rich with flora and fauna, leopards and lions,.." The person of good character respects other species and would not destroy the environment. Utilitarianism: "…and human communities that can grow in a sustainable way…" Sustainability assumes long-term happiness (survivability) for all. Deontology: "… things will have to change around here, and fast." It is our duty to be stewards of the environment. This statement could argue at different levels simultaneously.

3	*World Growth in Wealth*: Previously there were two continents with high energy consumption: U.S. and Europe. China and India are emerging to double the Earth's energy consumption. Since their populations are so large, eventually their consumption will itself double. Add the rest of far-east Asia, Russia, and Brazil-Middle East, and the energy consumption can equal nine times the U.S. – or more. (Ch. 5 [2])	L,N,G	Egoism: Higher energy costs impacts my profit. Utilitarianism: Current energy use, implemented worldwide, is not sustainable and leads to unhappiness (assumes limited resources or that consumption has a negative effect: pollution). Deontology: Our way of living does not work on a larger, worldwide scale.
4	*Oil Revenues fuel Muslim Extremists*: Saudi Arabia constitutes only 1% of the world Muslim population, but funds 90% of the expenses of the entire faith, through Wahhabi fundamentalism. Although Wahhabis are not the base religion of the terrorists, our oil purchases indirectly encourage terrorist activities, through fanaticism and donations by the wealthy. (Ch. 6 [2])	N,G	Egoist: Terrorism may harm the speaker. Utilitarian: Terrorist activities are seen as detrimental to aggregate happiness. Virtue: A good person would not help to fund terrorists, even indirectly.
5	*Global Wierding:* Scientific reasons to assume climate change is occurring ([18], Ch. 7 [2]) E.g.: Measurement of average CO2 in atmosphere has increased from 280 in 1750 to 390 ppm in 2007. E.g.: CO2 and water vapor are greenhouse gases. They hold more heat than oxygen or nitrogen. E.g.: Warmer air holds more water and thus causes more intense storms and dryer terrain.	L,N,G	Scientific reason is going to be, in almost all cases, Utilitarian reasoning. Utilitarian: More CO2 increases global temperatures and makes human life more difficult. Therefore we should avoid increasing CO2. The happiness of the species is at stake. Virtue: Even if these scientific facts do not prove that CO2 causes climate change, a good person would minimize impact to the environment.
6	*Biodiversity:* "It gives me goose bumps" says Career, who founded a non-profit to promote sustainable ranching on the Amazon frontier. "It's like witnessing a rape. You can't protect it. There's too much money to be made tearing it down. Out here on the frontier, you really see the market at work." (Ch. 8 [2])	L, N, G	Egoist: Raping nature will kill tourism. Virtue: Protecting the environment is a good thing to do. Deontological: It is my duty to reject the rape of nature because it leads to a (universal) extinction of species, and loss of human enjoyment of the natural environment.
7	*Energy Poverty:* As other regions become wealthier, competition will cause the price of energy to increase. This will make it more difficult for the remaining underdeveloped nations to compete. (Ch. 9 [2])	L,N,G	Utilitarian: We must strive for equality of wealth (or happiness) for all nations. Deontology: Our energy use will result in haves and have-nots. Therefore, it cannot be universalized, and is bad.
8	*Increased Competitiveness:* Energy efficiency can reduce costs and provide new technologies for sale worldwide. (Ch. 10, 14 [2])	L,N,G	Egoism: The new costs and technologies benefit me. Utilitarian: the new costs and technologies will make people happy, since there will be lower prices and more jobs for all.
9	*Losing the Battle:* Despite efforts to green America, the greenhouse gas problem is measured at increasingly higher rates annually. The problem must be taken much more seriously. (Ch. 11 [2])	L,N,G	Egoism: Will the additional costs outweigh the benefits to me? Utilitarian: Will the additional costs outweigh the benefits to humanity? Virtue: What is the right thing to do?
10	*Inefficient Power Utilities:* Power utilities have little incentive to be efficient, since they grow with higher consumer demand. Thus, utilities build for peak demand, instead of encouraging consumers to use power during low energy consumption times. IT will help to make utilities more efficient. (Ch. 12 [2])	L,N,G	Egoism: This could also be a solution. Commonly, we provide an incentive for companies to change behavior (here, save energy). We focus on their egoism in order to improve the well-being of all. Deontology: A universal solution goes to the source (the power plant) instead of assuming all individuals will adhere to fixes.

The Use of a Classroom Response System to More Effectively *Flip* the Classroom

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***Abstract*—Classroom Response Systems (CRS) have been shown to improve student learning outcomes by encouraging student engagement with the course content, instructors and student peers. The system's ability to provide immediate and quality feedback to both students and instructors, particularly in large classes, is highly desirable. While CRS has been used for well over a decade and been shown to successfully improve student engagement and participation, a number of studies have also identified that its use could potentially mean that less material is able to be covered in lectures. Clearly, the approach of cramming CRS into already content-heavy class time does not embrace the potential for CRS to improve student engagement and student learning. The use of CRS should be planned as an integral component of the course which enhances and reinforces the learning outcomes. The effectiveness of CRS depends strongly on the quality and variety of the questions, and the design of the activities to encourage students to engage with the questions.**

This case study explores the use of a new, low-cost, state-of-the-art CRS (Top Hat Monocle) which allows students to use their mobile devices (phones, tablets, laptops) to respond to a variety of numerical, multiple-choice, short-answer and open-ended discussion questions posed during face-to-face workshops. In order to allow sufficient time to fully engage with the workshop activities traditional lectures were revised and the classroom lecture was flipped. Students worked through narrated lecture material (hand-e-lectures) online, prior to attending the workshops. CRS was included as part of the e-lecture content and feedback from this was incorporated into the workshops. Workshops extended the e-lecture content by including a variety of carefully designed, engaging activities (many were group activities) that used CRS questions to facilitate discussions, problem solving and case study analysis to enhance student cognition. Overall, the new flipped lecture and CRS teaching format demonstrated a substantial increase in the level of student engagement, motivation and attendance compared to previous cohorts.

Keywords— Classroom response systems (CRS); engagement; Top Hat Monocle; flipped classroom; hand-e-lecture

I. INTRODUCTION

Traditional Classroom Response Systems (CRS) are instructional technologies that allow instructors to rapidly collect and analyse student responses to questions posed during class [1]. Typically, students are presented with a question and a small number of multiple-choice answer options, and students vote for one of the options using the electronic hardware (clickers). The instructor can then display the students' responses, provide feedback and facilitate class discussion regarding the responses. This type of rapid feedback is an ideal form of assessment [2] as it is positioned close to the leaning, and students' responses are anonymous to other students, unlike other forms of response like raising hands. The use of CRS allows instructors to provide immediate formative (and, in some cases, summative) feedback, particularly in large classes [3]. Feedback is the 'most powerful single influence' on student achievement, and providing timely feedback is one of the main support conditions for student learning to take place [4]. For this reason, the use of CRS has great potential for student learning outcomes.

CRS have been shown to improve student learning outcomes by encouraging student engagement with the course content, instructors and student peers [5, 6]. Research has indicated that CRS make classrooms more engaging for students, improve student participation and interaction, improve cognition and retention, and can even improve grades [7]. Including effective active learning strategies is fundamental to providing a successful engineering education [8].

The ability of a CRS to provide immediate and quality feedback to both students and instructors, particularly in large classes, is highly desirable. It is vital that the device used to deliver student responses is user-friendly, reliable and inexpensive; the sustainability of the system for instructors and staff will determine its long term use. Many traditional CRS only allow students to answer simple multiple-choice type questions. Unless these types of questions are well designed, they may not allow students to demonstrate their depth of knowledge or understanding, or to develop higher-order thinking skills such as analysis, synthesis, and evaluation [9]. This study explores the use of a new, low-cost, state-of-the-art CRS (Top Hat Monocle) which allows students to use their mobile devices (phones, tablets, laptops) to respond to a variety of numerical, multiple-choice, short-answer and open-ended discussion questions posed during face-to-face workshops.

While CRS has been used for well over a decade and been shown to successfully improve student engagement and participation, a number of studies have also identified that its use could potentially mean that less material is able to be covered in lectures [6]. Toto and Nguyen [8] recognised that it is very difficult to continue to cover the amount of material needed while also opening up class time to include the active learning strategies so necessary in engineering. Demetry [10] reinforced this view by maintaining that content-crammed courses have been a perennial barrier to more widespread adoption of pedagogies of engagement in engineering education.

Clearly, the approach of cramming CRS into already content-heavy class time does not embrace the potential for CRS to improve student engagement and student learning. The use of CRS should be planned as an integral component of the course [9] which enhances and reinforces the learning outcomes. The effectiveness of CRS depends strongly on the quality and variety of the questions, the design of the activities to encourage students to engage with the questions, and most importantly, allowing sufficient time for students to read, comprehend, discuss and work through the questions at their own pace, as well as allowing enough time for them to submit their answers in a stress-free environment. Trying to add the use of a CRS alongside traditional lecture class material, rather than augment the use of the CRS, will not demonstrate the true benefits of using CRS to students and will generally also not improve student learning.

This study trialled the introduction of a new, state-of-the-art CRS in a third year engineering Fluid Mechanics course to improve student engagement, motivation and cognition. The course was completely redesigned and restructured to address and alleviate content-cramming issues [6, 8, 10]. It was recognised that for the potential benefits of CRS to be fully realised, more time must be allocated for student engagement and the active learning components of the course. In order to allow sufficient time to fully engage with the CRS and other classroom activities, traditional lectures were revised and the classroom lecture was flipped [10, 11]. This paper presents the initial case study results.

II. Flipping for Learning

Flipping allows for an instructor to provide traditional, low cognitive level, lecture materials in an alternative format outside the classroom, freeing up class time normally used to 'convey' information to students [8]. Instruction that used to occur in class was then accessed in advance of class (generally at home), so that students were well prepared and could derive the most benefit from time spent in the face-to-face learning environment [12]. Students worked through specially developed narrated lecture material online each week using our learning management system (LMS), prior to attending the face-to-face class sessions. Face-to-face sessions were then used to foster student engagement by working through typical problems, providing feedback, introducing advanced concepts, and facilitating student discussions and other collaborative learning activities [8, 12]. Toto and Nguyen [8] maintain that flipping lectures retains the best qualities of the traditional teacher-centred lecture model while also including the best qualities of the active learning or student-centred teaching model.

In order to avoid confusion, the weekly narrated flipped lectures were renamed hand-e-lectures to reflect the convenience and flexibility these online lectures offered students. The time slot allocated for the original lecture was renamed the workshop. The students could work through and study the hand-e-lectures when and where they wanted, and for as long as they wanted. Different students learn at different rates and this arrangement allowed them to spend as much time on the material as the needed. All students need time to be able to absorb and process the information needed before it can be applied [8]. In order to encourage students to utilise and engage with the hand-e-lectures, a number of graded CRS questions were included as part of the online hand-e-lecture content. In order to answer the weekly online hand-e-lecture questions, students were first required to register as students on the Top Hat Monocle (THM) website (https://www.tophatmonocle.com/).

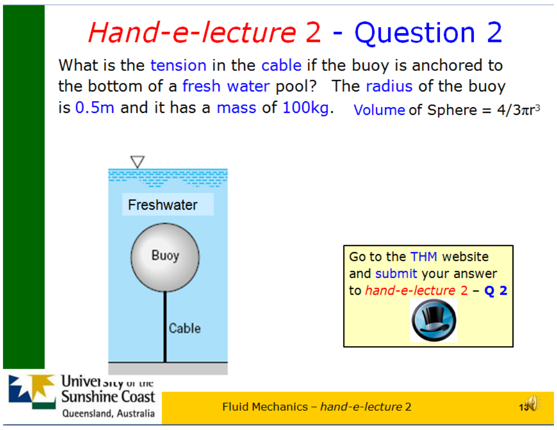

Fig. 1. Typical *hand-e-lecture* CRS Question

Typically, each hand-e-lecture would contain between four and six CRS questions based on the weekly lecture material (Fig. 1). Students were required to solve and submit answers to the CRS questions before attending the workshop session. Students could submit their answers to the CRS questions online, using a PC, laptop or Smartphone, or by SMS if these were not available. Reports showing the range of student responses to the hand-e-lecture questions were generated before each workshop and these were used to provide feedback and to identify any problem areas. Fig. 2 shows a typical report from a numerical answer-type question. The numbers listed down the left hand side of Fig. 2 show the various student responses to that particular question. The percentages listed down the right hand side of Fig. 2 represent the percentage of students that submitted that response. The numbers in the horizontal report bars show the actual number of students. The correct answer (200) is highlighted yellow in Fig. 2.

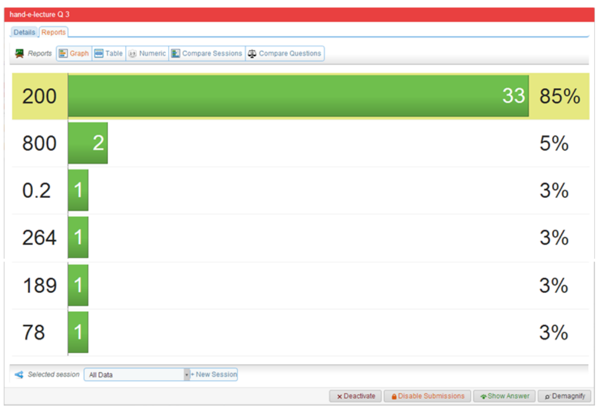

Fig. 2. Typical *hand-e-lecture* CRS Question Report

Workshops extended the hand-e-lecture content by including a variety of carefully designed, engaging activities (many were group activities) that used CRS questions to facilitate discussions, problem solving and case study analysis to enhance student cognition. Students used their mobile devices (phones, tablets, laptops) to respond to the CRS questions posed during the workshops. This arrangement also provided opportunities to identify potential problem areas, and to enable on-going assessment and evaluation of learning outcomes. To encourage participation in the workshops, students were also graded on their participation in the CRS process and on the correctness of their responses to the questions. A maximum of 15% of the total student grade was allocated for participation in the hand-e-lecture and workshops using the CRS.

One of the many pedagogical benefits of the instant feedback provided by the CRS in the workshops was that it allowed students to evaluate their own performance and to monitor their own understanding of the workshop content [6]. This has been shown to result in a significant increase in students' long-term retention of knowledge [13, 14]. A further pedagogical benefit of receiving instant feedback on the students' responses was that the instructor could immediately identify areas that students were having difficulties with, or conversely, areas where the students were having no problems understanding. This allowed the instructor to adjust their instruction to provide further explanation on any problem areas, or to move on to the next topic with confidence that the students have understood. The flexibility that the instant CRS feedback gave the instructor in the workshops was particularly valuable. Traditional lectures are usually 'passive' in nature and it is very difficult to tell whether students are actually learning [8].

A further benefit of using the new CRS to ask students to answer summative questions posed in the hand-e-lectures and workshops was that the instructor could tell at a glance how students were doing overall. The new CRS trialled in this study provided instant EXCEL score sheets for all questions at the click of a button. This was very valuable information as it allowed the instructor to identify any individual students that were struggling. The instructor could then intervene and spend more time one-on-one with the students to provide extra instruction before the students became frustrated or gave up [15]. The instant score sheets also allowed the instructor to identify areas of general misunderstanding within the class and provide extra explanation where required. An added benefit of this was that the students quickly realised that the instructor was very aware of how much effort the students were, or were not, putting into their learning.

III. Evaluation

A range of evaluation methods were used to gauge the effectiveness of the new teaching format in achieving increased student engagement, including classroom observation, student surveys using THM, feedback from student emails, and analysis of attendance and assessment results.

A significant increase in the levels of student engagement was observed during the new workshops. Students actively participated in the workshops using their mobile devices. There was always much interaction and discussion among the students whenever a new THM question was posed. This was generally accompanied by a significant change in noise level within the classroom. It was interesting to observe how the noise level changed after each new question was posed as it generally followed a similar, cyclic trend, namely:

- The noise level would rise substantially as soon as the question was posed as students discussed the question amongst themselves;
- The noise level would gradually reduce over the next minute or so, as the students started working on their questions individually;
- The noise level would then reduce to nearly zero when the students were deeply engaged with their solutions;
- The noise level would then slowly start to rise again as more students submitted their answers on THM and discussed their answers with others.

From the instructor's point of view, this cyclic trend in noise levels was a very useful gauge of the appropriate time to move on to the next topic or question.

The CRS was also used to survey students on their perceptions of using the new technology and to gain a deeper understanding of how its use could be improved. At various times during the course, a number of evaluation questions were posed for evaluation purposes. The CRS was also used to obtain information on technical issues, such as which internet browser or phone provider the students were using or how they found the registration process and similar logistical queries. Fig. 3 shows the results of the survey question: *"Do you like or do you not like being able to participate in the Workshops using THM?"* This question was asked in the second week of the new course at the end of the second workshop.

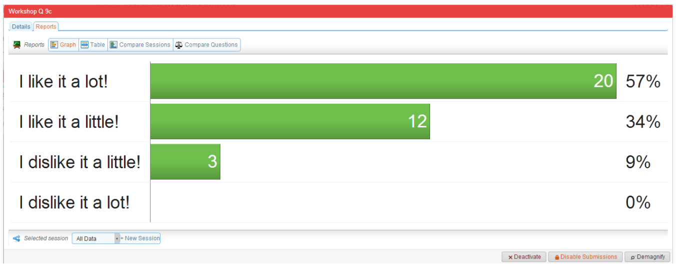

Fig. 3. Report of One of the THM Evaluation Questions

As shown in Fig. 3, 91% of students surveyed (n=35) liked that they were able to participate in the workshops using the new CRS (THM). This was very encouraging, particularly as most of the students had never used a CRS before and this was only two weeks after they had first been introduced to THM. However, three of the students said they didn't like it much. Another benefit of the reporting system is that it is very easy for the instructor to see which students are responding to the questions. As it turned out, the three students that said they disliked it a little answered in the negative for all of the CRS evaluation questions posed that day. They also got most of their answers to the workshop questions wrong. Perhaps they were just having a bad day?

Fig. 4 shows the results of the survey question: *"Do you think that the new hand-e-lecture and Workshop format will or will not help you to better understand the course material?"* This question was also asked in the second week of the new course at the end of the second workshop.

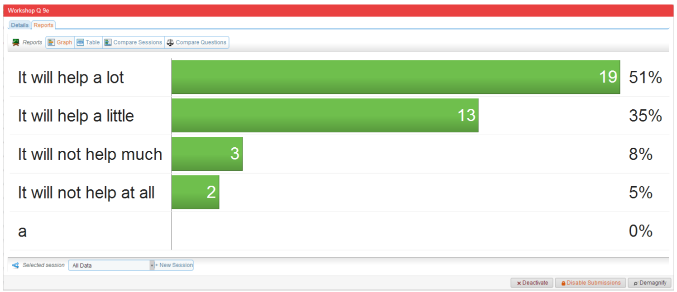

Fig. 4. Second THM Evaluation Question Report

As shown in Fig. 4, 86% of students surveyed (*n*=37) thought that the new hand-e-lecture and Workshop format would help them to better understand the course material. Fig. 5 shows the results of the survey question: *"Do you like or do you not like being able to work through the material whenever it suits you?"*

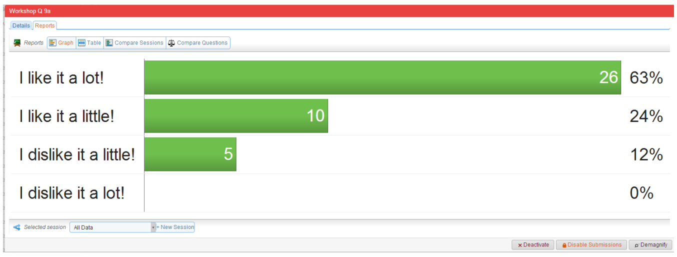

Fig. 5. Third THM Evaluation Question Report

As shown in Fig. 5, 87% of students surveyed (*n*=41) liked being able to work through the material whenever it suited them. Student feedback on the other evaluation questions posed produced similar positive results which reinforces previous research findings that CRS promotes greater student engagement and higher levels of motivation [5, 7, 8, 10, 12, 16].

The CRS was also used to collect feedback on technical and logistical issues associated with the use of the system. As this was the first time that this system had been trialled anywhere in Australia, another of the study aims was to investigate different students' experiences of interacting with THM using different Australian internet and mobile telephone service providers. In addition, the students' views on, and experiences with the registration process was of interest in this study. One of the first week's hand-e-lecture questions asked: "How did you find the registration process through the Top Hat Monocle website?" The results are shown in Fig. 6.

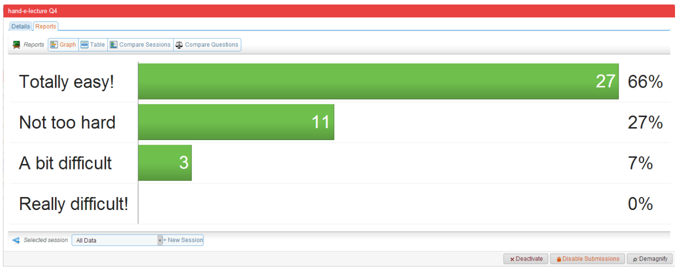

Fig. 6. Report of Evaluation Question on Registration Experience

As shown in Fig. 6, 93% of students (*n*=41) found the registration process easy. This is a very good result considering that this question was asked in the very first week of semester and most students had never used any type of CRS beforehand.

In addition to the formal evaluation that was conducted on the new teaching format, students were also asked to provide informal feedback by way of email on their perceptions of the new teaching format. While this invitation did not generate a large number of responses, the feedback that it did generate was generally very positive and supportive of the new teaching format. Two examples of this student feedback on the new teaching format are shown below:

- *"One of my favourite things is that we are exposed to, and tested on our understanding of new material at our own pace. This enables me (us) to bang our heads against something we find a bit curly until we have at least some understanding of it (or failing that narrows it down to 1 or 2 points that are easily cleared up in the 'workshop'). So when we are exposed to it in the workshop it's nothing new and we can focus on its applications and broader implications."*
- *"Between the hand-e-lectures, the THM questions and the TuT questions I am engaged, and importantly not swamped, by material to keep it on my mind and to 'hold', if you will, the learning. That way the workshops are more like a spit and polish of the rough knowledge from the HeL and the TuT questions are the double check."*

The new flipped lecture and CRS teaching format demonstrated a substantial increase in the level of student engagement, motivation and attendance compared to previous cohorts [7, 8, 10]. However, the increased levels of engagement did not appear to reflect on any large increase in students' individual grades in comparison to previous cohorts, although at the time of writing, the final grades were not yet complied. There are also many variables that could influence the results from one student cohort to the next and these would have to be taken into account to enable a realistic comparison. This was the first time that this new teaching method has been trialled and the inconclusive nature of the results could be attributed to the preliminary nature of this case study. The study is ongoing and it is expected that as more data becomes available, this will allow a comprehensive analysis to be undertaken on the pedagogical benefits of this new teaching format.

IV. CONCLUSION

This case study explores the use of a new, low-cost, state-of-the-art CRS which allows students to use their mobile devices (phones, tablets, laptops) to respond to a variety of numerical, multiple-choice, short-answer and open-ended discussion questions. In order to allow sufficient time to fully engage with the CRS and other classroom activities, traditional lectures were revised and the classroom lecture was *flipped*. Students worked through specially developed lecture material online each week prior to attending the face-to-face class sessions. Face-to-face sessions were then used to foster student engagement by working through typical problems using the CRS, providing feedback, introducing advanced concepts, and facilitating student discussions and other collaborative learning activities.

A number of inter-related issues are contained in this paper that were difficult to tease apart. Separating the advantages of using a CRS in general, using THM in particular, the way in which the instructor used THM, and the overall teaching quality of the instructor is very difficult. The data gathered and discussed in this paper regarding THM are inextricably linked to the manner in which THM was used.

Overall, the new flipped lecture and CRS teaching format demonstrated a substantial increase in the level of student engagement, motivation and attendance compared to previous cohorts. Generally, students' perception of the effectiveness of using the new teaching format was overwhelmingly positive. The study is ongoing and it is expected that as more data becomes available, this will allow a comprehensive analysis to be undertaken on the pedagogical benefits of this new teaching format.

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Development of an Automated Manufacturing Course with Lab for Undergraduates

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Abstract*— Many engineering programs at universities across the country have dropped machine shop and manufacturing courses from their curriculum due to budget constraints, accreditation requirements, and concerns about student safety. At the University of Portland, we have resurrected and enhanced a hands-on advanced CAD and automated manufacturing course that introduces students to advanced solid modeling techniques in CAD, such as sweeps, lofts, and surfacing methods. In addition, students learn manual machining and vacuum forming in our machine shop, along with learning how to create tool paths for CNC machining their designed CAD parts out of wax on various three axis end mills, a 3D printer, and a 3D laser scanner. The end mills were all refurbished and/or repaired over a period of four years to get this course up and running. A commercial software package, MasterCAM, was used in conjunction with SolidWorks as the platform from which to learn about automated manufacturing. In addition, a MakerBot 3D printer was built from a kit to give students experience with future manufacturing techniques. The 3D laser scanner was student designed and built and creates CAD surface models of parts, useful for learning about reverse engineering. The machinable wax used for machining is recycled, melted down, and formed into blocks again for reuse. This saves considerable money. Our goal has been to enhance design quality in our curriculum through experiential learning. Prior to taking this course, all mechanical engineering students are required to take a solid modeling CAD course to learn the basics. However, our experience has been that students do not conceptually understand the importance of designing for manufacture. Although emphasized in all courses, without the hands-on experience, it is difficult for students to remember to apply fillet radii to the bottom of pockets, for example. When faced with having to fit a block with sharp corners into a machined pocket with its default small corner radii, however, learning is instantaneous. The early outcomes of this course show students have learned a great deal about design for manufacturing and manufacturing techniques from taking this course.

Keywords- experiential learing, manufacturing, CNC machining, hands-on laboratory experiments, undergraduate engineering, 3D printing, rapid prototyping, MasterCAM, SolidWorks

I. INTRODUCTION

This article covers the reintroduction last year of an automated manufacturing course in the mechanical engineering department at the University of Portland. This course existed for many years, but faded away in 2000 after the instructor retired and the small end mill used for the course stopped functioning. Over the past four years, it has been my goal to revitalize this course and begin offering it again. The new and improved version of this course will now be offered every year.

Why offer an advanced CAD and automated manufacturing course? It has safety risks, equipment purchase, maintenance, and refurbishment costs, and requires a large investment of time and faculty resources to provide a lab-based course to a couple dozen students. The reasons are numerous, but mainly hinge around the fact that the demographic of our engineering student body has changed, and the vast majority of our students have had no exposure to or use of manufacturing equipment of any kind. Since the early 1980s, two-thirds or more of high schools nationwide have eliminated their technical education classes [1], mechanical and electronic devices have become too complex for the average teenager to work on [1], and many colleges have had to eliminate lab courses due to budget constraints. Engineering students frequently graduate with little hands-on, experiential learning, and there is a "disconnect [and] engineering students are not adequately prepared, in [industry's] view, to enter today's workforce" [2]. Also, the world of manufacturing is changing, and engineers of the future will need to be able to work with new equipment, technologies, and manufacturing techniques. Awareness of these techniques will be key to their professional development and success as engineers [3].

The need to shift from scientific inquiry to engineering design has been addressed by the Next Generation Science Standards, as being critical for our students [4]. The core concepts they want students to acquire are achieved through the experiential learning we have implemented:

1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

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2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

The National Research Council of the National Academies has also been involved in revising our K-12 science education, and they are also focusing on integrating scientific inquiry with the skills of engineering practice [5]. They have stressed that a narrow focus on conceptually teaching science has led to the unfortunate consequence of students believing science is a body of isolated facts. By integrating the knowledge of a science with skills simultaneously, students' minds are cultivated to be able to engage in scientific and engineering inquiry.

This type of experiential learning needs to be carried forth into the college level. In another National Research Council publication, "Promising Practices in Undergraduate Science, Technology, Engineering, and Mathematics Education: Summary of Two Workshops", the authors found that some of the strongest predictors of success were in-class activities that actively engaged students in the learning [6]. They found notable success when students were involved in problem-based learning, beginning with a problem to be solved, followed by some content delivery of theory, skills, or case studies, followed by small group activities, and completed by designing a solution.

At our university, we have noticed that students often make "manufacturing errors" in their CAD solid models, such as neglecting to put fillets in the bottoms of holes. This is due to their ignorance of manufacturing tools and how they are used. "The disappearance of tools from our common education is the first step toward a wider ignorance of the world of artifacts we inhabit" [1]. It is difficult, if not impossible, for us to explain why such things as fillets are required on their designs, since they have no context to understand what we are saying. We feel this points to an underlying weakness in problem solving among our students, as the vast majority of our curriculum uses textbooks with "answers" in the back of the text. This problem persists all the way into our senior design capstone sequence, where students produce beautiful CAD models and assemblies that cannot be manufactured or assembled. Thus, we have embarked on a strategic plan to increase the amount of design and experiential learning in our mechanical engineering curriculum.

The redesigned advanced CAD and automated manufacturing course is intended to provide hands-on experiential learning through a variety of equipment and software tools. The lab now contains four end mills, all three axis, a 3D laser scanner for reverse engineering, and a small 3D printer. Additionally, student teams have lab rotations through the machine shop to learn manual machining, vacuum forming, and molding techniques. The remainder of this paper discusses all of the course curricula in detail, the equipment and how it was refurbished, the costs of establishing this course, and the outcomes achieved.

II. Lab Equipment Details

All our mechanical engineering students are required to take an introductory course in engineering graphics, which includes the use of SolidWorks®. This knowledge is used in follow-on classes, such as finite element analysis (also required), a balsawood bridge design competition, and in senior design. Students coming into the advanced CAD and automated manufacturing course have this background in CAD, which is used as a basis to begin the instruction with the introduction of new software, MasterCAM for SolidWorks®. This new product offering by MasterCAM is an add-in module embedded within the graphical user interface of SolidWorks®. Thus, it is easy for students to adapt to the increased functionality, and they are comfortable switching between modes to edit or adjust dimensions on their CAD models, and then return to their tool path model. MasterCAM® allows the students to embed their CAD model in a block of material and then machine away the excess until the CAD model is again revealed. For 2012, we used SolidWorks 2012 (Educational edition) and MasterCAM X6. We upgrade to the latest revision of all software every year.

The CAD and CAM modeling was taught in a computer classroom that contained 35 Windows 7 workstations with enhanced graphics cards and 21 inch LCD monitors. The textbook used for the MasterCAM was "MasterCAM for SolidWorks X6" by In-House Solutions. The text came with all the CAD models to do the exercises in all 13 chapters, but to improve the students' CAD skills, I had them make all their own models and only provided the models for classroom exercises. The chapters were very thorough, perhaps too complete, as the students could follow step-by-step to create their tool paths. However, all the lab rotations were open-ended designs that the students developed themselves, and they had to then create their own tool paths from scratch.

Lectures in the computer classroom were one day per week, and labs were the other day each week. The first five lecture periods were devoted to learning MasterCAM and refreshing CAD skills by building the models for the exercises. The next eight lecture periods were devoted to learning advanced techniques in SolidWorks. As there are no good textbooks on SolidWorks, I worked with my local software distributor (MCAD in Beaverton, Oregon) to obtain a couple of their instructional course books. These were outdated by one revision, 2011, but they allowed me to copy, paste, and combine them in any way I wished to make an instructional course pack. I pulled mainly from their

"SolidWorks Advanced Part Modeling" and "Surface Modeling" books. As I did not have any of the referenced models, and the books were meant to be used with instructor guidance, there were many challenges with the course pack I created. However, we were able to cover many advanced topics, including sweeps, lofts, and surfaces.

On lab days, the students had two weeks at each of six stations. During the first lab period, students would read the various equipment tutorials I had prepared and dry run through the entire set up procedure. Then, they would build their own model and machine it the following week. As the semester progressed and the students got more enthused about what they could do, the time to machine their models increased, so the students often came back on their own time (in pairs) and finished their machining.

For the lab, I utilized machinable wax. There were a number of wax blocks available from the prior course in 2000, and a crock pot and aluminum mold that had been made into a wax recycling system. The machinable wax blocks were 3 inches by 6 inches by 1.5 inches thick, and new ones cost about six dollars each to purchase. So, we utilized the wax recycling system to melt down all the stored shavings and discarded projects into new blocks. The color was muddied from blue or purple to a brownish purple at first, as the stored shavings had bits of plastic and other debris. When collecting the shavings from the new blocks, we purchased a clean shop vacuum that attached to a five gallon bucket. We used only that bucket for the new blocks, and they molded into serviceable and nicely colored new blocks.

The lab contains four end mills, a 3D laser scanner, and a 3D printer. In addition, the machine shop contains a manual end mill and a vacuum forming machine. Each of these pieces of equipment will be discussed below, including when it was purchased, how it was refurbished, and its capabilities.

A. EMCO PC-50 Mill by Maier Industries

This small, tabletop three-axis mill was purchased in the 1990s for the original automated manufacturing class. It was purchased without the onboard controller and instead used a Windows 98 and DOS-based software interface. My predecessor had determined that a couple of the cards in the EMCO were faulty and had purchased replacement cards. I had those installed, but could not get the computer to run. It turns out that someone had inadvertently disposed of the Windows 98 computer that served as the controller. Fortunately, they had removed the ISA card first. According to Maier, the Windows 98 environment cannot be emulated, so I had to locate another Windows 98 computer that had an ISA slot. Most Windows 98 computers used PCI slots, so it was challenging, but I finally managed to locate one that met my needs. The MasterCAM software would not run on this computer, however, so a Windows 7 computer was also needed. To transfer files, we use the CD Read/Write drive, as the Windows 98 computer cannot read a USB drive. All of this could be overcome by refurbishing the EMCO with a new controller, but that would cost $6000. It is slated for refurbishment sometime in the next three years, depending on other lab needs. The EMCO itself machines beautifully and produces high quality parts in wax, plastic, and aluminum. It is a very safe machine that will only operate when the door is closed, and it will stop itself rather than exceed a safe travel limit. There are many of these EMCO PC-50 mills around, and they are a low cost way to start an automated manufacturing course.

B. Techno Da Vinci Mill by Techno, Inc. Education Division

The lab contains two Techno Da Vinci three-axis tabletop mills that were purchased in 2005 to support a mechanical systems and controls lab course. Although they were outfitted with Dremel®-style rotary cutting tools, they were used exclusively as pen plotters. The encoders were outdated technology, and the software interface was extremely challenging for the students to learn how to use. These were refurbished with all new encoders in the spring of 2012. The refurbishment took one day, and each mill cost $7500. These two mills now interface through Techno CNC Interface software directly to MasterCAM and have been the most popular ones to use in the course. They are capable of machining up to three feet square, but that requires additional fixturing. They are each outfitted with a vise that holds the wax blocks.

The Techno mills are still available for purchase and are widely supported by local distributors. They are straight forward to operate and provide a great learning environment; however, the rotary tools provide inferior cutting and the collets make tool change difficult. The collet must be removed from the rotary tool in order to put in a new tool bit. Collets of one-quarter and one-eighth inch are available, so end mill tool bits are limited to smaller sizes. Also, the gantry-style movement of the rotary bit is jerky and does not provide as nice a surface finish as the other mills we have. For safety, I had both mills outfitted with Plexiglas shields and hinged doors. I also had an air blowing system attached to each tool head to help clear wax shavings.

C. Bridgeport Explorer I CNC Mill by Bridgeport

I purchased this three-axis knee mill in 2009 off of Craigslist for $3000 and then moved it up to the university in a pickup truck using a forklift and chains to get it in and out of the truck. The mill was transported to near the door of the building and then lowered onto a rolling platform to bring into the classroom through the double doorway. It was then lifted with the forklift again and placed in its final position. It required three-phase power, which was previously installed for it during the building renovation. The Bridgeport mill was in good working condition, but very outdated. I had the computer, keyboard, and software updated for $4000. The mill was also cleaned up and painted and got a new adhesive panel backdrop for the controls. The software is a standard Fanuc controller, suitable for our machine, and I downloaded the post for it for free from MasterCAM. To place files on the machine, we purchased a special USB drive that plugs into the back. This USB drive provides access codes and also serves as extended machine memory. For safety, I had three six-foot high Plexiglas rolling walls made to surround the three sides of the machine. The machine has oil coolant, but I opted to use the mill only for wax during the course. It is capable of machining aluminum as well as steel and can support the use of large tool bits.

D. 3D Laser Scanner (Student built)

Manufacturing techniques are changing rapidly, and one trend is biomimicry and reverse engineering, where designs are organic and inspired by nature. Traditional CAD software is notoriously ill-equipped to model organic forms, so engineers are searching for new ways to input CAD geometry and surfaces into their designs. One way to input such surface data is with the use of a laser. Our device is a green line laser that is hand-swept over the object of interest. A student developed this for me in 2010. Behind the object is a grid of calibration dots that allow the software, we use David®, to capture the surface contours. The object can be rotated multiple times, and the finished scans can be aligned in the software to recreate the entire object. The surfaces are then fused together, and the finished object can be viewed in SolidWorks and printed on a 3D printer. Our 3D laser scanner is of very low quality, but it illustrates the concepts well, and students gain a lot from the awareness of such techniques.

E. Cupcake 3D Printer by MakerBot

I won this 3D printer from MakerBot in 2010 by entering an essay contest, explaining how I would use it in my courses. The printer came as a kit with hundreds upon hundreds of pieces, but if I were to have purchased it, the cost would have been only $1500. Now, they are even cheaper. Building the printer (and then optimizing it) provided several of my students with interesting focus and independent study projects that gave them valuable hands-on experience with hardware and electronics. The software is open source and is called Replicator G. The Cupcake is an ABS extruder (fused layer deposition). It works like a hot glue gun, melting the ABS plastic at 250 degrees Celsius and building layer-by-layer on the heated build platform. The build platform is less than three inches on a side, but the resolution is actually not bad for hobbyists. Like the 3D scanner, its purpose was to expose students to this new manufacturing technique, as industry is beginning to manufacture car parts and other exciting designs that could never be machined using conventional methods.

3D printing is truly the future of manufacturing. Many of our senior projects desire 3D printed prototypes, and we have had to send these requests out to local industry, as our capabilities are limited. However, a donor has given us $25,000, which we supplemented with departmental funds, and we have purchased a Stratasys Dimension 1200es SST. This new 3D printer has a 10 x 10 x 12 inch build volume and can print in nine different colors of ABS plastic. We chose this printer because it provided robust, functional parts that could be used directly as prototypes, and had relatively high resolution of .010 inches. The speed is moderate compared to other technologies, but we were pleased that the scaffolding material was environmentally safe and water soluble. Parts are placed in a water-based solvent part washer for several hours and are then rinsed in the sink. The solvent can be poured down the drain and replaced as needed. Since the water-based solvent is heated to 70 degrees Celsius, we are requiring students to wear insulated dish gloves, safety glasses, and masks, just to make sure they are not exposed to any chemicals unnecessarily.

F. Manual Machining and Vacuum Forming

In the machine shop, we have a three-axis Bridgeport mill. Students are asked to machine a paperweight out of aluminum. The purpose of this training is to help them gain a realistic sense of what feeds and speeds mean in the MasterCAM software. It also lets them feel the resistance of the machine if they make too deep of cuts or try to travel at too fast of a speed.

Also in the machine shop, we have a vacuum forming machine. The plastic material, such as polystyrene, is held in a sheet and heated from above the object to be captured. When it reaches the right temperature, the sheet is lowered quickly, and air ports in the lower table seal the plastic around the object. Finished molds are then trimmed out of the cooled sheet and can be filled with a hardening foam or plastic material to make replicates of the original object.

G. Safety

To minimize the risk to our students, we conduct two full class periods of training, one for the automated manufacturing lab and each piece of equipment it contains, and one for the machine shop. Students are not allowed into either location without safety glasses, pants, and closed toe shoes. They must use leather gloves to change tool bits and must have all shields engaged before turning on the machines. Other safety is also covered, such as tying back long hair, not wearing loose clothing, and applying appropriate force to vises and collet nuts. Both the instructor or technician and a lab assistant are present at all times. Once students are fully trained, they are permitted to use the machines outside of class time, whenever the building is open. They are required to work in pairs, and they have to carry written permission with them, in case anyone asks if they are allowed in the lab. Any injuries are reported to the university. So far, one student cut his hand on a tool bit when checking to see if the wax block was secure in the vise (it came loose). A second student used his personal pocket knife to open a cardboard box and cut his hand.

III. RESULTS

This past academic year, 25 students took this new course in advanced CAD and automated manufacturing. The students each completed over ten MasterCAM tool path codes, and about a dozen SolidWorks models. As teams of four, the students also fabricated six of their own designs, one on each piece of equipment, as well as a final project on a machine of their choice. Many students incorporated surface modeling in their designs and many others built mechanisms of several wax-cut pieces, such as the Geneva mechanism in the photo. Since then, many of these students have continued to use what they learned to make projects on their own or as part of their senior design prototypes. One team machined an entire foam RC airplane wing on one of the Techno mills for their senior project. Another used the MakeBot to make a buckle for a medical device, also for their senior project.

There have been numerous glitches throughout this first year course offering. The Bridgeport mill developed some mechanical problems and had to be repaired. It was also limited to 256 kilobyte files, and some of the feature-based milling techniques in MasterCAM exceeded this limit. I did not learn until after the semester ended that the USB drive could allow us to machine larger files. The Techno mills do not adequate grip the tool bits in the collets unless the collets are first removed from the rotary tool and assembled with the tool bit. Also, the collets were old and had some looseness. Thus, some of our early attempts failed to machine properly, because the tool bit loosened and starting falling out of the collet during machining. New collets were purchased, and the students were trained on the proper technique for changing tool bits. Hopefully, some replacement rotary tools with a chuck key system can be found in the future. The MakerBot printer was having trouble with the ABS plastic not adhering to the heated build platform. This was resolved by adding a raft under the parts. The larger, looser surface area of the raft was better at adhering. The raft then had to be peeled off the part after fabrication. Finally, the 3D laser scanner software, David® 2.0, could only produce .STL files. This is not an editable format in SolidWorks®. There are other software options out there at free or low cost, so those will be investigated.

IV. DISCUSSION

This course was very well-received by the students and received a lot of positive feedback. The overall assessment of the course by the students was 4.78 out of 5.00, with 78% giving a rating of "strongly agree" on the course being a valuable learning experience. The remaining 22% answered "agree" to this question. Below are some of the comments students made about the course:

"I really enjoyed learning the advanced CAD and automated manufacturing techniques learned during this course. I think all of these skills will be very beneficial to my career."

"It is a fantastic introduction to Advanced CAD and Automated Manufacturing. It has been the most hands-on of any class I have had so far, and thus has been the most enjoyable. I certainly like that several different types of automated manufacturing are introduced in the lab."

"The course teaches an engineer how to bring their designs to reality and the problems that arise in manufacturing a product from a drawing. The instructor was prepared for problems when they arose and was able to keep the course moving forward even when problems resisted."

The students also gave me some beneficial feedback to help improve the course this next year. One of their main criticisms was the time slot. Because we needed both a computer classroom and a heavily-used lab, the course was offered at night. This interfered with student jobs, placed the course back-to-back with an optional review course many of the students were enrolled in, and limited how late we could stay, since the machine shop technician needed to go home. Thus, next year, we are switching semesters the course will be offered. In the spring semester, we can offer the course in the late afternoon with no conflicts.

Another complaint was the poor quality of the course pack I created for SolidWorks and the amount of advanced techniques we were able to cover. The students were not as skilled at SolidWorks from their introductory class as I had anticipated, so a lot of time was needed to go over more remedial skills. Most of them did not know how to create a dimensioned engineering drawing, either, so that will need to be added to the instruction next year. Because of these challenges, we did not get an in depth coverage of surface modeling. I am working with an exceptional student to develop my own advanced CAD book for SolidWorks for next year's course.

V. CONCLUSIONS

As our knowledge of science and engineering increases in complexity, we feel it is important to maintain the hands-on skills portion of scientific inquiry, as well as to develop student ability to formulate a problem and design an engineering solution that addresses all of the many faceted issues that may be involved. As the integration of design into the engineering curriculum is now an ASME and ABET criteria, we are addressing this issue across multiple courses.

Overall, this new course offering in advanced CAD and automated manufacturing has been a successful addition to our curriculum. There is a lot of room for improvement, but the main objectives of the course, which were to give students experiential learning and thus improved design skills through hands-on manufacturing of their own designs, has been achieved. It is a future goal to assess the impact this has on our student outcomes.

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Virtual Learning Environments in Engineering and STEM Education

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ABSTRACT—*This paper discusses an innovative approach to teach engineering concepts using Virtual Reality based Learning Environments (VLEs). New learning modules have been created using Virtual Reality technology and introduced in interdisciplinary senior level and graduate level courses targeting mechanical, industrial and electrical engineering students. These Virtual Reality based learning environments have been used to teach micro systems related topics as part of overall efforts to enhance the learning experiences of students. The learning outcomes including student performance are discussed. The process undertaken to design and develop these VLEs are elaborated along with the technologies used to develop such environments. A brief discussion of next generation Internet technologies which hold the potential to impact engineering and K-12 education is also provided.*

I. INTRODUCTION

This paper discusses the potential of Virtual Environments which use Virtual Reality (VR) technology for education and learning activities. In general, such Virtual Environments (VE) are widely used in various engineering domains from robotics assembly to more complex space systems design. Virtual Learning Environments (VLEs) are a subset of virtual environments which are created and used for educational and learning contexts at university and K-12 levels. In this paper, we discuss the design and introduction of these VLEs to teach engineering concepts at Oklahoma State University to both undergraduate and graduate students.

Virtual Reality [1-22] and Cyber computing techniques [23] are among the more recent technologies adopted for educational purposes. The potential of using such technology to teach simple and complex Science, Math and Engineering (STEM) concepts is significant [22, 23, 24]. Our students live in a cyber enhanced digital world where use of digital technologies is commonplace. Educational trends need to explore adoption of such technologies. As noted in [23], computer or software based learning tools refer to a larger set of tools and environments which enable students to learn using some type of a computer technology (which may be web based or running on a PC). Virtual Learning Environments (VLE) are a smaller subset of such computer based learning environments [23, 24].

II. VIRTUAL LEARNING ENVIRONMENTS (VLE)

VLEs involve the creation of 3D based graphics rich environments that can also interface with Virtual Reality technology (such capabilities are crucial to supporting both immersive and non-immersive interactions by users or students. With recent advances in Internet technology (such as Internet2 and the more advanced GENI type frameworks, see [23]), the impact of such VLEs is expected to rapidly transform the way our students learn.

Virtual Reality, in general, can be described as a technology that enables the creation of a 3 dimensional (3D) simulation environments; users can interact with such environments using 3D eyewear and trackers (figure 2). The 3 levels of immersion are non, semi and full immersion [22].

Non immersive environments [22, 23] do not provide active stereo views of the target simulation; here the environment looks similar to a typical 2D computer screen (figure 1); this is the most basic of VLEs. At the next level are Semi immersive environments; these can provide active 3D stereo views of target environments and users can interact using trackers, sensors and 3D eyewear (or stereo eyewear, see figure 2). The screen of interaction can be a computer screen or a much larger wall sized screen. These environments are referred to as 'semi immersive' [23, 24] as the user can interact with the 3D environment when they want to but also can look

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away at the real world around him or her (meaning they are partially immersed).

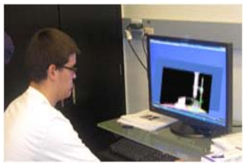

Fig 1: A non immersive VLE

Fig 2: A semi immersive VLE

Fully immersive environments are environments where your reference to the real world is completed eliminated (or the immersion is 360 degrees). Users can wear Helmet Mounted Displays (HMDs) on which the target environments are projected. Other types of such environments are also called CAVEs (CAVE Automated Virtual Environments) where multiple projectors are mounted in various configurations.

The term 'Virtual Prototype' [7, 20-21] has many descriptions; in this paper, we use the description as in [7], where it is described as a three Dimensional (3D) computer model which seeks to 'mimic' a target (or 'real world') object, system or environment using Virtual Reality technology. This model can be a representation of a target environment, a simple object or a system of 'objects' at various levels of abstraction.

Several reports highlight the potential of computer simulations in engaging and motivating students especially in Science Technology Engineering and Mathematics [STEM]. However, as noted in [11], there is a need for additional research to study the impact of such simulations oriented learning to improve science achievement.

Other researchers such as Sourin [16] report a 14% improvement when students utilized a virtual world during their learning of computer science concepts. Other less extensive studies involving student surveys report that students indicated that virtual reality environments helped them learn [17, 18].

Research papers have also attempted to address what the students experience when interacting with such VLEs. In [12, 13], the authors outline a phenomenon referred to as *flow* where individuals enter a state of completely focused motivation which facilitates learning**;** when students experience such a state of 'flow'**,** they report that they became focused only on the task and become less aware of extraneous factors [14, 15].

In the context of *engineering education*, it is important to note that other than our own pilot project (discussed in section 4) involving use of Virtual Reality to support learning, there have been very few reports on the impact of using VLEs and related technologies in engineering at the university level [11]. In the context of technology, it should be noted a majority of the literature reviewed deal with *non-immersive simulation* environments [1-10]. While there is a growing literature of studies utilizing virtual reality and simulations for student learning [19], very few studies have attempted to demonstrate objectively that learning can be enhanced when students have access to virtual reality learning environments.

As indicated earlier, the main emphasis in this paper is on how VLEs are used in teaching engineering concepts at the college level and the impact on student learning. Results from a pilot study involving use of VLEs in teaching engineering students will be discussed

III. Developing the VIRTUAL Learning Environments

Since 2004, VLEs have been used by J. Cecil's group (while he was at New Mexico State) to introduce students to complex engineering concepts in various manufacturing domains including computer aided manufacturing, electronics assembly as well as emerging domains such as micro and nano assembly. In recent years, the process of creating virtual prototypes in general has also been studied for various engineering domains including micro assembly [25].

The main phases in creating such VLEs include:

1) Identify the Learning Objectives and Target Student body
2) Understanding of the engineering process of interest
3) Design the Virtual Learning Environment (VLE)
4) Build the VLE

In the first phase, the instructor identifies the learning objectives specific to the students in the course. Subsequently, a collaborative team of experts, VLE designers, and education assessment specialists design and develop the VLE under the supervision of the instructor in phases 2, 3 and 4. In the second phase, the understanding of the target engineering process takes place. As such, the experts bring in their content and skills to engage in understanding the process that goes on in the development of the VLE. The third phase is the software design of VLE.

Designing the VLE is one of the most important phases in the creation of a Virtual Learning Environment (VLE). This complex phase involves developing a detailed architecture of the VLE (including identifying and specifying the various modules in the software environment); formal techniques such as creating collaboration, sequence and class diagrams are useful as they provide a structured way to design the VLE. The fourth phase is the building of the VLE using software tools and VR technology. A key part of this activity include developing (or 'coding') the various components or modules of the VLE.

IV. IMPLEMENTATION OF VLE IN CLASSROOM

Several VLEs have been created and used as part of engineering courses targeting senior and graduate students from industrial, mechanical and aerospace engineering programs. These VLEs have been used in a course titled Introduction to Micro Devices Assembly course at Oklahoma State University (OSU). These VLEs were developed as part of a pilot initiative funded as part of an NSF DUE project. Two of the VLE based modules introduced students to the design of micro assembly work cells as well as assembly planning techniques using Genetic Algorithm (GA) based concepts.

In the Micro Assembly course (IEM 4353/5343), one of the topics where the students did not perform well related to Genetic Operators including cross over, mutation and inversion. Specifically, one of the identified issues was problems involving forming new child sequences when various GA operators (such as cross over, mutation, etc.) were used; subsequently, these operators were adopted as part of a more complex assembly planning approach. The creation of the VLEs focused on improving student understanding of these operators as well as helping students develop robust work cell designs involving assembly of micron sized parts using a given set of physical design elements (such as micro positioners, grippers, cameras, etc).

A semi-immersive VLE was created where students were able to run a number of simulations using various sets of parent links for assembly sequence generation tasks. When a user wanted to continue their learning for different problems or questions, the VLE randomly changed the sequences of the parents to provide a diverse variety of examples (there was no limit to this number of examples); students could pause during the simulation as well as navigate or zoom in to get a better view of the problem question as well as the answers in the examples. Students could learn at their own pace and could learn interactively by selecting different candidate links. For example, in figure 3, the use of the cross over operator is shown (within the VLE).

One of the benefits of using such a VLE based approach is that it allowed students to learn by exploring various options and by executing a limitless supply of examples. Students could pause the simulation when a certain step in the sequence was not clear and repeat a step if necessary.

The design of micro assembly work cells was also taught using the VLEs (see figure 4). In this activity, the students were introduced to the major design components involved in automating robotic micro assembly tasks which included using cameras, micro positioners, advanced grippers and control components. They were then evaluated on their understanding of the functionality of these devices; subsequently, they had to develop their own design of their work cell based on these design elements.

The results showed that after introducing semi immersive based VLE based teaching techniques, there was an improvement in the overall performance of the students in understanding concepts in the 2 topics in which they were introduced. Assessment data was collected based on performance in homework and exam questions.

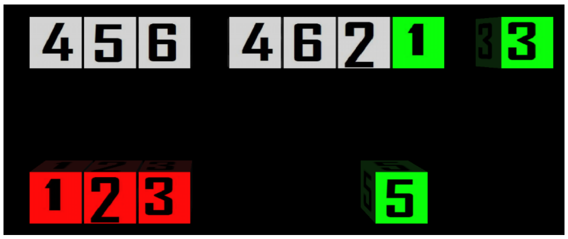

Figure 3: Closeup view of a VLE for teaching GA operators

The most significant outcome was in the improvement in the student performance in understanding concepts in the modules in which the VLEs were introduced. Assessment data was collected for 60 students based on performance in quizzes, homework and exam questions. The performance of the students with and without the VLEs was studied. Thirty students were taught these concepts using the traditional lecture and discussion approach. Another thirty students were taught the same concepts using the VLEs. The initial assessment results indicated the following:

(i) Student performance in quizzes increased by 22%;

(ii) Student performance in homework and exams increased by 30% (for the modules in the 2 topics: work cell design and genetic algorithms (GA) operators).

The experiences of the group of students were also studied through surveys. A majority of these students (86%) preferred VLE based learning over traditional classroom lectures and discussions. There were ten undergraduates and twenty graduate students who learnt the micro assembly concepts using VLEs.

A more detailed discussion of the outcomes can be found in [4]. Our assessment and analysis work is continuing in this and other engineering courses. This study is one of the first that has focused on the design and impact of such VLEs in engineering education. As discussed in [7], the use of VLEs holds significant potential in impacting learning in engineering education.

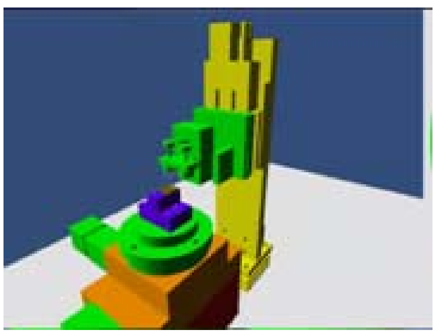

Figure 4: Closeup view of one of the virtual micro assembly work cells (developed as part of the VLE based learning approach to teach work cell design)

Other assessment and evaluation activities are continuing on studying the impact of using VLEs to teach engineering concepts. It is important to note that this is a pilot study and is the first of its kind targeting engineering students. In this pilot study, there was no assessment of the learning patterns of the students or their backgrounds. Data was not collected about the performance of students based on gender, race and economic background. Additional comprehensive studies are needed to throw more light on the learning patterns of a diverse body of students. Future studies also need to address the impact of team based learning when using VLEs.

V. OTHER EMERGING CYBER TECHNOLOGIES

One of the more recent developments is the adoption of cyber technologies and tools to support educational activities. The adoption of cloud technologies as well as other next generation Internet tools is expected to revolutionize the way students access, share and learn using distributed resources from different locations.

As part of a pilot initiative, one of the VLEs modules related to teaching micro assembly work cell design was made accessible through a cloud. Students were able to access this learning module through their ‘smart’ phones.

Two other important initiatives in Next Generation Internet and Computing are underway which hold significant potential in impacting engineering and STEM education in a significant manner. The GENI (www.geni.net) initiative involves the design and deployment of the next generation of Internets (which is being funded by the US National Science Foundation NSF). These advanced networks and approaches (being explored in these initiatives) have several innovative aspects including software defined networking and adoption of cloud technologies; these networks will enable students and teachers in distributed locations to access and share resources especially involving high bandwidth data; using such networking approaches and technologies will enable sharing of VLE based environments (involving rich 3D virtual reality data), as well as enable students to interact with distributed manufacturing equipment in educational labs (where camera monitoring of remote manufacturing and engineering activities enables better learning).

The US Ignite initiative (http://us-ignite.org/) is another initiative whose outcomes will profoundly impact engineering and education (among other areas). It seeks to foster next-generation Internet applications that provide transformative public benefit using ultrafast high gigabit networks. The six national priority areas are Education & Workforce, Advanced Manufacturing, Health, Public Safety, Energy, and Transportation. Both the GENI and US Ignite initiatives underscore the impact of next generation computing frameworks on engineering and educational practices.

In a pilot demonstration of the potential of next generation Internet frameworks, educational activities involving sharing of resources and learning modules among K-12 and engineering students was conducted in spring 2013 involving Oklahoma State University and University of Wisconsin Madison.

Apart from demonstrating the use of such technology for school students, an important objective was to demonstrate the feasibility of this next generation technology on helping children with autism learn using VLEs that were equipped with haptic interfaces (figure 5). One of these demonstrations involved children with autism interacting with their teacher at another location using haptic device (which enabled them to "feel" the objects they touched virtually inside a computer); the next generation collaborative framework was used to teach science and math concepts to autistic students in grades 1 and 1 from a local school (Sangre Ridge Elementary) in Stillwater; this pilot demonstration was part of a project aimed at supporting learning activities for children with autism; some of these activities have been recorded and posted on youtube.com at https://www.youtube.com/watch?v=BAfd2ax6tk4. Another recording of interactions among middle school students (from Stillwater Middle School) can be found at http://youtu.be/EIlNqpCAIu4 [25]. In these demonstrations, students at different locations could interact with each other and explore a micro robotics simulation environment using next generation Internet networks.

These collective pilot demonstrations highlight the potential of the next generation Internet frameworks for supporting educational activities; while the current Internet has had a phenomenal impact on education, the next generation of Internets holds the potential to further revolutionize educational activities especially for engineering and STEM learning contexts. It will enable (a) teachers and students to interact with each other from different locations, (b) facilitate special education students to learn using immersive and haptic interfaces as well as (c) enable accessing resources from geographically distributed location using cloud and other related technologies.

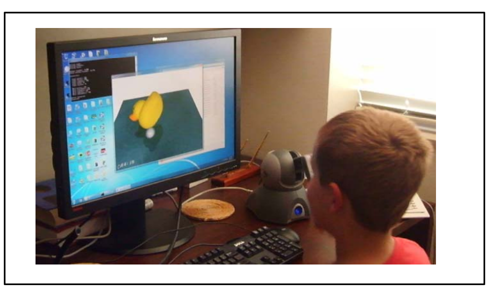

Figure 5: Using next generation Internet technologies for supporting learning among children with autism

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Figure 6: View of a virtual solar system

VLEs (with or without networking capabilities) can also be used to supporting teaching Science Technology Engineering and Mathematics (STEM) concepts for K-12 students including children with autism. One of the VLEs created was a virtual solar system for elementary school students (figure 6). Other VLEs developed for middle school students introduce them to physics concepts including properties of matter including mass-volume-density relationships.

VI. CONCLUSION

In this paper, we have provided an overview of Virtual Learning Environments (VLEs) and their use in engineering education. A brief discussion of the process of creating such VLEs was also provided. The impact on student learning as part of an engineering course at Oklahoma State University (OSU) was also discussed.

One of the main challenges in the development of VLEs is that it is a time consuming process; the creation of a VLE can range from six months to more than a year (depending on the scope and level of complexity of the targeted engineering concepts). The faculty and engineers involved need to also be familiar with Virtual Reality technology and design of VLEs [22-24]. As the outcomes of this study for engineering students (reported in this paper) indicate, (once the VLE is developed), the impact on student learning and performance can become the basis to justify the investment in cost and time.

The paper also briefly discussed the emergence of next generation computer networking technologies and related initiatives including GENI and US Ignite. Pilot demonstrations conducted highlight the potential of these emerging technologies to support engineering and STEM education.

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Teaching computer programming: a practical review

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***Abstract* — Recent developments in computer programming environments have been introduced to the academic community. Scratch is one of such environments which seek to offer innovation features as a support to teaching computer programming. This study reports on the results from a case study conducted with young students for teaching algorithms and programming.**

Keywords — programming teaching; algorithms teaching; Scratch.

I. Introduction

Much has been argued, both for and against the use of computers in Education. Those who argue for their use have claimed that computers may cut down school drop-out rates and improve low performance indexes in several subjects. On the other hand, critics have emphasized that both educators and students still lack capacity for the massive insertion of technology in the classroom.

In the 80's, during a discussion about the role that computing would have on education in the future, some researchers stood for the idea that by the end of the 20th century, students would get their education from computers and no longer from teachers. This forecast did not come true [1]. However, in the 21st century, the contributions to society and, especially, to education, made by information and communication technologies cannot be ignored.

Reference [2] emphasizes the major advantages of the use of computers in education: it arouses curiosity; increases creativity; helps in the learning process; raises productivity in relation to the required time for studying; and emphasizes the need for continuous training to keep up with technological development.

Training students to face several everyday situations and also those in the job market means a challenge to modern schools that intend to offer conditions so that a student is inserted in a society which entails ever more information and communication technologies.

This article addresses a common issue in the computer courses area: the difficulty in learning the contents of algorithm and programming subjects. These subjects deal with key contents for the background of computer professionals. Students face serious learning difficulties with them; likewise, teachers experience severe problems on how to teach them.

In Brazil, in particular, Basic Education curriculum does not include algorithms and computer programming subjects. Perhaps this fact adds to the great degree of difficulty faced by students at the beginning of the graduation course. The purpose of this study is to report the qualitative and quantitative results from teaching algorithm and programming subjects in a research conducted with students in the city of Assis.

The guideline of the study was based on the principle that the adoption of a computational tool for teaching algorithms and computer programming may improve logical-mathematical thinking and problem-solving skills of young students.

Computational resources used by teachers as pedagogic tools can be classified as: educational or applicational. In this study, the former will be approached. The purpose of educational software is to make teaching-learning processes easy, and this study is based on this point of view.

This study has been divided into 5 sections: this Introduction, which shows the goals and reasons for the performance of the study; the next section explains the related works to this paper; the third section addresses the educational support, Scratch; the fourth section reports the case study conducted with young students and, finally, the last section shows the author conclusions and guidelines for future studies.

II. Related Works

The use of Scratch, the educational tool adopted in this study, as shown by other researchers, increases student engagement in the initial aspects of programming [3, 4, 5]. Positive reports were also found on the use of activities such as the creation and development of games in introductory subjects to the Computer Science course [6, 7, 8].

An important research related to this study explored the use of the contents of conditional structure with young students from 12 to 13 years of age [4]. Students received training on the Scratch programming environment and then were carried out to build an application that controls the functionalities of an elevator, as requested by the user. The results, from the pedagogical point of view, were very interesting, because the Scratch environment was able to encourage students to understand the use of conditional sentences. Moreover, Scratch has the potential to provide students to view themselves as technology makes and not simply as consumers of technological products.

In their studies [7] have reported their experiences using Scratch with young students at Harvard University and The College of New Jersey. The authors note that after a short time using Scratch, students said they would prefer to develop programming activities to play video games.

Concerned about the number of dropouts and failures in introductory courses in Computer Science, [5] worked with blockC, an extension of Scratch, for teaching the C language. The experiment was conducted with 40 students at the University of Cagliari. Preliminary results were very interesting because the blockC helped students avoid syntax errors and remember the command syntax C.

III. SCRATCH

Scratch is a new programming language which was designed in order to facilitate the learning process of beginners who are starting to learn algorithms; it was developed by the Lifelong Kindergarten Group located within the MIT Media Lab, with the Squeak programming language, (http://scratch.mit.edu) [9].

It has graphic interface resources and commands in the form of building blocks that users easily understand. It also offers sound, music, charts and animation resources, which lead to more significant results and better development of systematic thinking for beginners.

Even though it is a form of introduction to programming, Scratch allows students to have a solid base on programming logics and mathematics, which are its main features.

The expected result of a Scratch-developed project is the user's improvement in creativity and intuitive learning capacity. The learn-as-you-play method spares the users of the boring static environment and the effects of the more common programming environments, in which the lack of a specific character causes several problems [10].

One of Scratch's major features is making the creation of applications by children and beginners with no programming language background whatsoever easier; it is recommended for people who are curious about programming, and its motivational features' sole limit is creativity.

IV. CASE STUDY

A. Participants

With the purpose of getting to know the research's target public, the social and economic level of students selected randomly was determined. The result was a group of ten students from public schools in the city of Assis, in the age range from 11 to 13 years old. All students had internet-access computers at home and said they used the computer to play, and, in some cases, to use social networks. It is important to point out that the students had no experience with computer programming. This group of students was made up of nine boys and one girl; the students' social status, according to current standards, is middle class.

B. Procedures and Results

The study was divided into three stages: pre-test, Scratch course and after-test.

The first stage involved giving a pre-test with the purpose of checking the students' reliability and knowledge level about the content to be studied. The pre-test was made up of essay questions in which students had to assess the expression versus variable relation, as well as the use of parentheses in the general precedence of arithmetic operators and the construction of variables which accumulate values.

The students' performance in the pre-test is shown in Table I:

TABLE I. STUDENT'S PERFORMANCE

Scale of right answers	**% of students**
0.0 – 3.0	50
3.1 – 6.0	10
6.1 – 10.0	40

The overall average of correct answers was 4.4 and the standard deviation was 4.402.

As seen in Table I, 50% of the students showed little or no knowledge of the content required in the pre-test. Afterwards, the activities in connection with the 2nd stage of the case study began.

In the second stage, students took a 30-hour weekly course on Scratch for three months. The course had activities for students to learn the main initial features of the programming logics and develop skills to deal with any programming language. Note that the study is essentially focused on solving problems and on the development of logical-mathematical thinking.

During the course period, students worked with basic principles of information processing, logics, data storing and retrieving, comparisons, conditional and repetition commands, sprites motion and sensors, change in behavior and appearance of sprites and sound commands. These activities were a background for the development of ludic projects.

Finally, in the 3rd stage, students answered a test about the covered contents.

The assessment was made up of essay and multiple choice questions. There were questions to identify types of data, description on what a certain script would execute, coming up with a solution for problems which would be solved by block-grouping and identification of basic concepts of computer programming.

The achieved performance, after the conduction of the after-test is shown in Table II.

TABLE II. RIGHT ANSWERS OF THE AFTER TEST

Scale of right answers	% of students
0.0 – 3.0	50
3.1 – 6.0	30
6.1 – 10.0	20

Students had a global average of 4.0 points and the standard deviation was 2.614.

Even though the global average did not achieve a significantly positive value, note that 63.5% of students successfully answered the question in which they had to describe the operation of scripts which addressed conditional and repetition structures, and the use of memory variables.

This was an important after-test result, since it helped us understand which concepts and skills were well taught in the 2nd stage and which require additional time to be taught.

V. CONCLUSIONS

The guideline of this study was based on the principle that the adoption of a computational tool for teaching logic and computer programming may help improve the capacity to solve problems and also the mathematical logical thinking of students. During three months, teenage students attended classes about Scratch programming language with the purpose of achieving the goal established for this study.

After the conduction of the case study, the initially formulated hypothesis was partially confirmed, for the reasons explained herein. The results of students' assessment clearly show that important skills were acquired after this study was conducted: identification of the problem and use of conditional and repetition structures.

During the conduction of this research, it was noted that students were motivated at all times to learn the content, which contributed to the good progress of the offered activities. The projects designed by the students as well as the positive answers given in the after-test are reasons for the future use of this approach with students enrolled in the 1st grade of Computer Science courses.

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Models of Adoption and Best Practices for Mobile Hands-On Learning in Electrical Engineering

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Abstract - **Pedagogical practices in electrical engineering education have been shifting away from teacher-centered learning during the past decade. An innovation that has enabled the adoption of inquiry-based and problem-based learning into the curriculum using experimentation coupled with simulation and analysis has been the development of portable oscilloscopes and other instruments that rely on tablet or laptop computers to perform some of the data processing and to act as the display. Faculty members at six institutions of higher learning have incorporated hands-on experimental activities into existing courses and/or developed new courses that take advantage of these new tools. Assessment data collected by these faculty members have demonstrated that the change towards student-centered learning facilitated by portable electronics increased student interest in electrical engineering, built student confidence in their ability to design circuits and systems, and supported the development of a deeper understanding of the theories that the students investigate or apply in the hands-on activities. A summary of the challenges that are faced in the different implementation models and a discussion of best practices are presented.**

Index Terms – **Electrical and Computer Engineering Pedagogy, Hands-On Learning, Portable Laboratory Kit.**

I. Introduction

Education in electrical engineering (EE) has long had an experimental component. However, recent innovations in inexpensive, portable instruments that measure time-varying signals as well as generate arbitrary waveforms have enabled new pedagogical approaches in the teaching of theoretical concepts and design practices, and have allowed students to be actively involved in the demonstration of the application of these concepts and practices in either (or both) formal and informal learning environments. Hence, inquiry-based and problem-based learning can be integrated into the curriculum with a focus on student-centered learning rather than instructor-centered lectures.

Background on Pedagogical Approach

Engineering education research that has provided clear evidence of enhanced learning has driven much of the shift to student-centered learning. As noted in the recent National Academy Press report [1], one area where discipline-based education research has had less impact is in learning experiences traditionally limited to laboratory courses. Most institutions continue to hold lab courses in specialized classrooms where students construct prescribed circuits that demonstrate some subset of the theories presented in a companion lecture course, make measurements as required in the experimental procedures, and document the results in formal lab reports. Few experiments are designed to encourage students to freely investigate concepts. In addition, students typically cannot access equipment outside of their scheduled lab, presenting a barrier to those students who may wish to explore ideas on their own time. Direct classroom exploration also is hindered; transporting rack-mounted or bench-top instruments to the classroom to demonstrate concepts to students during lecture can be very challenging. Thus, instruction on abstract concepts and practical application of those concepts are segregated by time, learning environment, and, sometimes, by instructor.

In the early-2000s, several groups independently began to develop a pedagogical approach, hands-on learning, to test the hypothesis that the lack of connection between theory and practice has led to the decrease in student interest in the field and to determine if a more student-centered learning environment can stimulate a deeper understanding of the principles in EE and increase student engagement [2-4]. Faculty members at other institutions have partnered with these pioneers [5,6], contributing to the number of hands-on activities. The concepts demonstrated in the hands-on experiments have expanded beyond circuits and, the number of courses in which hands-on learning is incorporated has increased. Several methodologies have been adopted to integrate hands-on learning to address the needs and constraints at each institution, within different undergraduate degree programs at the same institution, and in various teaching modalities of the same course at one institution. A collaborative effort began in 2012 to review the activities at six institutions that have been engaged in the development of hands-on learning in EE and to identify the best practices for each model of implementation [7].

II. Portable Electronic Instruments

Although the set of equipment that each institution has chosen for the hands-on activities differs, the common denominator in each experimental platform is a portable

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electronic instrument that can measure time-varying voltage signals (i.e., an oscilloscope). Several of the portable instruments have options that include one or more arbitrary function generators, dc voltage supplies, spectrum analyzer, and the ability to display a Bode plot. And, surprisingly, some of these scopes have a measurement frequency range that extends into the MHz range, well beyond the maximum frequency that the typical breadboard can support. These oscilloscopes leverage the USB ports on students' laptop or tablet computers for power and the computers' capabilities to analyze and display the measured signals. As the instruments range in size from a pack of cards to a paperback book and are light-weight, they can be carried to a classroom for use by students (assuming that the seats in the room do not have small writing areas) or may be used at home in practical homework assignments and projects.

The portable oscilloscopes are inexpensive, ranging from $99-$199 per unit. Other expenses include the breadboards, components, and, occasionally, a digital multimeter. Generally, the cost is born by the institution, where the equipment may be distributed to students for each hands-on activity or loaned to the students for part or all of their academic careers. In some settings, partial or total cost may be borne by students who are expected to have the equipment available for hands-on activities at any time during their academic careers. The components used in the hands-on activities are typically provided by the institution.

III. Models Of Implementations

The predominate instructional goal at each of the six universities was to support problem-based learning, where one of three general models of instruction has been employed to meet this goal. The first model of instruction represents a blended approach, where the classroom experience is a combination of lectures and hands-on activities used to reinforce the concepts. The second mode of instruction is the inverted, or flipped, classroom, where students are expected to read material outside the classroom prior to their investigation of the concepts via hands-on activities in the classroom. Within this approach, students read about the theories that they have seen applied in the hands-on activity in class and about which they have been asked to develop their own conjectures. The third model uses outside-of-the-classroom hands-on activities that are part of homework problems, design projects, and/or a nontraditional laboratory component. The last model of implementation has been also used in the development of online laboratory courses [8,9].

In each model, hands-on activities are developed to provide students with a different perspective on concepts, particularly the ones that students have found difficult to understand when they are presented only as an abstract theory. Typically, students work in small groups when the hands-on activities are conducted in a classroom environment. Students may work individually or in teams when activities are performed outside of the classroom.

In blended instruction, the number of hands-on activities introduced into each course is limited to target the most challenging concepts. This approach reduces the barriers to adoption for course instructors as there is limited training required of the new instructor in each course on the hands-on activities; there is minimal disruption of the traditional instructional mode, which minimizes the perception about loss of class time that is being devoted to hands-on learning. Additionally, the effort required to develop hands-on learning activities is smaller when compared to the other two models. A challenge to this approach is logistical. The length of the class places constraints on the type of hands-on activities that can be introduced. To address this, portions or all of the circuits used in the hands-on activity can be pre-built, allowing students to focus on making measurements and analyzing experimental results. Desk space must be available to conduct the hands-on activities, which places constraints on the classrooms available to hold these courses.

The inverted classroom can alleviate some of the logistical issues associated with the blended instructional model as the entire class period can be dedicated to the hands-on activity. This approach requires a new approach to teaching and learning; both the instructor and students must be willing to adapt to this model. There is a greater effort required for this approach as learning materials must be developed for the hands-on activities as well as the instructional materials that students study outside of the classroom. It is relatively easy, however, to adopt the inverted classroom model after implementing the blended instructional model.

The nontraditional laboratory model places a greater responsibility for independent learning on students when compared to the traditional lab model where an instructor or teaching assistant is usually present or to the other two models. Supplemental materials that address common issues confronted by students, hardware-related or conceptual, have to be available to students as they conduct the hands-on activity. The instructor of the companion lecture course may not be responsible for the nontraditional lab, minimizing the number of faculty members who must learn how to teach the lab course; however, this separation may increase the chance of disconnect between the lecture and experiment.

IV. Assessment Results

Assessment of students learning at each of the institutions has shown that students' response to the hands-on learning activities, regardless of the model of implementation, has been extremely positive. Hands-on application, exploration, and practices improve student understanding in the class as a whole. Results indicate that the greatest impact of hands-on learning is the conceptual understanding by students who had the weakest grasp of the material after lecture-based instruction. Students also express a higher degree of confidence in their ability to be engineers because the hands-on activities have helped develop their abilities to design solutions to meet specifications in the projects. The hands-on activities also increase student engagement in the discipline.

Development of a common assessment tool to evaluate student learning across the six institutions has begun to compare the various models of implementation. The assessment results will help identify differences in learning that tied to the implementation method and to highlight areas for improvements in a particular method of implementation can be made to equalize student understanding of concepts. Also under construction is the development of an assessment tool to evaluate the stages of concern by the faculty when adopting hands-on learning and adapting the pedagogical approach to meet the needs of their students and the constraints within their institution to determine the supports required to insure a successful implementation. A discussion on these two assessments will be presented.

CONCLUSION

Researchers at six institutions have joined together to assess the value of the pedagogical methods and to determine the supports needed for students, as they progress towards their bachelors' degree, and for faculty members, as they change their teaching styles. Several issues must now be addressed at these institutions as they move to create the infrastructure to sustain and maintain the hands-on pedagogical practices and to foster adoption of the approach by others. Challenges include the identification of the best practices in design and implementation of student-centered learning that takes into account variations in institutions' culture, organizational structure, and available resources, optional paths to sustain change at institutions that have developed or adopted hands-on learning, and efficient and effective models that promote adoption of the pedagogical approach by addressing the concerns of students, faculty, staff, and administration.

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Playing Online Games on Facebook: The Conscious and Unconscious Learning in Database Design

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Abstract — This study intends to examine how conscious and unconscious learning in game-based learning (GBL) enhance student's understanding in database design. Conscious learning refers to intentional learning whereas unconscious learning indicates unintentional learning. Using Facebook's online games, this study evaluates the effectiveness of GBL in enabling students to grasp the normalization concept and Entity-Relationship Diagram (ERD). Additionally, this study adopts content analysis of the semiotics approach for data analysis. The preliminary findings reveal that unconscious learning encompasses student's realization in that a purportedly simple online game is built on a complex, highly functional database. The preliminary results also uncover that conscious learning constitutes (1) student's cognitive reflection on normalization concepts during database design and (2) a better understanding of ERD resulted from the collaborative effort of database design. Drawing on these findings, this study infers that the aforementioned outcomes of unconscious learning lead to student's appreciation of conscious learning.

Keywords—database design; game-based learning; entity-relationship diagram

I. Introduction

The abstract and complex domain of database design [4] poses challenges for educators to impart knowledge while making it difficult for learners to comprehend the intricate modeling concepts. Essentially, the core studies of database design are conceptual data modeling and relational database design [5]. This learning scope demands high level abstraction that brings about ambiguity and vagueness to learners [5] and imposes a heavy cognitive load that degrades learner's understanding of the subject matter [11].

To improve student learning in database design, previous studies [5] suggested using Game-Based Learning (GBL). In essence, GBL theory posits that learning is often experience based or exploratory, relying on experiential, problem-based, or exploratory learning approaches [8]. Accordingly, this study adopts online games on Facebook to examine how GBL fosters the understanding of core concepts of database design through conscious and unconscious learning.

This study collected data from 25 students who worked in different groups. Using the semiotics approach for data analysis, the preliminary findings uncover that unconscious learning mainly constitutes student's recognition of a complex, highly functional database structure in the online game platform. On the other hand, the conscious learning incorporates student's cognitive reflection on Entity-Relationship Diagram (ERD) and normalization concept related to database design.

II. Motivation and Research Objectives

There are a few studies focusing on using GBL to fulfill the pedagogical objectives. These studies usually highlighted the interactive visualization in support of learning, the motivation factor that engaged students in the learning process, the challenges of incorporating GBL into curriculum, and how GBL supported problem solving and collaborative learning [6-9]. However, there are not many studies discussing the conscious and unconscious learning of an abstract subject matter, such as database design.

Therefore, this study intends to examine the conscious and unconscious learning of database design in the context of GBL. In this respect, this study intends to uncover how learners explicitly produce relational data model by applying the complex, abstract knowledge that is held tacit. The research findings will then shed lights on how to promote the overall understanding of database design.

III. Literature Review and Theoretical Framework

A. *Game-Based Learning (GBL) and a Dichotomy between Conscious and Unconscious Learning*

The theoretical framework embodies GBL model and theory postulated by the previous studies. Drawing on the GBL theory, GBL entails problem-based learning (PBL) [8] encompassing active and collaborative learning [14]. Additionally, experiential gaming model posits that GBL supports reflective learning [9] wherein learners consciously think, analyze, and learn through the reflection of their experience [1]. We argue that both problem-based and reflective learning represent conscious learning. In essence, conscious learning involves learners who intend to learn, pay attention to learning, hold high awareness for learning, and control their learning processes [15]. Accordingly, problem-based and reflective learning requires learner's active participation, awareness, and initiative, thus exemplifying conscious learning.

On the other hand, unconscious learning refers to incidental learning characterized by "*discovering something while in the process of doing something else*" [15]. That is, learning is unintentional and a by-product of learner's activities. Previous studies suggested that GBL engendered unconscious learning [6]. While playing games, learners experimented, explored and brainstormed for problem solving so as to achieve their learning goals but somehow they inadvertently encounter a new discovery unrelated to their original learning objectives.

B. Core Concepts of Database Design

Essentially, the concepts of database design encompass Entity-Relationship Diagram (ERD) and normalization. ERD is a logical representation of the physical database system to be constructed [3]. In particular, ERD consists of entities (person, thing, place etc.) and the relationships among the entities. On the other hand, normalization is a technique to create successful database design by eliminating data redundancy to avoid data anomalies [3].

IV. RESEARCH METHODOLOGY

A. Research Design

In the context of conscious and unconscious learning, this study measures how GBL promotes the learning of database design in relation to conceptual and relational data modeling. The core concepts incorporate Entity Relationship Diagraming (ERD) and Normalization. At the beginning of the database class, students were taught the core concepts of database design. Then, by the end of the semester, students were required to play an online game (e.g. Treasure Madness, Farmville) on Facebook to know all the items (e.g. coins earned, treasure collected etc.) involved in the games. After comprehending the online game's structure, student had to apply what they learned earlier to design ERD for the online game. Each entity in the ERD must reach third normal form.

B. Content Analysis of the Semiotics Approach

This study employs content analysis under the semiotics approach for data analysis. Semiotics is mainly pertained to the meaning of signs and symbols in language wherein words/signs can be classified into main conceptual categories attributing to theory testing [13]. Content analysis, a form of semiotics, discovers structures and patterned regularities in the text and draws inferences hinged on these regularities [13].

Content analysis of the semiotics approach is appropriate to analyze written text made of student's feedback. Using this approach, this study found regular patterns in text to uncover the preliminary research findings.

C. Data Collection

This study was conducted in a regional Midwestern University. We spent two semesters to collect qualitative data with student's written feedback. There were a total of 8 groups consisting of 25 students. We had 6 traditional students and 19 non-traditional students. These students were sophomore and they had no prior knowledge of database design. The student's age ranged from 19 to 55. The average age was 31.There was only one female student involved in this study. Upon completing the group projects, each student was required to provide written feedback regarding their learning experience. Overall, this study had collected 60 pages of written feedback.

D. Data Analysis

The important notion that frequently appeared in text was student's realization of the complexity involved in developing a purportedly simple online game. About 60% of students came to this realization.

"When I first looked at the game Treasure Madness I thought that it was very simple, and easily made. Since I've been designing a database for this game I quickly realize that it's nowhere near easy to make such a simple game as this…."

"Even the simplest games and computer applications can have a very complex database structure holding them up. The Facebook application Treasure Madness drove that point home with me as my group and I analyzed and designed a database from its structure."

Next, we discovered that about 40% of the students gained understanding of database functionalities in the real world.

"*I've seen how involved a real-world database project can be and how important a well-designed can be for storing and fetching information.*"

"*…A database can work with a flash game…and what type of data is in those tables and how it all comes together make a popular game. The game has multiple objects and even objects can store other objects"*

"I realized that ERD was an essential part of being able to understand how a database works. ERD is also an essential part of being able to run accurate queries….."

Additionally, 32% of the students used ERD as a visualization tool for team communication.

"I created a basic model of the ERD which allowed us to visualize what we had talked about and to demonstrate ideas and concepts."

"The most useful tool, in my view is the ERD. It really helps to have a visual representation of what the database looks like to work from."

Another emerging key point was reflection on the previous lessons taught in class as well as learning reinforcement through collaborative effort. Approximately 68% students claimed that they experienced learning reflection and reinforcement.

"Doing the group project, I gained a better understanding of how to develop an ERD….One of the relationships within our diagram that I had the most trouble understanding was the unary relationship….however through examination with my group, I was better able to understand this concept and apply it… "

"After a period of observation and interaction with the popular online game, our team developed an understanding of how the data was stored [and] this helped with normalization."

V. DISCUSSION

Analysis results reveal that there are four emerging core categories consisting of (1) student's recognition of the complex database structure in the Facebook's online game; (2) student's realization of database functionalities in the real world; (3) student's discovery of Entity Relationship Diagram (ERD) as a visualization tool for team communication; and (4) cognitive reflection on learning.

As mentioned, this study intends to examine the effectiveness of GBL in enhancing student learning related to the core database design concept (ERD and normalization). Building on the analysis results, we argue that conscious learning subsumes cognitive reflection on learning. That is, students were well aware of their learning objectives concerning ERD and normalization. Hence, students actively constructed an ERD and ensured that each entity attained third normal form. In doing so, students participated in problem-solving under a group collaborative environment. During the process of problem-solving, students reflected the knowledge [4] gained from the lectures and applied their knowledge within their groups. Alternatively, students engaged in metacognitive activity in that students involved in the cognitive mode of conscious thinking, analyzing, and learning through the reflection of the knowledge and experience earned in the past [7].

The rest of the core categories represent unconscious learning. In other words, we contend that unconscious learning incorporates student's recognition of database complexities in the Facebook's online games, student's realization of database functionalities in the real world, and student's discovery of ERD as a visualization tool for team communication.

We assert that the learning outcomes of unconscious learning enable students to perceive the usability of Entity-Relationship Diagram (ERD) coupled with the complexity and functionalities of database in real life. Accordingly, students may appreciate their initial learning objectives (conscious learning) once they discover the importance and sophistication of database (unconscious learning). That is, the outcomes of unconscious learning demonstrate that the initial learning objectives (conscious learning) are worthwhile, thereby leading to student's appreciation and justification of their conscious learning efforts. This draws parallel with the previous studies suggesting that students will appreciate learning when they perceive the pedagogical objectives as worthwhile [2].

VI. CONCLUSION AND FUTURE RESEARCH

Since this is a research-in-progress, this study only uncovers the preliminary finding. That is, in the Facebook's online gaming platform, a combination of intentional/conscious and unintentional/unconscious learning of database design promotes student learning. Conscious learning fosters the cognitive reflection of database design knowledge. Not only the unconscious learning sheds light on the critical role of database in online games but also helps learners to appreciate the learning objectives and justify their efforts invested in conscious learning.

At the preliminary stage, the research implication suggests that Game-Based Learning (GBL) can motivate learners by facilitating authentic experience that leads learners to discover the elements in support of their original learning goals. In the future study, we plan to run pre-test and post-test studies and compare the student learning outcomes between the students who have experienced GBL and those who have not. Overall, this is a research-in-progress so more in-depth study is required to yield meaningful findings for improving student learning.

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TEST: Serious Games for Radio Communications Learning

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***Abstract*— The game industry has suffered an impressive explosion of popularity, becoming the largest entertainment industry in the world. Games have become a sophisticated extension of the reality and an interesting way for complementing human mind utopias. Training software allows the trainee to immerse in quasi-real controlled situations that could be measured by trainers. In this work we discuss the duality existing between the training based on a serious game and a simple game, based on state of the art technologies. Then we show a training system for telecommunications technicians based on a combination between serious games and "traditional" e-learning platform. We show results for a trial made with a group of students from different disciplines (not only engineering) in order to evaluate learning outcomes using serious games versus other learning approaches. In this paper we discuss such results and make a descriptive statistical analysis of the results.** *(Abstract)*

Keywords-component; games, serious games, e-learnning, training software.

I. Introduction

The term Serious Game sound like a contradiction; play is about simulation, a game is fun, pleasant and free. Then the question is: How can a game be serious? To take something seriously means that you are talking honestly and it is well known that in a game you have to lie, knowing that you are lying. It differs from a "true lie" because all the people involved in the game know that you are lying, because it has been arranged from the beginning [4]. However, if the game is used with a specific finality, beyond the game itself, then we can say that is a Serious Game [8].

Generally speaking, the game searches for the satisfaction of the player [5]. Any additional consequence is far beyond the game finality. It means that the use of this recreational experience with a learning goal, then we are talking about serious games [8]. This special kind of game has shown an especial interest in the consequences of the game, conceiving those experiences as training processes or development guides [3]. Playing is a quite fun way of training, is the way as a lion learns hunting. Without training games, perhaps a young lion will not survive, or die while learning. Another example of this kind of "Serious Games" is combat pilots, because you cannot train a pilot in a real combat without a high risk of losing human lives or pay a high cost. A previous simulated training process is quite important, before passing to the real life. Simulation conditions are quite real, but simulated. If the plain crashes, nobody gets hurt. One of the characteristics of a serious game is that the goal is a serious one; they are not designed for leisure or entertainment but for learning.

Otherwise, conventional training software does not consider the user preferences or interest. They presume that if a user is using the software, then he needs to learn about such issue. For this reason, there is no interest for developing an "emotional" interface. Perhaps boring is one of the premises of this kind of software, converting these developments in a digital version of a traditional lecture imparted in a classroom. Finally the result is a new format for teaching, not a change in the learning process where the human contact is lost and the potential of new virtual media is not exploited. That's why in recent years, the concept of serious games and the use on 3D technologies has been taking relevance, and especially with the use of open technologies [7], [9].

In this paper we mention a serious game for learning telecommunications and an evolution of such game that was developed as a training tool used for training technicians in Radio Frequency related activities and for learning in undergraduate courses. With this software, we conduct a trial with undergraduate students in order to compare learning outcomes between "traditional" learning activities like reading notes, learning activities using multimedia content and the game.

The main contribution of this paper are the results of our trial, using descriptive statistics, to show the relationship between learning activities like reading, multimedia (video) watching and playing and the learning outcomes derived from each activity. For this purpose we apply a test to 66 undergraduate students from different disciplines after they have done some of the mentioned learning activities with different combinations: one activity and two (i.e. read and play). In this initial study, we have found some evidence of a bigger dispersion of results. Also, we found that the scores associated with the game activity are more disperse than those associated with traditional activities. A similar result is obtained for those students that play the game and read.

The paper is organized as follows: Section II, discuss aspects of training software and serious games; in section III, we describe a training tool based on serious games; in section IV we describe the evaluation process; in section V we show statistical results and finally the conclusions and further work.

II. FROM TRAINING SOFTWARE TO SERIOUS GAME

A training program or conventional education, like used in lectures, typically use a behaviorist approach; i.e. the system guides the student through a series of pre-defined steps which goal is to take the student in a "A" grade of knowledge or competence and lead him to a competence "B", guiding the student through a series of steps or data that lead to the same final point, using almost always the same predetermined way. Behaviorist approach knows the learning goal and the shortest way to guide the apprentice to reach the goal.

On the opposite side, the constructivist approach gives more relevance to the learning experience than the way from A to B. The learning experience is more important than the knowledge itself. The learning goal is important but not the most relevant. The ways to reach the goal have the same importance than the goal. The apprentice experience during the learning process is quite important as the learning itself.

Then, the serious game is proposed as a tool with a constructivist approach, where the immersion grade is high enough as in real training process. Besides, the player (apprentice) is influenced with an emotive load and surprising situations, exploiting the advantages of virtual media and gaming technology, with it sensorial richness.

The basic idea is that serious games act in similar way as entertaining games. A good example of this kind of games are Flight Simulators, originally designed for pilot training but later used also for entertainment to add other aspects such challenging missions. The difference is only the goal of the game: Training or leisure. We developed a serious game with the idea of training engineers in specialized activities related to radio communication systems and, at the same time, use it in undergraduate courses.

The game called "TESt" absorbs the complexity of some concepts like antenna type, radiation pattern, etc, (Figure 1), related with the mathematical behavior of such models. Besides, it is supported in real maps, obtained from Digital Terrain Models from real cities that usually represents a challenge for radio planning. All these features are linked with several missions, oriented to improve the abilities of the player.

Moreover, the game is supported by a real planning tool [1], the results are similar to those obtained from a commercial planning tool (Figure 2), like those used by mobile operators. Towers, antennas (Figure 1) and other elements are modeled with high realism. In this way the concept of a serious game is fully applied to this tool.

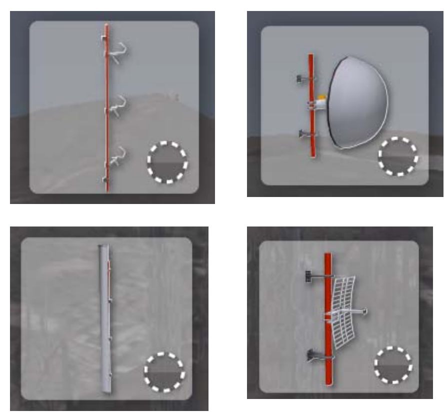

Figure 1 An example of 3D models of antennas

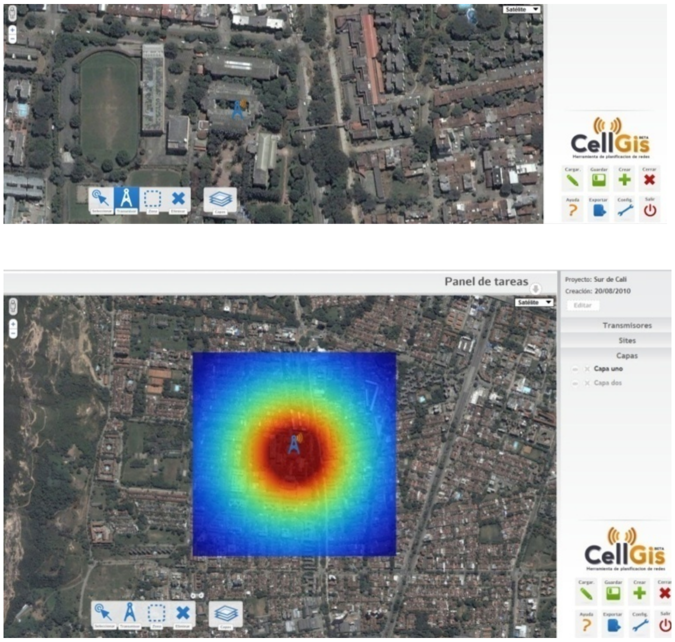

Figure 2 Results from CellGIS Planning Tool

III. SERIOUS GAMES AS TRAINING SUPPORT: TEST

From the experience obtained with the development of COMCITY [6], we begin the development of a training system for radio technicians that develop activities in the outside, as installations or technical surveys on radio stations. This work requires some specific skills, and then the system has some specific requirements. This system was called TEST (TESAmerica Software Training), from the name of the company that will use it initially.

TEST is a series of “virtual learning objects” (a total of 6 “missions”) running on a learning platform (Moodle), which combines serious games with training software. The goal of the system is to train people for a specific job and evaluating the most qualified people for the outside job. TEST is in part an application of COMCITY for specialized training.

In order to complain with TEST requirements, we modify some aspects in COMCITY, specifically some missions and scenarios with problems oriented to some typical task that the trainees will perform in their jobs. In these missions, the trainee must solve problems related with radio technologies (Wimax, UMTS, etc), antenna type (panel, monopole, dipole, etc) and frequency bands.

For example, in the antenna identification mission, shown in Figure 3 and Figure 4, the player must solve eight cases, including: telecommunications support to the army, coverage of a transmission of bicycling tour and restore communication for the public transport service. The player navigates between cases and by selecting the most suitable antenna for each case, taking into account: environmental conditions, radio technology needed and available frequency band.

Figure 3 Cases for antenna identification mission

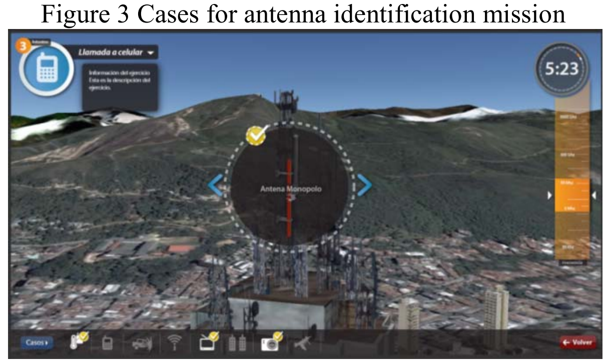

Figure 4 Capture of a mission for antenna identification

In this serious game, we try to reproduce real situations that the student will face in their real activities, preparing them to recognize potentially dangerous situations. Each activity that the player executes is associated with typical activities performed in real situations in remote areas where the trainee will work in a future, if the training process is successful.

In this way, the player (student, trainee) makes associations between real objects that will find in a real situation, but through simulated situations in a 3D environment.

In total, we developed six different missions with different objectives. Besides the Antenna mission, we also develop a Fresnel Mission (to verify pathloss in a microwave link), a Hunting mission, to locate interferers, a Site Survey Mission, oriented to identify objects in a real telecommunications building, and a Site Search Mission, oriented to identify potential candidates for radio transmitters location.

IV. EVALUATION PROCESS

With the antenna mission, we took a set of 66 students from different levels and disciplines, and give them the material for read, view the multimedia application and play the game, in order to evaluate the learning process. After each process (e.g. reading, multimedia viewing and playing) we evaluate some basic competences about identification of antenna type. For this purpose we use a basic test.

After the initial process, we select the groups and assign a different activity. People who have read written material then view the multimedia and other group plays the game, people that have played the game then read the written material and other group views the multimedia and so on. After this process we made another test that evaluates the same competences. Evaluation results are shown in the next section.

V. RESULTS

A. Statistical distribution for students results.

In Figure 5 we show the distribution of the obtained score in the evaluation made by the students after doing some of the learning activities described, or a combination of them. The ideal scenario for any teacher or educator is this where the score or learning outcome is concentrated in high grading results than low ones, i.e. the grades follow an asymmetric left shifted distribution.

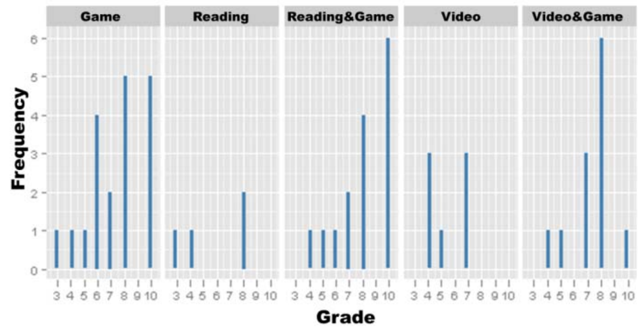

Figure 5 Statistical distribution of the obtained scores

So far, for our five different learning activities, it can be observed that the results obtained for students which read and play (Reading&Game in the figure) is the most desirable distribution. In a similar manner, the least desirable result is the one obtained from the students that only see the multimedia application (video).

B. Results' descriptive statistics.

Another way to analyze the results obtained from the different learning activities performed by the students is to analyze the descriptive statistics results associated to the grades obtained (shown in Table I). The highest mean grade correspond to the students that have read and played; meanwhile, the lowest mean grade corresponds to those who only saw the multimedia. Therefore, those students that read and play have a more desirable distribution in their results, but also a higher mean grade.

On the other hand, the median of the results for those students that saw the multimedia was the lowest (median 5), and for the remainder of the activities the median is 8. Regarding the minimum grade obtained by the students, this corresponds to the scenarios where the student only read or only played and its value is 3; whereas the higher grade obtained was 10 and corresponds to the students that perform the following activities: Play, Read-Play and Video-Play.

Table I Descriptive Statistics

		Play	Read	Read and Play	Video	Video and Play
Descriptive Statistics	Observations	21	5	15	7	13
	Mean	7,38	6,2	8,07	5,43	7,54
	Standard Deviation	2,01	2,49	1,98	1,51	1,66
	Median	8	8	8	5	8
	Min	3	3	4	4	4
	Max	10	8	10	7	10
	Asymetry Coefficient	-0,33	-0,34	-0,55	0,12	-0,51
	Kurtosis Excess	-0,29	-2,8	-0,44	-2,65	0,97
	Variation Coefficient	0,27	0,40	0,25	0,28	0,22

Asymmetry coefficient means a long tail on the left side meanwhile the value is more negative and vice-versa when the value is bigger than zero. Considering the results shown in Table I, it is possible to confirm what we intuited initially respect to the ideal scenarios. A lower quantity of people with low grades is found when the asymmetry coefficient is lower than zero; in this case the shifted to left distribution is that related with Read and Play, meanwhile the least desirable scenario is the Multimedia (Video) seeing activity.

Kurtosis excess means how normal (adjusted to Gaussian distribution) is the grades distribution depending on the activity. When the students just read or just saw the Multimedia before the test, the grades obtained are distributed in a less normal way than for the other learning activities.

C. Variance Analysis

After describing our experiment, the evident question that rises is: ¿is the expected score different depending on the learning activity assigned to the student? In Figure 6 we graph the estimated average score and its corresponding 95% confidence interval. Intuitively, the Figure let us thing that the average score for the learning activities that imply the game are higher than those that do not include a game.

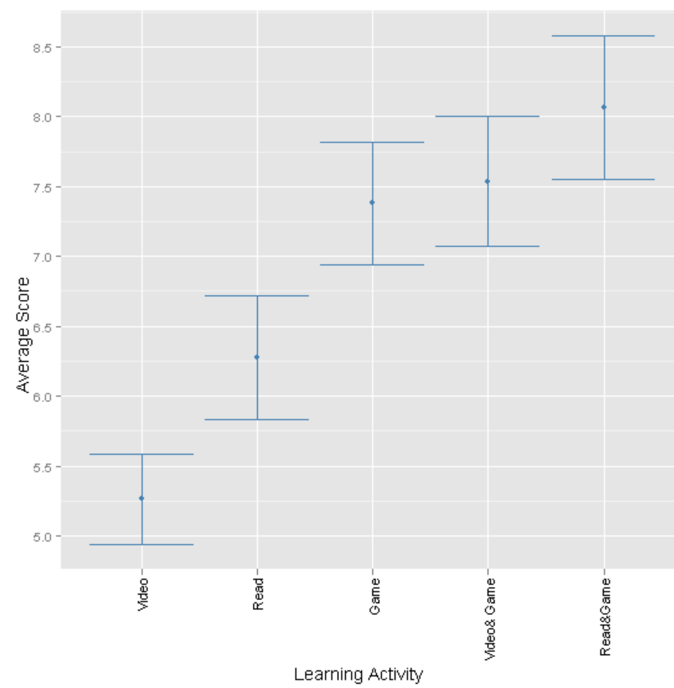

Figure 6. Confidence Intervals for the average score for the different learning activities

Due to differences shown in Figure 1 we estimate a one-way ANOVA model that let us test the null hypothesis that:

$$H_0: \mu_{playing} = \mu_{reading} = \mu_{watching\ a\ video} = \mu_{read\&watching\ video} = \mu_{watching\ video\ \&\ playing}$$

versus the alternate hypothesis that at least one mean is different. In this case the blocks correspond to the five different groups of activities assigned to each student. The dependent variable is defined as the score received by the student after taking the same evaluation. The results are reported in Table **I**Table **II**.

Table II. ANOVA

	GL	SSE	MSS	F	Sig.
Blocks	4	87.972	21.993	6.7373	***
Residuals	81	264.412	3.2643		

(***) Nivel de significancia de 1%

D.

E. Some comments about Learning Styles

In our University, we use the Felder and Silverman test in order to obtain the learning style of each student at the freshman semester. Having the learning styles of the students involved in this test, we made a quick analysis of the correlation between the learning style and the grades obtained in the different learning activities. Our initial hypothesis was that we will found a close correlation between learning activity and learning styles with results.

Our big surprise was that we do not found correlation that can relate the student learning style with the grade obtained in the performed activity. This result is a bit confusing for us, and then we expect to make more tests in order to have conclusive results about this result.

VI. CONCLUSIONS

We have shown statistical results for a serious game applied to a learning environment, with quite interesting results about the importance of combine learning strategies in order to improve learning outcomes.

Our results show that traditional learning activity like reading results on low grading and a big dispersion. On the other hand, the highest mean was found when the students combine reading with playing. This mean was accomplished with the lowest dispersion and a good shape of the distribution (left shaped).

Thereby, these results suggest some hypothesis that can be explored in future work. These hypotheses are:

1) The average grading of those students to which a game is assigned with a traditonal activity like reading obtained better results than those whom only a traditional activity was assigned.
2) Results' dispersion that use games in their learning process are better than those who use traditional learning activities.

Serious games are an excellent tool to acquire new knowledge and an approach to real skills, applicable directly in job environment.

TEST has become in an excellent experience for the creation of mechanisms for training and evaluation of candidates and for support of learning process in undergraduate courses.

The maturity of development tools influence the use of 3D games and allows designers, developers and educators to find a common place to obtain important results in knowledge generation.

The simulation of real situations gives us an efficient and inexpensive way to training and learning by experience.

The experience in the creation of serious games in COMCITY and TEST, allowed us to transform the complex concepts of a specialized area of knowledge and make them available to students in ways simple and striking, in a multimedia environment that involves different learning styles.

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Introducing Programming Concepts through Video Game Creation

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***Abstract* - This paper presents adaptable materials that teach programming fundamentals via game programming with Greenfoot, a free Java based game development platform. The materials consist of five independent modules, each of which focuses on a group of related computing fundamentals. Each module includes the shell of a game, lessons that teach programming fundamentals, hands-on exercises that apply the fundamentals to add functionality to the game, and questionnaires and content-based quizzes that can be used to assess the effectiveness of the lessons. An instructor's guide is also included. These materials were used to teach computing concepts to high school students in two different venues in summer 2011 and 2012. Formal assessments found that the students experienced a significant increase in knowledge in computing and an increased interest in computing and likelihood of taking computing courses in the future. The paper describes the motivation for this work, how it relates to other works, the teaching and assessment materials, the key concepts covered in each module, the venues in which the materials were tested, and the results. It also discusses how the instructional materials can be used in other venues and provides a link to the materials so that others may use them.**

Keywords –programming concepts; game programming; introductory computing

I. Introduction

This paper presents instructional materials designed by a team of undergraduates to teach computing concepts using game programming. They have been used successfully in two summer academies for high school students. The materials are modular and can be used in a variety of settings with a variety of target audiences. They are freely available for download. This goal of this paper is to describe and share these resources with others who may want to use them to teach introductory computing concepts and/or to stimulate interest in computing.

Section II describes the motivation for this work. Section III describes related works and what sets this work apart from others. Section IV describes the instructional materials. Section V describes each of the instructional modules in detail and includes sample excerpts from the instructional materials and assessment instruments. Section VI describes the venues in which the materials were tested and the results and describes other venues in which they can be used. It also includes conclusions and a link to a site from which the materials can be downloaded.

II. Motivation

According to the United States Bureau of Labor Statistics, the demand for software and application developers is expected to grow 30% from 2010 – 2020, and the demand for network and computer systems administrators is expected to grow 28% within the same period [1, 2]. Given this projected demand for positions that are necessary to our increasingly technology-based society, we need to encourage more students to consider Computer Science as a career. Unfortunately, the current supply of Computer Science graduates will not meet this projected demand. The number of students majoring in Computer Science plummeted between 2001 and 2007. Enrollments have risen since 2008, but are still much lower than the 2001 levels [3]. Similarly, Computer Science Bachelor's degrees awarded declined sharply between 2004 and 2009, have risen over the last three years, but are still not near the 2004 level [3]. Computer Science degrees awarded to women continues to decline, with only 11.7% of degrees awarded to women in 2010-2011 [3]. While the recent increases in overall enrollments and degrees awarded are encouraging, we still must produce more Computer Science graduates to meet the growing demand for skilled professionals. Educators are seeking ways to make computing more attractive to students. One such approach is to engage them in funs hands-on applications like game programming.

Games are not only fun; they also make important pedagogical contributions. Numerous studies have shown that video games can facilitate learning in math, science, engineering, geography, health, and other areas, including programming. Egenfeldt-Nielsen provides an overview of these studies and describes the contribution of video games from the perspective of different learning theories, including constructionism and the socio-cultural approach [4]. Both of these theories stress the importance of active learning as opposed to passive transfer of knowledge. Constructionism, which builds upon Piaget's Constructivism [5], stresses the

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importance of active learning using artifacts to facilitate learning. The video game provides a micro-world in which students can actively create and manipulate virtual artifacts. The socio-cultural approach that embodies the theory of Vygotsky [6] and others stresses the importance of having a teacher or peer guide the student. The video game provides a springboard for discussion with the teacher or peers.

Ke [7] synthesized findings from studies between 1985 and 2007 on computer-based instructional games. Only one out of 65 studies addressing effectiveness of instructional gaming found conventional teaching to be more effective than gaming. Studies on game-based cognitive or motivational processes found that games foster high-order reasoning and provide motivation across different learner groups and different learning situations. Studies on instructional game design found that instructional support must be included to have students learn the domain information rather than simply learn to play the game.

Using video game creation as an educational tool for programming has many practical advantages. Game programming allows the student to get visual feedback that illustrates the working of programming constructs and reinforces the theoretical concepts. Once the game is finished, students have a tangible product with which they can interact. Students can share their game with friends and family through sharing mechanisms that many educational game programming platforms provide. Game programming is an easily accessible medium. It requires only software and a computer on which to install that software. Groups and individuals that already have computers only need to install the game programming software. Using game development instructional materials, students can learn computer science concepts in a fun and engaging way. Having students complete the hands on activities with a partner can also help develop pair-programming habits and teamwork skills.

III. Background, Related Works, Contribution

Several game-based platforms have been used to teach introductory computing concepts. For a review of the most popular ones see [8]. Two of the most frequently used are Scratch [9] and Alice [10]. Scratch uses a purely drag-and-drop method of programming with blocks that generate scripts. It is often used for middle school students. Alice uses a drag-and-drop interface that generates Java-like code. It can be used to teach object oriented programming concepts. It has been used for middle school through introductory college students. In a special session at the 2010 ACM SIGCSE Symposium on Computer Science Education, Scratch, Alice and Greenfoot developers agreed that a progression from Scratch or Alice to Greenfoot is good in learning to program [11].

Greenfoot was developed at the University of Kent and Deakin University with support from Sun Microsystems. Greenfoot is a free IDE and is designed for high school and undergraduate level students [12]. It won the Premier Award for Excellence in Engineering Education Courseware in 2010. There is a textbook for teaching introductory computing using Greenfoot [13]. Greenfoot uses the Java programming

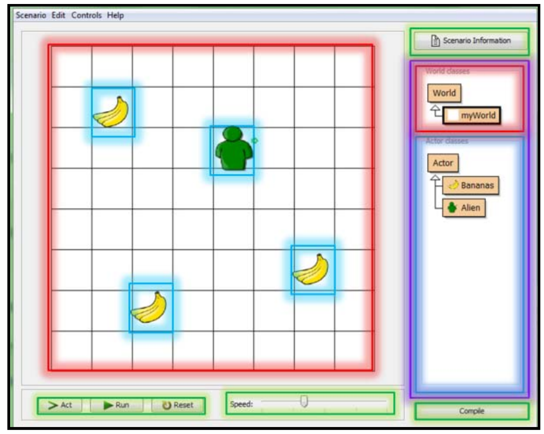

Figure 1. A sample slide of the Gathering Biofuel presentation illustrating the components of Greenfoot's interface.

language to create simulations and games. It utilizes both graphical and textual elements in its interface to teach students programming. A recent nationwide survey of undergraduate computer science departments found that Java was the language used by the largest percentage of surveyed schools to teach CS1 (48 percent) and CS2 (58 percent) [14]. Because Java is used in many Advanced Placement CS courses in high schools and is used as the entry level programming class in many universities, Java-based Greenfoot is a great tool for beginning programmers who want to learn a common programming language. Greenfoot also provides a mechanism for developers to share their creations. Allowing a budding programmer to share her creation with her family and friends can help keep her engaged when she receives positive feedback for her accomplishments, and it can help spark the interests of those who view her creation and encourage them to try programming as well.

Figure 1 illustrates Greenfoot's interface and points out its key components. One component is the world window. The world is made up of a 2-dimensional grid whose size is determined by the World's class constructor. Actors can populate this world. Actors are objects instantiated from classes created by the programmer. These created classes must extend the Actor class, which is provided by Greenfoot. Greenfoot illustrates inheritance in the Java programs in the right-most panes of its graphical interface. This is represented by the arrow coming from each subclass that points to the superclass. In the example in Figure 1, myWorld inherits from World, and Bananas and Alien inherit from Actor. This visual depiction of the relationship between superclass and subclass can be used to teach the concept of inheritance. Each created Actor subclass must have an act() method. This method designates the behavior of the actor once the program is run. In order to run a program, the user selects the "Play" button that is located with the control buttons at the bottom of the interface. "Play" indefinitely calls each class' act() method until the game is stopped programmatically or by pressing "Pause", which appears in place of the "Play" button when it is selected. Users can call one instance of each class's act() method by pressing the "Act" button. The "Reset" button removes all objects from the World and re-initializes each object. The "Compile" button compiles all classes.

Some educators have used Greenfoot to teach programming to undergraduates [15, 16, 17, 18]. Our work is more similar to that of Al-bow, who has used Greenfoot to teach programming to rising 9th and 10th graders and high school teachers [19, 20]. In Al-bow's programming sessions, students start by playing a pre-made game in Greenfoot and then in a series of exercises build a game by adding complexity one step at a time.

The instructional materials described in this paper teach programming principles through the use of game programming. An instructor uses the materials to guide the students through a series of exercises in which students create code to add functionality to a game. In each exercise students actively apply a programming concept (selection, repetition, etc.) to solve a problem and thereby enhance or complete a game.

Two things set our work apart from others. First, the modular nature of the instructional materials makes it easy to adapt them to different venues. Each of the modules can be used independent of the others, so they can be used in a one-day academy or as individual programming assignments in an introductory computing course. Second, all of the instructional materials are freely available for download and use by others.

IV. THE INSTRUCTIONAL MATERIALS

The instructional materials include five modules that can be taught individually or as a part of a weeklong lesson or a bridge program. Each module includes one incomplete game that is to be completed by students through a series of hands on exercises; and a complete version of the same game to be used as an example and a key. A PowerPoint presentation and a presenter's User Guide is also included, as well as the solutions to hands on activities that are completed by the students throughout the module. Assessment questionnaires and grading rubrics that can be administered to students are also included in each module.

A. Presentation and User Guide

A presentation is supplied with each lesson. The presentation introduces the lesson's concepts, the game, and its story. Throughout the presentation, students are taught concepts and then asked to apply those concepts in creating a portion of the game. These hands-on activities help engage students and reinforce what they just learned. Solutions to the hands-on activities are supplied. Presenters are also given a User Guide, which includes the learning objectives for the module and a slide by slide resource for the presenters that elaborates on each slide and suggests discussion topics for the group. This can help presenters who are unfamiliar with the program or concepts, which encourages a broader adoption of the materials.

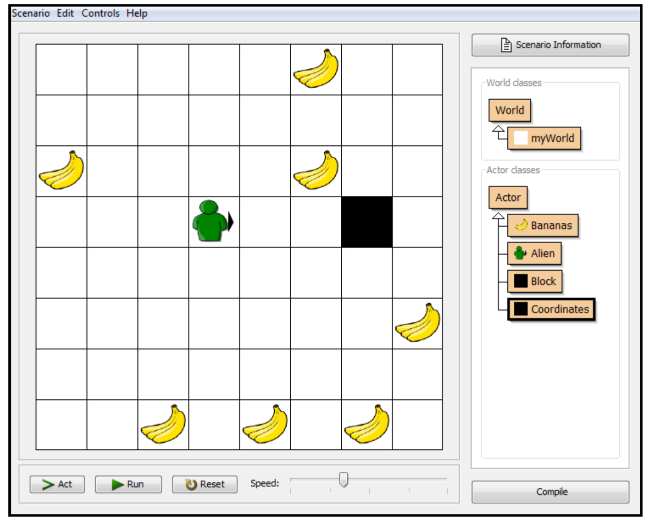

Figure 2. The Gathering Biofuel game.

B. Games

Two versions of each game are supplied. The student version is incomplete. Students complete this version during the hands-on activities. Comments are included in the incomplete version to highlight the section of code that must be modified or added by students. A second, complete version serves as a key and is used by the presenter to demonstrate the behavior of the game that is to be implemented by the students and to review the solution with students at the end of the hands-on exercises.

C. Assessment Components

In order to determine if the modules increase knowledge, content quizzes and grading rubrics are used. The questions test concept vocabulary and concept application. The grading rubric assigns point values for different answers. The quizzes are administered before teaching a lesson and after teaching a lesson. The scores on the pre-lesson and post-lesson quizzes are compared to see if there is a significant increase in scores, which indicates a significant increase in knowledge. In order to measure the reliability of the quizzes and rubrics, two different graders grade the pre-lesson and post-lesson quizzes independently. Consistency in grading can be tested by analyzing inter-rater reliability. Inconsistent grading triggers a review and modification of the quiz questions and/or grading rubrics.

V. THE MODULES

A story line unifies the five modules. The modules engage students in programming five independent games that help an alien return home. Sections A - E present the modules in the order in which they are used if the entire collection is to be used, for instance, as part of a week-long program.

A. Module 1: Gathering Biofuel

a) Learning Objectives. The goals are to familiarize students with the Greenfoot interface and introduce Java, Object Oriented Programming concepts (OOP), and the Java Applications Programming Interface (API).

b) StoryLine: An alien has stopped at Earth to gather bananas, which fuel its spaceship. The students learn how to populate Greenfoot's grid structure with bananas for the alien to collect.

c) Game: A screenshot of this game is shown in Figure 2. The game is based on the wombat tutorial supplied by Greenfoot [21]. The tutorial introduces the Greenfoot interface thoroughly, one of the main learning objectives of this module. This makes it a good choice as a basis for this lesson's game. In the supplied tutorial, a wombat traverses the screen and eats leaves that the user has added to the world. Users can add leaves for the wombat to eat by right-clicking the 'World' interface and selecting the appropriate method or creating a new object through Greenfoot's interface. Greenfoot's graphical interface lends itself well to teaching OOP concepts, which is another objective of this lesson. Greenfoot also has a documentation view that generates API documentation using Javadoc tools, which is used to teach the final objective.

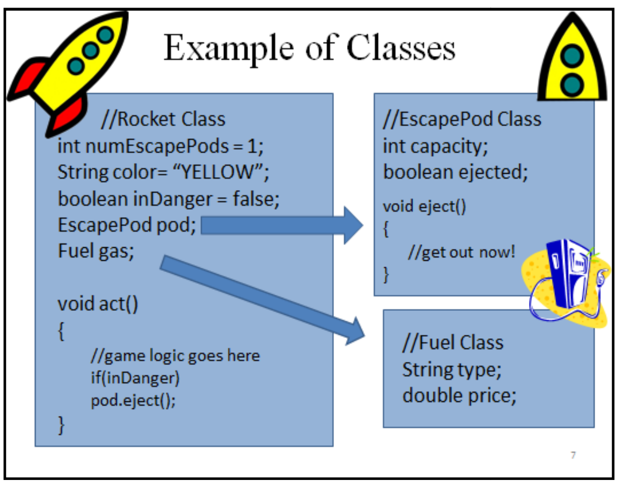

Figure 3. Sample slide that illustrates an example of classes.

What are two components of a class? Scoring rubric: (Cumulative) 1 pt each – "Methods" and "Variables"

Figure 4. Sample quiz question and scoring rubric from Module 1.

d) Hands-on activities: Students perform two hands-on activities in this module:

- create a banana object and set its location; and
- rotate an image by incrementing a variable and calling a method.

e) Sample instructional materials: Figure 3 shows a sample slide that illustrates the concept of a class. A sample question and scoring rubric from the assessment quiz for this module is shown in Figure 4.

B. Module 2: Accessing the Fortress

a) Learning Objectives: This lesson focuses on teaching students about arithmetic, Boolean and relational operations and simple if statements.

b) Story: The alien had its spaceship taken by the Spaceship Acquisition Crew (SAC.). The students must help the alien get the spaceship back from the SAC fortress by solving the puzzle to unlock the fortress door.

c) *Game:* A screen shot from this game is shown in Figure 5. In order to unlock the fortress door, the player must solve a 4x4 Sudoku grid. The student must implement the puzzle that must be unlocked in the game. Using arithmetic and Boolean operators, the student programs the population of the Sudoku grid with numbers, the mechanics to solve the puzzle, and the logic that checks to see if the puzzle is solved. The student accomplishes these tasks in a series of hands on exercises throughout the presentation.

d) Hands-on activities: Hands-on activities include:

- work with integer arithmetic, Boolean operators;
- work with if statements, Boolean, relational operators;
- write get and set methods; and
- import images.

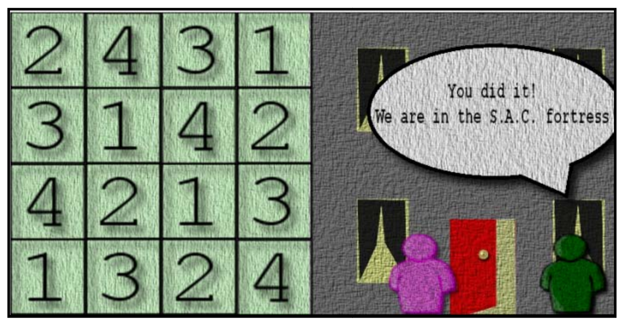

Figure 5. An image of Accessing the Fortress game with a solved puzzle.

```
/*
 *Hands on exercise
 *Write an if statement with the following condition
 *If newNumber equals 1
 *Then setImage (new GreenfootImage("one.png"));
*/
```

Figure 6. Sample hands-on exercise for Module 2: Create an if statement with relational conditions.

e) *Sample instructional materials*: A sample corresponding to one of the hands-on exercises for this module is shown in Figure 6. Comments in the students' partial game mark the spot and provide instructions for students to add content to the game. A sample question and scoring rubric from the assessment quiz for this module is shown in Figure 7.

Problem 4. 1 point awarded for each correct answer. Total of 3 points
int x = 2;
int y = 3;
boolean isJavaCode = true;
//Will the following expressions evaluate to true or false?	

Expression	Solution
x == y || x != y	true
x < y && x == 3	false
!isJavaCode	false

Figure 7. Sample quiz question and scoring rubric from Module 2.

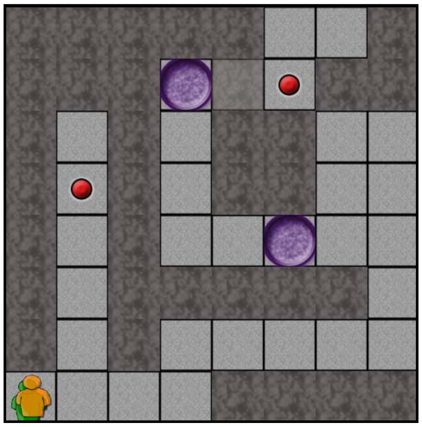

Figure 8. The Beginning of Fortress Maze. Two Players are on the bottom left; the small circles are buttons; the large circles are portals.

C. Module 3: Getting Through the Fortress Maze

a) Learning Objectives: Students learn selection and repetition structures and how they affect a program's flow of control.

b) *Story:* After the alien and student crack the code to get into the fortress, they need to work together to get through the maze that the SAC created to confuse intruders.

c) *Game:* This game requires two players. The players must disable the traps in order to access the buttons that open the hidden door to exit the maze. Figure 8 is an image of the game; in the maze, the traps are two moving portals, the large discs, which transport a player back to the beginning if they touch a player. Each player has a skill that, if used in cooperation with the other player, can disable the portals. One player can emit a field that will stun the portal so that it will not move. The other player emits a field that will disable a portal, but only if it is stunned. The cell between the topmost portal and button is a hidden door. It acts as a wall, but when a player 'steps' on a button the door is opened, but it will close once the player steps off the button. Once the portals are disabled, a player must step on the button to the left, which will allow the other player to walk past the hidden door to the exit, the cell in the upper right of the board. Once the player on the button steps off to head to the exit, the hidden door will close, but the player who is already past the hidden door can step on the button to the right and allow the remaining player to pass through to the exit. These rules are explained in the presentation and also in the game itself.

Students use the concepts learned in this module to implement core mechanics in this game. In hands-on activities throughout the lesson, students use switch statements to populate the game board with walls, portals, buttons, and the hidden door. Students use while-loops to implement the stun mechanism that is needed to remove the portals and if-statements to implement the mechanism that closes the hidden door once a player steps off the button.

d) *Hands-on activities*: Activities include:

- write complex conditional statements, nested ifs;
- use a switch statement; and
- work with the while loop.

e) *Sample instructional materials:* Figure 9 shows sample slides explaining the while statement. Figure 10 shows a sample quiz question and scoring rubric.

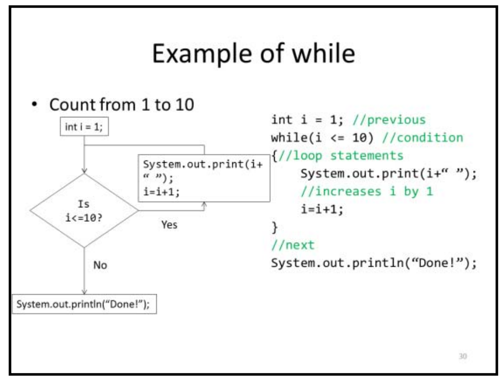

Figure 9. Sample slides used in Module 3 to explain the while statement.

Name 3 repetition structures used in Java. Score: (cumulative) 1 point each: while, do-while, for

Figure 10. Sample quiz question, scoring rubric for Module 3.

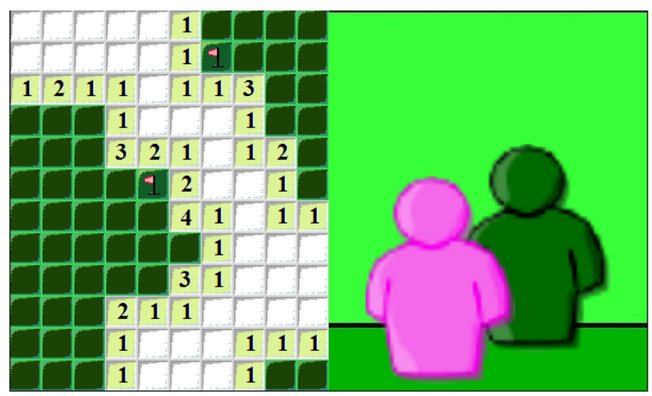

Figure 11. A game of AgentSweeper. The dark squares are active squares; the numbered squares are inactive squares bordering agents; the white squares are inactive squares not bordering agents.

D. Module 4: Agent Sweeper

a) Learning Objectives: Students learn about arrays and matrices, how to populate, access, modify elements.

b) Story: The students and the alien have managed to escape the maze and now need to avoid disturbing the sleeping guards so they can get to the alien's spaceship.

c) Game: Like the game Minesweeper, AgentSweeper requires the students to 'flag' all the sleeping agents before they can 'win' the game. Students click on the game board and use the numbers to determine where possible sleeping agents are located. Students can flag spaces where they believe agents are located. Once all the spaces are flagged or revealed as empty, the board will reveal where the agents are. This allows the alien to get through. A screenshot of the AgentSweeper game is shown in Figure 11.

Through the hands-on activities, students use for-loops to populate the matrix that represents the game board. Students also create and populate an array that holds the images of the agents that are revealed when the game is solved. In addition students implement the mechanism that counts and stores the number of agents that are bordering each square, which is revealed when an active square is selected.

d) Hands-on activities: Hands-on activities for this module include:

- use images in Greenfoot;
- create an array; and
- create, initialize, manipulate a matrix

e) Sample instructional materials: A sample solution to a hands-on exercise for Module 4 is shown in Figure 12. The solution is displayed on a slide and reviewed with students at the end of the exercise. A sample quiz question and scoring rubric are shown in Figure 13.

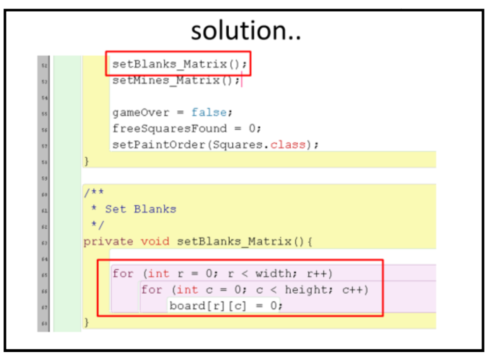

Figure 12. Sample solution to hands-on exercise in which students are to fill a matrix with zeroes.

What repetition structure can be used to fill an array/matrix?
Scoring:
2 points - for/nested for
1 point - while, do-while, or something along the lines of having to set the values in the array/matrix manually
0 points - anything else

Figure 13. Sample quiz question and scoring rubric for Module 4.

E. Module 5: Alien Flies Home

a) Learning Objectives: This lesson expands on the idea of classes and objects, and students learn about inheritance.

b) Story: Now that the alien has its ship back, it must navigate the asteroid field to arrive at its home planet.

c) Game: The student controls the alien spaceship in order to dodge the asteroids or blast them away. The asteroids periodically release power-ups that can help the alien regain health or gain a shield that blocks asteroids. The game board is illustrated in Figure 14.

In this lesson, the student creates her own class and implements her own power-up to help the alien reach home. By extending the Power_Up class, students can use the functionality already created and create their own methods to add another power-up, like one that increases firepower every time it is picked up.

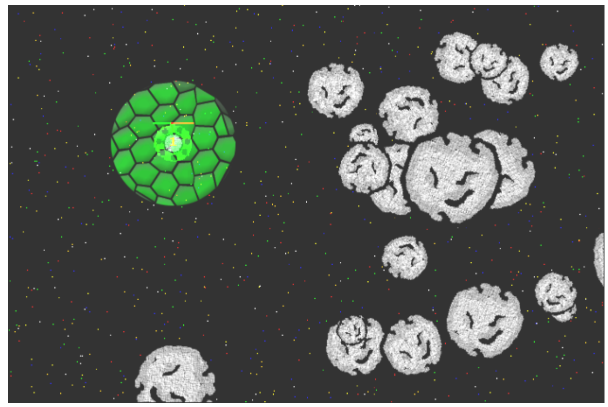

Figure 14. The alien flies home with a shield protecting its spaceship.

d) Hands-on activities: Hands-on exercises for this module include:

- create private variables;
- create a constructor;
- practice with nested if statements;
- manipulate images in Greenfoot; and
- detect collision in Greenfoot.

e) Sample instructional materials: A sample slide illustrating inheritance is shown in Figure 15. A sample quiz and scoring rubric for this module is shown in Figure 16.

VI. Results, Conclusions

In order to gauge the usefulness of the modules, the assessment seeks to answer the questions, "Does the completion of the modules increase knowledge?" and "Does the completion of the modules increase interest?"

These materials were used at Lamar University's INSPIRED High School Computing Academy in the summer of 2011. Students were taught game programming using these materials, as well as animation and web page development. Eighteen students participated in the academy: ten boys and eight girls. Analysis of the quiz assessment results shows that the students experienced a significant growth in knowledge of the computing concepts covered in all five modules [22]. Additionally, 81 percent of students reported an increase in interest in computer science courses [22].

The materials were also used in four afternoon sessions of a Lamar-hosted two-week residential academy for high school students interested in mathematics in the summer of 2012. Twenty-four 10th and 11th grade students participated: ten boys and fourteen girls. The sessions were taught by undergraduates who were not authors of the instructional materials. Assessment results show that the participants experienced a significant increase in computing knowledge in all five modules in this academy as well (t=5.279, p<0.000). A score of p less than 0.05 is considered significant. Also, 71% reported an increase in interest in computing, and 62% reported that they were more likely to take a class in computing in the future.

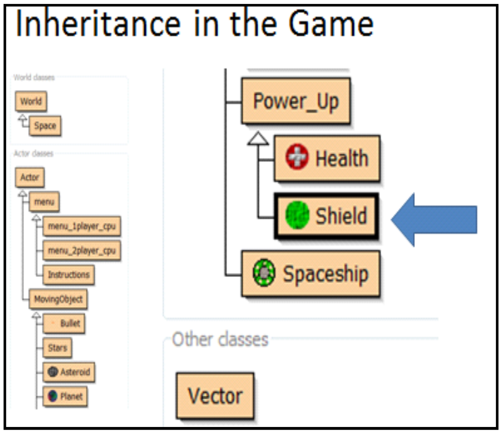

Figure 15. Sample slide from Module 5.

An object is defined by a class.
A class is the model or blueprint from which an object is created.
Score: 1 point awarded for each correct answer. Total of 2 points

Figure 16. Sample quiz question and scoring rubric from Module 5.

The results thus far demonstrate that these materials can be used to increase knowledge and interest in computing of high school students in different venues. The collection could also be used in a summer bridge program for entering freshmen. Because each of the modules has its own game and exercises that are independent of the other modules, they can also be used individually in one-day academies or as individual programming assignments in introductory courses.

The materials are available for download from: http://javagonegreen.blogspot.com/p/teaching-materials.html.

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Assessing the Impact of Video Game Based Design Projects in a First Year Engineering Design Course

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Abstract—**Introductory engineering design courses are an opportunity to engage and encourage first-year engineering students. In one such course, we implemented a novel student design project using a commercial video game. The game, Kerbal Space Program, is a simulation of rocket travel and provides a reasonably realistic representation of rocket propulsion and orbital mechanics. Teams of students were tasked with designing a rocket that could fly to the home planet's moon and return safely. The efficacy of the project was assessed using a pre- and post-activity survey, and results are compared with those from a larger-focus research project on the effectiveness of toys in the classroom.**

Keywords—games; engineering design; engagement

I. Introduction

Engineering students' first experience with the engineering discipline often occurs within introductory engineering design courses. As a result, these courses play an important role in retention and engagement of students in engineering. A variety of strategies have been employed in the past to improve retention and engagement of students. This article details a preliminary study conducted as part of a larger programmatic investigation on the efficacy of toy-based engineering design projects to increase retention of students in engineering disciplines. The contribution we made was to investigate the potential of video games as toys within this context.

Student retention is believed in part to be related to student attitudes about engineering, confidence in engineering skills, and interaction with peers [1,2]. Our approach uses team-based, hands-on projects to engage students. Another aspect of our approach is to use projects that provide students with engineering related coursework that does not have the heavy math and science focus common to the majority of their first-year curriculum. This allows them to build confidence in engineering apart from their still-developing quantitative analysis skills. The impact of these strategies was assessed by pre- and post-activity survey on self-efficacy of learning in engineering, engineering career interest and student perception of program usefulness.

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II. Background

Video games are a ubiquitous form of entertainment in modern society. They can be now found on a variety of platforms including home computers, standalone gaming consoles and smartphones. The level of computational power used by these systems has grown substantially over recent years, to the point that video games may now contain sophisticated simulation environments for a variety of different types of physics. The combination of popularity and wide availability of these games has created a situation in which over 65% of college students report at least occasional video game use [3]. By leveraging the advanced computational platforms available for video games, there is an opportunity to engage students and harness an existing student leisure activity for educational purposes. A common aspect of many games is the development of a community of practice. As players collaborate, learning as a social process builds connections to what is being learned and situations where the learning can be applied [4].

Games and game-like activities have been used in a variety of classroom settings [5]. Educators have considered games as an environment for content delivery, where learning objectives are integrated with the game itself. Games may also be used as a practice environment for drilling and repetition in a (theoretically) more enjoyable task. Consideration has been given to "gamification," where common game reward structures are integrated into traditional learning to provide motivation. Lastly, games can be considered simply as a reward activity for students.

Previous studies have considered the ability of video games and other virtual environments to be used for engagement or learning purposes in an educational setting. In a physics classroom, virtual manipulative tools were shown to be effective as compared to hands-on experimental activity by students [6]. Coller and Shernoff [7] utilized games and game programming as an avenue to address numerical methods in an engineering simulation environment. They showed higher levels of student intrinsic motivation and overall engagement when working within the context of the game, as compared to traditional classroom activities. Other studies have considered the impact of mobile, augmented reality games in pre-college educational environments [8]. A study by Virvou et al showed gains in student learning through gaming especially in students whose previous mastery of the material was low, but caution

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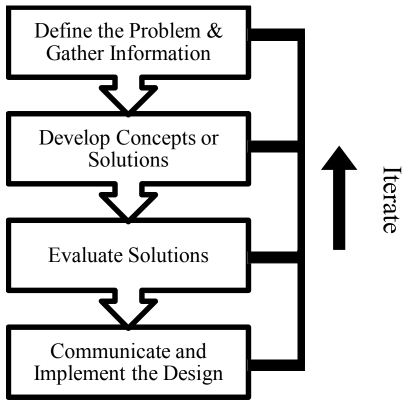

Fig. 1. The four-step engineering design model used in the course

that students will compare the production value in the games being used in the classroom with those commercial games that they encounter [9].

In this study, we considered the effectiveness of a commercial spaceflight simulation video game in the engineering design classroom. The game was used as an environment where students could practice engineering design by using the simulation to facilitate the production and testing of concepts throughout the design process. The game also produced a somewhat realistic depiction of the physics of rocket propulsion and spaceflight, providing students an environment to explore these concepts as they played.

III. Description of the Work

This study was part of the Toys ‘n MORE research program, which focused on measuring student engagement and retention through a series of toy based interventions in introductory engineering design and other courses. This program spanned several sections of the course, as well as several different university campuses. The interventions were implemented individually by each instructor, resulting in some variability in the projects for each course, though with the common theme of using toys in some way. One example of the Toys ‘n MORE program using LEGO Mindstorms robot design was reported by Sholtz and McFall [10].

The course in question was Introduction to Engineering Design, a course intended for first-year engineering students. The course covers topics of “engineering design processes, methods, and decision making using team design projects,” as well as engineering communication and graphics. The formalized design process used as a guide for students was a four-step model, shown visually in Fig. 1. In this course, students worked in groups to complete two team design projects. Survey data was compared for two groups: all students completing the Toys ‘n MORE version of the course (909 students from 2009-2012) and three course sections of students who completed a project using the video game simulation (58 students during the 2012/2013 school year).

A. The Video Game Project

The project we implemented to investigate student response to video games in the classroom was based around a commercial video game entitled Kerbal Space Program [11].

Fig. 2. Sample screenshot of a rocket under construction

Fig. 3. Sample screenshot of a rocket in-flight

This game is still under development, but at present is sufficiently complete to provide a comprehensive spaceflight experience. In the game, players can construct rockets from a variety of parts. Some examples are solid rocket motors, liquid rocket engines and fuel tanks, guidance systems, fins and other steering components, radial and axial staging separators, landing parachutes and structural supports. After constructing a rocket, the game provides a simulation environment where these designs can be launched and flown (requiring manual piloting) into orbit in a virtual outer space that includes other planetary bodies. A pair of screenshots from the game is shown in Fig. 2 and Fig. 3. For our study, the demonstration version of the game was used, because it was freely available and used a smaller set of components. While still allowing students the freedom to explore in their designs, this limitation did help provide focus.

The project assigned to students was to investigate the rocket parts and develop a rocket that would be able to reach space, fly into lunar orbit and return to safely land on earth. This flight plan mimicked the real-life flight of Apollo 8. Note that the earth, moon and sun were the only astronomical bodies that could be visited in the demonstration version. Landing on the moon was provided as an optional extra-credit goal, due to the additional piloting challenges that we felt would turn the learning focus away from the design. Besides practicing engineering design within the simulation, students did need to develop insight into some basic orbital mechanics principles, like the relationships between velocity and altitude. The latest versions of the game include built-in tutorials that could also be used to help acclimate students to the simulation. Students were given some instruction on these topics, specifically on how to create an orbital trajectory that would approach the moon.

Two specific learning objectives were addressed by this project. First, students were expected to be able to apply a four-step engineering design process to successfully complete a design goal. The second learning objective was for students to be able to demonstrate effective and professional teamwork behaviors throughout the process. The design process-related outcome included identification and articulation of design problems and challenges, identification of specifications for the design, and development and testing of multiple concepts in reaching a final design.

The video game we used fit well with the design learning objective, in that it required a workflow where students would piece together components and conduct test flights to evaluate the performance. Within the game's simulation environment, students encountered a broad set of challenges that their designs had to be modified to address. Example design decisions that students had to make were decisions about the type of rocket engine to use, the amount of fuel to carry, the rocket staging arrangement. In test flights students were able to observe how their choices impacted thrust-to-weight ratio, ease of control and flight stability, and how these parameters affected their ability to achieve their design goal. The application of the design process became a natural part of the playful activity. Another strength of this approach was the opportunity for students to iterate very rapidly on their designs.

The student deliverable for the project was a written report. They were instructed to focus on reflections about the implementation of the design process (e.g. concept generation and testing) and the measurable performance of their design. They were also asked to discuss their approach to teamwork in developing their design. Student grades were based primarily upon the stated learning objectives; their articulation of their design within the context of the engineering design process and their use of teamwork were the primary criteria. After completing the project, students received a detailed rubric providing the basis for their grade with an emphasis on the learning objectives. This was done to enable them to identify the shortcomings and receive feedback to improve their application of the design process on subsequent projects in the course.

B. Survey Data Collection

Student response to the learning activities was assessed using a survey adapted from the Longitudinal Assessment of Engineering Self Efficacy (LAESE) instrument [12,13] and a second technology self-efficacy instrument [14]. The pre- and post-activity survey was implemented for the entire Toys 'n MORE program. The survey was made up of seven demographic questions and 41 items related to aspects of engineering self-efficacy that mapped into nine subscales:

- Teaming self-efficacy (3 items)
- Technology self-efficacy (3 items)
- Communication self-efficacy (4 items)
- Engineering self-efficacy I (5 items)
- Engineering career expectations (7 items)
- Engineering self-efficacy II (6 items)
- Feeling of inclusion (4 items)
- Efficacy in coping with difficulties (6 items)
- Math outcomes efficacy (3 items)

Sample questions from three of the subscales are shown in Table 1. Note that the subscales detailed in Table 1 are those that had statistically significant results.

The pre-surveys were administered on the first day of class. This was to accommodate the fact that students were introduced to the game as a free-time activity at the beginning of the course so that they could play with the game freely and get a context for the upcoming project. The project was discussed with students at that time, but the formal assignment and expectations were provided in the 4th week of the course. Students had four more weeks to work on their designs and reports. The post-surveys were administered in the 8th week, after the projects had been completed.

TABLE I. SAMPLE QUESTIONS FROM SELECTED SUBSCALES

Subscale	Sample Questions
	Prompt: How confident are you in your current skill and ability to… (Not at all confident = 0 to Completely confident = 10)
Tech. self-efficacy	…design and build something new that performs very close to your design specifications? …quickly grasp the limits of a technology well enough to judge whether a project should use it?
Comm. self-efficacy	…organize a message so that it is clear and logical? …write reports that communicate clearly to the intended audience?
	Prompt: For each statement, indicate your level of agreement. (Strongly Disagree=0 to Strongly Agree=6)
Engr. self-efficacy I	-I can succeed in an engineering curriculum while not having to give up participation in my outside interests. -I will succeed (earn an A or B) in my physics courses.

IV. Results and Discussion

Results are considered for two separate groups of students. The first group represents students taking a Toys 'n MORE version of this course at our campus that did not include the video game. This group was made up of 909 students who took the course between 2009 and 2012. These students performed a hands-on design project that involved toys, but did not use the video game. The second group was the 58 students who took the course in Fall 2012 and Spring 2013, and who did both a toy-based design project and the video game-based project.

Due to the small sample size for the video game group, only three of the subscales were found to show statistically significant changes (two-tailed test significance less than 0.05). For two of those scales: Technology self-efficacy and Communication self-efficacy, an increase in mean rating was observed, while the third, Engineering self-efficacy I, showed a decline. The larger toy-only group showed statistical significance in the following subscales, with all showing an increasing trend from pre- to post: Teaming self-efficacy, Technology self-efficacy, Communication self-efficacy, Engineering self-efficacy II, Feeling of inclusion and Coping efficacy. These results are shown in detail in Table 2.

While some favorable results were seen for the video game group, there are some obstacles to interpretation. There is a relatively small sample size, with lower initial means. Additionally, the video game sections of the course had a different instructor than the rest, and one section had a slightly high number of sophomores. What we do conclude is that on the whole, the toy project provided benefits to students in some of the measured areas, and that the video game preliminary data shows gains, but would benefit from additional investigation.

Some subjective observations from the implementation of the project are worth considering. Students were extremely enthusiastic about the game. They frequently arrived at class early in order to play. In the first section using the game, students were given more time with the game and were primarily allowed to discover the orbital mechanics through free exploration. Some students began to express difficulty with this approach, and supplemental instruction was provided. The second group of students were provided with some orbital mechanics instruction early in the project, and qualitatively seemed to have a better experience with the task.

Another important qualitative observation is related to the engineering design process learning objectives. Because of the somewhat specific nature of the defined task (producing a rocket to orbit the moon), students seemed to have difficulty understanding how the game fit into the context of the four-step design process. An intervention was used during the second implementation of the project to provide a more concrete explanation of how the design process was relevant to playing the game. After this intervention, students offered informal feedback that they now saw how the process fit into their natural gameplay activities and felt that the game was a good example of the process.

One design process feature that the game demonstrated particularly well was iteration. All of the student groups identified iterative elements on their way from testing of multiple prototypes to the design of their final rocket. No groups were successful from their first launch and all had to make improvements on the basis of observations of the design weaknesses. We felt this was one big advantage over hands-on classroom design projects in which expense and time constraints can preclude students from building and testing multiple prototypes.

TABLE II. SUMMARY OF SURVEY RESULTS

	Toys-Only Group (n = 909)			**Toys and Video Game Group (n = 58)**		
Subscale	Pre-Mean	Post-Mean	Diff	Pre-Mean	Post-Mean	Diff
Team self-efficacy	7.09	7.56	+0.47	NS[a]	NS	N/A
Tech self-efficacy	7.44	8.00	+0.66	7.26	7.80	+0.54
Comm self-efficacy	7.51	8.03	+0.52	7.32	7.94	+0.62
Engr self-efficacy I	NS	NS	N/A	4.77	4.53	-0.24
Engr career expect.	NS	NS	N/A	NS	NS	N/A
Engr self-efficacy II	4.91	4.98	+0.07	NS	NS	N/A
Inclusion	4.37	4.69	+0.32	NS	NS	N/A
Coping efficacy	4.90	4.98	+0.08	NS	NS	N/A
Math outcomes	NS	NS	N/A	NS	NS	N/A

a. NS - Not statistically significant

V. Conclusion

The use of video games in the classroom is thought to have a great deal of potential to increase student engagement. We tested the use of Kerbal Space Program, a video game simulation of space travel, in a first-year engineering design project. Students were found to have enjoyed the project and were enthusiastic about the opportunity to play games in class. Some recommendations about the use of this game can be made on the basis of our experience. Students needed some guidance to understand the link between the video game and the academic content that it was meant to illustrate. However, once students began to feel comfortable with this relationship, they did observe features (such as rapid iteration) that the game was able to uniquely demonstrate. Survey data collected for the project showed that the game brought student gains in technology and communication self-efficacy ratings, and a decline in engineering self-efficacy. We believe that the outlook for this type of project is favorable as a demonstration of the engineering design process or similar activities, and that greater benefits to student participants can be realized with more experience.

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DISCLAIMER

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Education for Energy Efficiency through an Educational Game

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***Abstract* — This paper presents an assessment of an educational game for teaching the efficient use of electricity. Developed with Adobe Flash®, it is a virtual board game where participants choose a car that starts the path and reaches the same final goal, going through a number of track steps defined in terms of a dice that each player rolls in turn. The car moves if the participant is able to correctly answer a question that is randomly generated by the software. The objective of the game is to answer questions related to energy efficiency promoting a healthy and attractive learning process for participants on concepts related to energy efficiency such as: the rational use of energy, the basic concepts of forms of energy generation, among others. The main objective of this paper is to assess the impact of the application of this virtual game in the teaching and learning process of high school students. Therefore, the game was applied in the discipline of physics in a class of junior high public school in the state of São Paulo. Initially, the class that had 43 students was divided into 10 groups of 4 students, and 1 group of 3 students. Each student group competed with one another. The idea was that each of them should indicate a student who was the representative of this group until only 4 group leaders were selected for the finals. At this stage, each student could interact with a group of up to ten students that acted as advisers. The adopted assessment process is based on the model proposed by Savi [7]. Then, at the end of the game, the students answered a prepared questionnaire based on the model proposed by Savi. According to Savi, although there are significant studies that show the importance of educational games for the process of cognitive development and learning concepts of students, there are few papers that present forms of assessing the potential of these resources. Thus, the assessment criteria proposed by Savi are based on the model of training evaluation by Kirkpatrick [3], taken as a reference to measure the efficiency of processes of continuing education courses for professionals. The authors assert that the metric of the evaluation proposed to assess the game is based on the first level of the model proposed by Kirkpatrick.**

Keywords: educational game; game-based learning; education; energy efficiency.

I. INTRODUCTION

Through playing activities to explore the reality, students can reflect and incorporate different environmental and cultural aspects we live with. Anyway, the game lets you transform the reality through imagination and allows the establishment of a network of constructive meanings [1].

When playing, children are given the opportunity to fully develop experiences, discoveries, creations, and skills. Playing is essential for the physical, emotional and intellectual development of the child.

Playing behavior is not only a necessity for children, but it is also inherent in human beings, since various activities that are performed in our everyday adults lives are imbued with playfulness: myths (fantasy games) in language (word games), religion, food, among others [2].

It was developed an educational virtual game under a partnership with a company established in the energy industry sector in Brazil – *Centrais Elétricas Brasileiras S. A. – Eletrobrás* – whose goal is to provide learning situations in the classroom in which questions about the efficient use of electricity can be discussed and problematized. In this paper, it is presented a review of the game developed in a real classroom situation. It was used, as instrument for data collection, a questionnaire based on the model of Kirkpatrick [3] for training evaluation, the ARCS model proposed by Keller [4], Gamez [5] in the field of Game User Experience, and the taxonomy model proposed by Bloom [6].

II. EVALUATION MODEL

According to Savi *et al.* [7], although there are significant researches that suggest the importance of educational games both for the process of cognitive development and learning concepts of students, there are few works that have forms of assessing the potential of these resources. Thus, the assessment criteria proposed by Savi is based on the training evaluation model by Kirkpatrick, fixing the attention on the degree of satisfaction and the perceived value by the students as for the learning experience they had to interact with along the game.

The evaluation model of training programs developed by Kirkpatrick, taken as a reference in processes of measuring the effectiveness of continuing professional training courses, is based on four hierarchical levels:

1. **Reaction:** It refers to the degree of impression that the training professionals had from the program. That is, we seek to understand how the training program motivated, awoke professional interest in learning the content, and developed the skills and competencies proposed in the training program.

*Students of electrical engineering

2. **Learning Process:** It is related to knowledge built by the professional during the training program.

3. **Practical Application:** For this search criterion, it was aimed measuring the professional capacity, developed during the training step, in applying the gained knowledge in practice.

4. **Results:** It refers to the positive effects of the training program for the organization in which the professional works.

The authors affirm that the evaluation metrics developed for assessing the educational game are based on the first level of Kirkpatrick model.

So, to specify the degree of motivation of students, as well as the value they attribute to the experience they had in the educational game, the authors build categories based on the ARCS model proposed by Keller, on the user's field of expertise (UserXperience - UX), proposed by Gamez, and on Bloom's taxonomy.

In the ARCS model proposed by Keller, it is assumed that the motivation to learn is a fundamental element for the whole educational process and that, to be established, it is necessary for the student to interact with the game, to have the expectation of success, and to assign value to the results obtained in this interaction. Thus, some categories may be established: Attention, Relevance, Confidence and Satisfaction.

- **Attention** is understood as a cognitive response given by the students to instructional stimuli used in the teaching and learning process. Therefore, it is essential that the instructional game has the merit of encouraging students not only at the beginning, but throughout the whole interactive process mediated in the act of playing.
- **Relevance** is considered a value assigned by the student from which he or she recognizes the importance of the educational activity for their learning.
- **Confidence** is understood as a sense developed by the student, during the development of the educational activity, from which he or she feels capable of overcoming the challenges that are proposed. In this sense, the educational game will be motivator if players feel confident enough to overcome the proposed obstacles.
- **Satisfaction** is interpreted as being the positive feelings of accomplishment and reward perceived by students during the execution of the proposed activities. Therefore, the game should be a source of satisfaction, that is, feelings of accomplishment and reward for students.

With respect to the contributions of the user's field of expertise (UserXperience - UX), the categories are based on the idea or perception that a given user formulates or feels after using a particular product. In this way, Savi *et al.* highlight that UX takes into account the thoughts, feelings and sensations triggered through the user-product interaction, as well as the present or previous expectations with respect to its use.

Thus, the authors, influenced by the categories proposed by Gamez, select those that showed to be more suitable for assessing educational games:

- **Immersion:** It refers to the level of involvement that the student has with the game, in order to divert the focus from the real world into the context that the game creates.
- **Challenge:** Considered by the authors as being the main aspect of good educational games, the challenge needs to be established to motivate students to get involved with the proposed activities. To this end, the game needs to have rhythm, that is, submit a schedule in which the rate at which new challenges, problems or tasks arise is appropriate. It is also necessary that the challenge level is proportional to the skills of the players and then increase as the game develops, in order to increase motivation.
- **Competence:** The student should feel able to confront challenges proposed by the game. If the proposed challenges are above the student's capacity, there will be a sense of anxiety, discouragement and, consequently, of demotivation.
- **Fun:** The game should generate a feeling of pleasure, satisfaction, joy, and contentment. This will establish in the student the desire to play again and recommend its use to other students.

Savi *et al.* use the first three levels of Bloom's taxonomy to evaluate potential aspects of the game in providing learning concepts to students. Bloom has proposed taxonomy based on specific areas of cognitive, psychomotor and affective domains. For cognition, understood as processes related to learning process, that is involving the construction of new knowledge and the development of intellectual skills. The levels used by Savi *et al.* are listed below:

- **Knowledge:** It is related to the ability to remember information and previously discussed content. In general, the purpose of this category is to identify whether the apprentice is able to bring to mind the knowledge and the information learned.
- **Understanding:** It is related to the ability to understand information or facts, to give meaning to the content that you are being informed about, using them in different contexts.
- **Practical Application:** It is related to the capacity or ability of the learner to use, in different situations, information or knowledge in real situations. In this sense, the learner should be able to apply rules, methods, models, concepts, principles, laws, and theory into practice.

Fig. 1 presents the assessment model proposed by the authors of the current paper to be used when evaluating educational games.

Based on this assessment model of educational games, a basic questionnaire was set which, after playing the game, students were invited to answer.

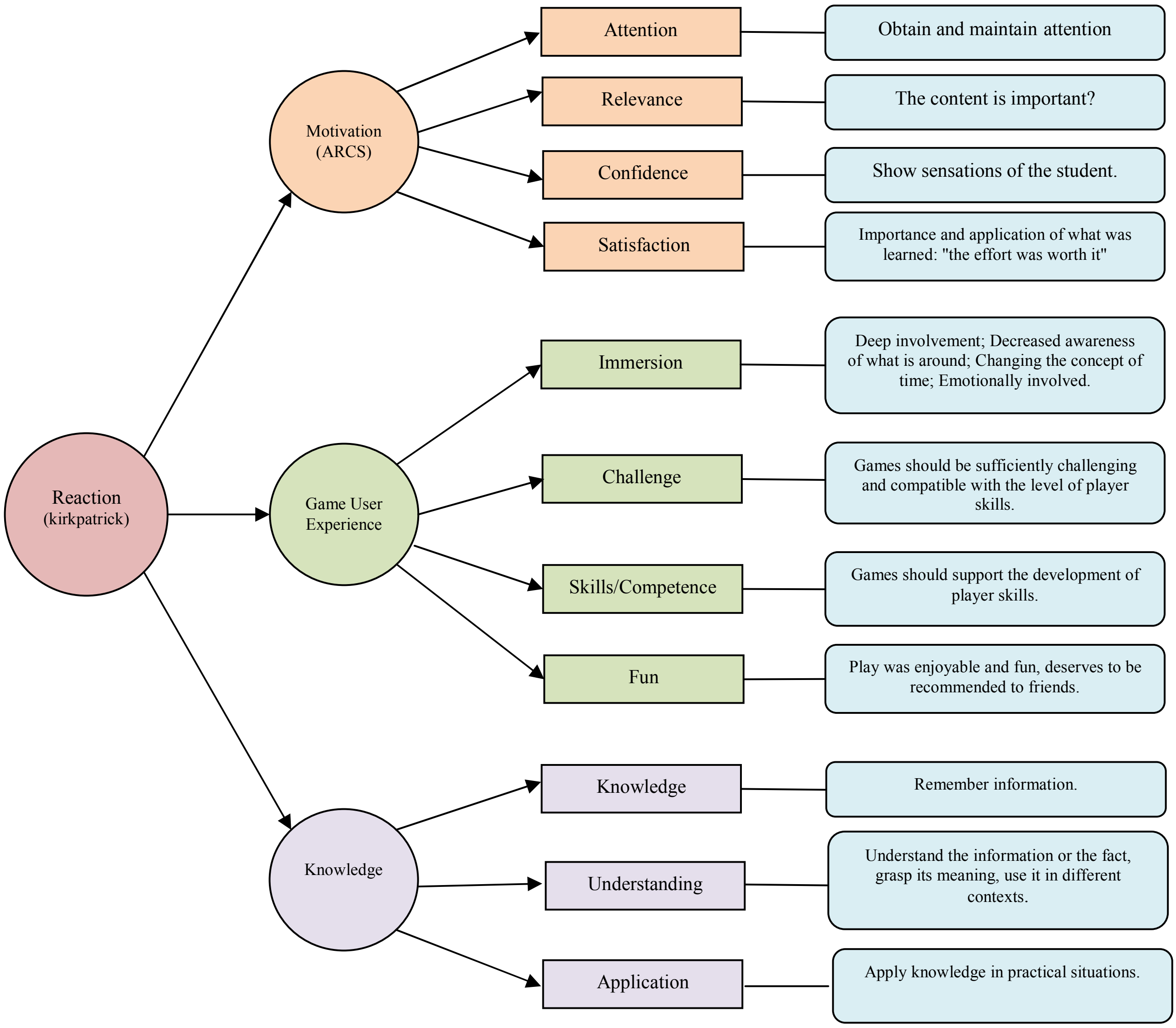

Fig. 1. *Proposed assessment model of educational games*

III. METHODOLOGY

The survey was conducted in the context of a school with high school students. The game was applied in the discipline of Physics in a class of junior high public school in the state of São Paulo, considering that the concepts involved in the questions are part of the contents taught in this discipline. The selection of the school took place in the context of a continuing education course for Physics teachers taught at UNESP, campus of Guaratinguetá. In this course it was held an invitation for the participants to apply the virtual educational game within their classes. The high school teacher had the autonomy to choose the school and consequently the class of students with whom he or she would work.

The class had 43 students who were divided, randomly, into 10 groups of 4 students and 1 group of 3 students. Each student group competed with one another. The idea was that each group should indicate a student who was the representative until only 4 group leaders were selected for the finals.

A pre-test was not applied to the students once we sought an instrument that did not limit us to a process-product research, but offered more general data, such as motivation, social interaction, among others.

As the students had no access to any reference materials during the execution of the game, it was allowed that, in the last stage, each student interacted with a group of up to ten students who acted as advisers. At the end of the game, the students answered the assessment questionnaire.

IV. EDUCATIONAL VIRTUAL GAME

The game, developed in Adobe Flash®, aims to provide learning situations of concepts for the rational use of energy, energy efficiency, and renewable and non-renewable energy sources to high school students. Fig. 2 shows the initial screen of the educational game.

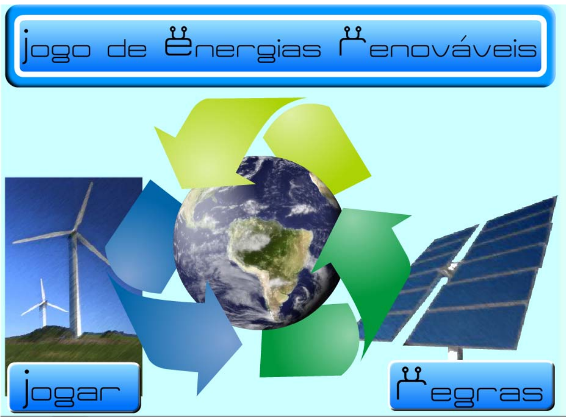

Fig. 2. Initial screen of the educational game.

The game is composed of an autorama track consisting of thirty houses to be travelled through. The board is set up (*jogar* button) during the booting stage of the game with two, three, or four lanes. In each board lane, the player has five houses called as REVES (for the setback condition: see below). The position of these houses is performed randomly by software during the game startup, as well. Fig. 3 shows the game set up with four lanes, that is, the game is set to four participants.

The game starts when a player rolls the dice on the virtual board and advances the number of track steps according to the value obtained. In each of these steps, the participant is asked questions with four alternatives of which only one is correct. If the answer is correct, the order of turns is not changed. If, on the other hand, the player mistakes the answer, he or she must spend a turn without playing. Such a condition is displayed immediately on the screen of the game. Fig. 4 shows the screen containing a typical question presented to players during the game.

The player who can position his or her cart in the step at the end of the track first wins the game. Thus, each player rolls the dice clicking on the icon shown on the screen, and goes through the number of houses obtained after the release. Then, the students may answer a question on one of the following topics: rational use of energy, energy efficiency, and renewable and non-renewable energy sources.

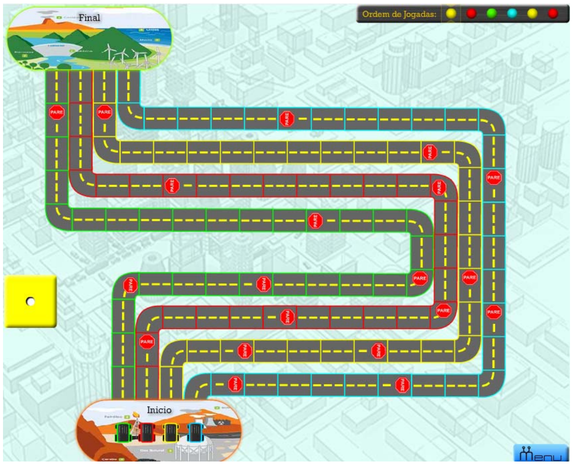

Fig. 3. *Board set with four lanes.*

If the answer is correct, the player rolls the dice the next round and the game continues normally. If the answer is wrong, the player loses a turn to throw the dice in the next round.

During the game, each player may suffer one or more setbacks. That is, an unfavorable situation related to the misuse of energy resources at his or her disposal. In that case, as in the case of mistaking an answer, he or she must spend a turn without playing, or even retreat already covered steps. All questions, as well as the setbacks, are randomly generated by the software.

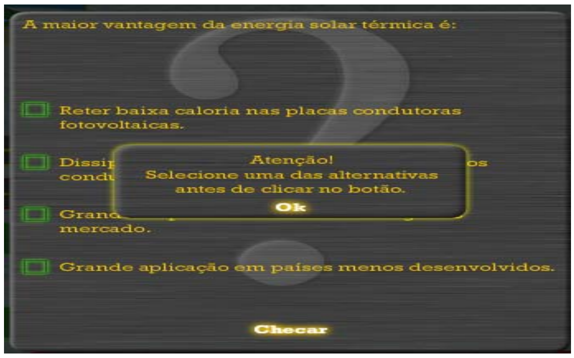

Fig. 4 Question screen.

The game ends when one of the players reaches the step called as the END. At this point, the player must answer a challenge question that has eight alternatives of which only one is correct. The game is ended when one of the players correctly answers the question. Otherwise, the game goes on until one of the other participants answers this challenge question correctly.

V. RESULTS

As pointed out before, a basic questionnaire was proposed, based on the assessment model of educational games. The assessment instrument was organized in three sections, corresponding to the MOTIVATION, GAME USER

EXPERIENCE and KNOWLEDGE categories. Based on data collected from the responses provided by the students, individually, from the completion of the assessment questionnaire, it was noted that, in relation to the section of the proposed assessment instrument for MOTIVATION category, all students have highlighted that the game has some features that triggered their attention, no student pointed out any aspect of the game that has generated lack of motivation, and a significant number said that already had some knowledge about the content involved in the game. Furthermore, the significant majority of students replied that not only liked the game, but also felt motivated by it, and found that the addressed topics were current and interesting.

The results obtained from the analysis of the questionnaires are shown in the form of Tables (Tables I, II, and III, in the sequel). With respect to the MOTIVATION category, the employed assessment tool has adopted the following aspects: attention, relevance, confidence, and satisfaction. The proposed questionnaire for the assessment of this category is presented below:

- **Attention:**
  - (1) Was there anything interesting at the beginning and during the game that called your attention?
  - (2) Is there any lack of motivation in the game?
- **Relevance:**
  - (3) Is the content of the game related to things you already knew?
  - (4) Did you like the game so much to the point of wishing to learn more about the addressed topics?
  - (5) Is the content of the game relevant to your interests?
- **Confidence:**
  - (6) Was the game more difficult to understand that you would like it to be?
- **Satisfaction:**
  - (7) Did you feel good when finishing the game?

Some points could be detached from data on Table I. Firstly, with respect to the *attention* aspect, one can see that most of the students (35) acknowledged that there was something interesting in the game that caught their attention. With respect to the *relevance* aspect, one can see that most of them (40) enjoyed the game so much to the point of becoming interested in learning more about the covered topics. It is interesting to notice that, with respect to the *confidence* aspect, most of them had no difficulty understanding the game. Finally, with respect to the satisfaction aspect, most of them felt good when the game was over.

TABLE I. *STUDENTS OPINION ON THE MOTIVATION CATEGORY.*

MOTIVATION							
	Attention		**Relevance**			**Confidence**	**Satisfaction**
Question	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Strongly Disagree	0	10	0	0	0	40	0
Disagree	0	3	7	2	0	3	5
Agree	35	0	16	40	21	0	35
Strongly Agree	8	0	20	1	22	0	13

With respect to category GAME USER EXPERIENCE the employed assessment tool adopted the following aspects: immersion, challenge, competence, and fun. The proposed questionnaire for the assessment of this category is presented below:

- **Immersion:**
  - (8) Have you noticed the time going by when playing the game?
  - (9) Have you concentrated so hard on the game to the point of not realizing what was going on around you when playing?
- **Challenge:**
  - (10) Have you felt anxious at any point during the game?
  - (11) Have you felt bored at any point during the game?
  - (12) Has your knowledge gradually increased with overcoming the proposed challenges of the game?
- **Ability/Competence:**
  - (13) Have you felt that the game was appropriate to your learning level?
  - (14) Has the game granted a great collaboration between you and your colleagues?
  - (15) Has this collaboration helped your learning process?
- **Fun:**
  - (16) Did you like playing the game for a long time?
  - (17) When it ended, were you disappointed because you wanted to go on playing?

TABLE II. *STUDENTS OPINION ON THE GAME USER EXPERIENCE CATEGORY.*

GAME USER EXEPERIENCE										
	Immersion		**Challenge**			**Ability Competence**			**Fun**	
Question	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**	**(17)**
Strongly Disagree	0	6	2	36	0	0	0	0	0	0
Disagree	0	10	28	7	4	6	3	0	1	12
Agree	34	25	10	0	30	37	30	30	42	30
Strongly Agree	9	2	3	0	9	0	10	13	0	1

The results presented in Table II indicate that students have been significantly involved in the game to the point of their thoughts not become dispersed with others questions that would not involve the approach of the game. The questions were appropriate to the level of the students, because they felt challenged with the same and with the problems proposed in different stages of the game. In this regard, the assessed students emphasized the fact of the game require different skills and competencies. Another aspect highlighted by the interviewees was that the game allowed them to experience moments of fun and at the same time, contributed to make learning more enjoyable.

As for the KNOWLEDGE category, the employed assessment instrument adopted the following aspects: knowledge, understanding, and practical application. The proposed questionnaire for the assessment of this category is presented below:

- **Knowledge:**
  (18) After the game, are you able to remember the several pieces of information related to the theme presented along the game?
- **Understanding:**
  (19) After the game, have you felt more capable of better discussing about the subjects related to the theme of the game
- **Application:**
  (20) Do you feel you can apply the knowledge acquired in the game in practice?

TABLE III . *STUDENTS OPINION ON THE KNOWLEDGE CATEGORY.*

KNOWLEDGE			
	Knowledge	**Comprehension**	**Application**
Question	**(18)**	**(19)**	**(20)**
Strongly Disagree	0	0	0
Disagree	0	0	0
Agree	37	32	21
Strongly Agree	6	11	22

From these data, we observed that the different questions proposed demanded different levels of cognition of the students. From the students' own perception, the proposed issues not only demanded knowledge of basic information related to the rational use of energy, as also challenged them in relation to the understanding of different contexts and the application of knowledge to solve certain problems.

VI. CONCLUSION

More than motivate and provide moments of fun for the students, the educational game involved students in processes of social interaction that provided a deeper understanding of the issues addressed.

In the opinion of the authors, the virtual game is not an educational resource that suffices by itself. The game has no innovation in terms of bringing in itself mechanisms for self-learning. However, depending on the way the teacher uses it in the context of the classroom, it can become an interesting resource, not only as a pre-test, but as a motivational tool for learning, a trigger of social interactions, from which an entire conceptual discussion can be established. Thus, the teacher can use the game to assess students' prior knowledge before beginning the process of teaching and learning, or even identify the concepts that need to be further emphasized after the teaching process. So the game is not the end, but the means from which the teacher will be able to evaluate students, verifying: doubts, knowledge level of the class, pre-conceptions about the previous theme, among others.

In this sense, we finish this article calling the attention to the importance of both the role of the teacher as the key element to manage the process of teaching and learning, and the use the game as a ludic and motivating instrument in the learning process.

ACKNOWLEDGMENT

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Towards the Establishment of an Agile Method for OERs Development and Delivery

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Abstract — **Open Educational Resources (OERs) have been emerged as an important mechanism for democratization of access to education. In fact, the free and open distribution of these resources contributes with the dissemination of knowledge and facilitates the access to information, benefiting the society as a whole. Similar to software, the development of OERs requires the application of appropriate methods and practices to ensure the productivity and quality of the resulting products. Agile methods seem to be an interesting approach in this perspective. However, initiatives to foster the development and delivery of quality and reliable OERs, according to agile principles and with reduced costs, are still incipient. In our work we discuss the establishment of an agile method for the development and delivery of OERs. The proposed method is based on the main characteristics, practices and principles of well-known agile methods for software. To illustrate our ideas, the method is discussed in terms of its application in the development of an OER in the FLOSS (Free / Libre and Open Source Software) domain.**

Keywords—open educational resources; open content; agile methods.

I. Introduction

The dissemination of information together with the adoption of computer and communication technologies have provided new ways of thinking, teaching and learning. Thus, issues associated to innovative educational processes are increasingly in evidence, attracting more and more interest from researchers and practitioners around the world.

In this context, the development of OERs (Open Educational Resources) has been widespread and investigated by the scientific community as a way to facilitate the access to education [7], [16]. Essentially, an OER encompasses: (1) *learning resources*, such as learning objects, full courses and educational modules; (2) *tools*, such as supporting systems for the development, (re)use and delivery of learning content; and (3) *implementation resources*, such as intellectual property licenses to promote the publication, reuse and dissemination of the educational content [9].

An important characteristic associated with the development and delivery of OERs refers to the dynamic and evolutionary aspect of knowledge, from which the resources should be continuously evolved in consequence of previous learning experiences. Furthermore, the elaboration of an OER may involve collaborative aspects in which developers, locally or remotely distributed, interact and cooperate to its construction [4].

To ensure that OERs effectively contribute to the teaching and learning processes, it is necessary to use appropriate approaches and methodologies that support the design and development of tasks and associated activities. In this perspective, agile methods constitute an interesting development alternative, providing flexible and suitable approaches for elaboration of products in constant evolution, such as OERs. Nevertheless, initiatives that consider the aspects mentioned above are still incipient.

In our work we discuss the establishment of a method which aims effectively support the agile and collaborative development of quality OERs. The proposed method is based on the main characteristics and practices of agile methods, taking into consideration the intrinsic aspects of OERs development. To demonstrate the practical application of the method, we discuss its adoption in the development of a short course in the FLOSS (Free/Libre and Open Source Software) domain, referred to as FLOSS OER.

This paper is organized as follows. In Section II an overview of OERs and agile methods is presented. In Section III we describe the main characteristics of the proposed agile method for OERs. In Section IV we illustrate the instantiation of the method in the development of FLOSS OER. Concluding remarks and further works are presented in Section V.

II. Background

A. *Open Educational Resources*

According to Atkins et. al. [1], Open Educational Resources (OERs) can be characterized as teaching, learning and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or re-purposing by others. They include full courses, course materials, modules, textbooks, streaming videos, software, and any other tools, materials or techniques used to support access to knowledge.

The OER movement originated from developments in open and distance learning and in the wider context of a culture of

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open knowledge, open source, free sharing and peer collaboration [15]. The movement starts from the idea that knowledge is a public good and that technology, and the Internet in particular, provide a great opportunity for everyone to share and reuse this knowledge [8].

The term "open" provides to the user, through a license, permission to perform four main actions (4R) [16]: (1) *Reuse*: the right to use the content in its unaltered/verbatim form (e.g., make a backup copy of the content); (2) *Review*: the right to adapt, adjust, modify, or alter the content itself (e.g., translate the content into another language); (3) *Remix*: the right to combine the original or revised content with other content to create something new (e.g., incorporate the content into a mashup); and (4) *Redistribute*: the right to share copies of the original content, your revisions, or your remixes with others (e.g., give a copy of the content to a colleague).

The dissemination of OERs in higher education depends on many factors, from government initiatives until the effective collaboration of students [17]. Fundamentally, the quality of OERs should be guaranteed [18]. In this direction, there is a need for flexible approaches and methodologies that support the development of effective OERs, with reduced time and costs.

B. Agile Methods

Agile methods have emerged as an alternative to traditional methods, defining a new approach for software development, focusing on agility, flexibility, communication skills and ability to deliver products and services with added values to the market in due time [2].

Similarly to traditional development methods, the main goal of the agile methods is to produce high quality software. However, one aspect that differentiates the traditional from agile methods is that the latter are focused on people and prioritize a fast supply of the system and an effective collaboration of those involved in the project [2], [3].

Among the several agile methods existing in the literature, we can highlight Scrum and eXtreme Programming (XP) as the most well-know and widely used ones. Scrum [12] focuses on planning and project management. It prioritizes work based on business value, improving the usefulness of which is delivered to the customer and increasing their gains more quickly. XP [5] focuses on projects whose requirements are vacant and those changes often. It is based on a set of values and best practices that are mutually supportive in the software development.

III. An Agile Method for OERs development and Delivery

In many aspects of development, the production of OERs is similar to software development. In the case of software, processes, methods and tools have been established in order to contribute to the development of quality software products [4]. Similarly, the use of appropriate mechanisms to ensure the productivity of the development process and the quality of the resultant products are also critical to OERs.

In this section we describe our proposal of an agile method for OERs. The method is based on agile methods for software, particularly Scrum and XP. Besides that, Web 2.0 technologies are also considered as a way to encourage the effective participation of developers and users in developing the OER, also supporting the collaborative and distributed development of these resources. According to Gimenes [18], Web 2.0 technologies can significantly improve the production of OERs and the access to information, besides providing a way to facilitate computer communication and collaboration between educators and learners. There is also an emerging culture of Open Educational Practice which draws in ideas of Web 2.0 technologies [13] to emphasize the social praxis behind of the OERs [6].

Initially, an analysis of the agile methods was conducted in order to verify the main characteristics, similarities and differences among them. This analysis served as the basis for the proposition of the agile method for OERs. From the analysis conducted, we noticed that each method has some particular characteristics. On the other hand, there is also a series of common characteristics shared by them (Table I).

TABLE I. COMMON PRACTICES AMONG THE AGILE METHODS FOR SOFTWARE

Practice	Description
Iterative Development	Occurs in small cycles (sprints or iterations). The goal is to produce and integrate parts of the software constantly throughout development.
Incremental Development	Occurs incrementally through repetitive cycles, adding new features or evolving the features already implemented.
Flexibility	Due to the iterative and incremental issues, the development becomes flexible to accommodate changes in requirements and software design.
Collaboration	Developers, customers and users are involved in the software development. The customer provides quick feedback and facilitates communication among stakeholders.
Testing	Testing is conducted at the beginning of the project and extends throughout the development process.
Planning	The focus is on the continuous and short-term planning, since the degree of uncertainty is much higher in the long-term planning.
Estimative	Estimative are made with transparency and communication. Instead of treating the estimative as facts, it is considered that there an uncertainty in relation to the estimated value for each increment of the software.

It can be inferred that Scrum and XP have different but complementary approaches. While the focus of Scrum is on the planning and project management, XP focuses on the software development practices.

A correlation between practices of the investigated methods was also carried out. Table II summarizes the main practices observed in Scrum and XP. For instance, in XP, the current versions of code are integrated every day in order to reduce integration errors (incompatibility), and to identify implementation errors as fast as possible. In the case of Scrum, the integration occurs only at the end of each sprint (iteration). In XP, developers create tests for each feature before implementing them (Test Driven-Development – TDD). In Scrum, tests occur in parallel with the implementation within the sprint.

The characteristics and practices observed in the investigated agile methods were also used as foundation for the establishment of specific method for OERs. The most important practices from the perspective of OERs were incorporated and adapted to its context of development.

Figure 1 illustrates the sequence of development of the proposed method. In summary, the OER project starts from the needs of the instructor and/or learner (customer). These needs are reflected in resources that are prioritized by the customer during the iteration planning. From this, the development team selects and estimates the resources that are capable of being created during the current iteration.

TABLE II. CORRELATION BETWEEN SCRUM AND XP PRACTICES

Practice	Scrum	XP
Release and Iteration Planning	√	√
Stories	√	√
Metaphor		√
Daily Meeting	√	√
Iteration Evaluation	√	√
Release Evaluation	√	√
Retrospective	√	
Test Driven-Development (TDD)		√
Simple Design		√
Refactoring		√
Coding Standard		√
Code Collective Ownership		√
Continuous Integration		√
Single Repository		√
Small Releases	√	√
Pair Programming		√
Real Customer Involvement	√	√
Informative Workspace	√	√

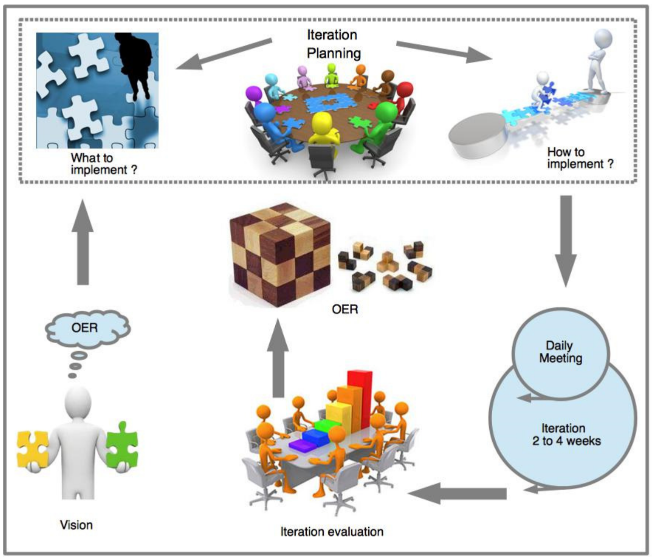

Fig. 1. Agile method for OERs: development flow

The development project is divided in cycles or iterations. Each iteration ranges from two to four weeks. Every day, the team makes a quick meeting to monitor the project progress and present the main obstacles to accomplish the work. At the end of each iteration, the team comes together to evaluate the work done within the iteration. Afterwards, a retrospective of the iteration is conducted to gather lessons learned and improve the next iteration. The process repeats until all resources are met, culminating with the final version of the OER.

The method consists essentially of agile development practices and associated roles. Issues of the collaborative development of OER are considered, including the adoption of Web 2.0 tools. Next, the proposed method is described in terms of its practices, roles and life cycle.

A. *Practices*

Iterative and Incremental Development

The OER development occurs incrementally by short repetitive iterations, which lasts approximately between two and four weeks. Periodically, the customer has the opportunity to use and evaluate the OER release, providing feedback to the development team. A release represents a functional module of the OER that will add value to the customer. New resources and enhancement requests are created as development progresses in the process. The resources are constantly integrated throughout the development until reach a final version of the OER. At the end of all iterations planned for the OER, a stable and robust version to be used and shared with others is delivered.

Collaborative Development

All those involved in the OER project must interact and constantly cooperate throughout development, either personally or through collaborative technologies. Thereby, problems and difficulties related to the specification, modeling and implementation of the resources may be solved more quickly, reducing development time and effort.

Metaphor

The development of OERs usually involves people from different areas (educators, designers, web designers, testers, programmers, among others). Therefore, it is important that the OER functioning be described using a common language and easy to understand (without the use of technical terms). This allows a more effective communication between the various parties involved, as well as assists in creating a simple project for the OER development.

Stories

All resources of the OER are briefly described as stories (into small paper cards), highlighting only the main ideas of each resource. Each story contains an estimative and its priority of creation. To describe the resources, we suggest a very simple format proposed by Cohn [19], which shows the benefit associated with each resource: As an <user/role> I would like to <resource> for <the importance degree of resource for teaching/learning>.

Iteration Planning

In the iteration planning, the team comes together to analyze and decide the set of resources of the OER that must be created within the iteration. The manner in which the work will be conducted has to be planned, as well.

The iteration planning can be divided into two parts. In the first part, the goal is to decide about the iteration target; something that generates value or benefit to the customer. Thereby, the resources to be created during the iteration are defined. Initially, the customer shows the resources according to its priority order, indicating what should be done with each one. Then, team estimates the effort needed to elaborate them and comes into agreement with the customer about what will be delivered at the end of the iteration.

In the second part, the goal is to decide how the work will be conducted during the iteration to maintain a commitment to the iteration target. Team decides how to elaborate the planned resources. In this context, the team divides resources into individual tasks. Once the tasks are established, developers select the amount of work they undertake to develop and deliver at the end of the iteration, and estimate the time (in hours) required to complete them. Thus, it is possible to obtain a detailed plan of what will be created within the iteration.

Daily Meeting

Team members conduct short and daily meetings (15 minutes in average) to discuss the completed work, the main obstacles and problems found and the next work to be performed. Daily meetings are a way to disseminate knowledge and information about the status of the project, allowing continuous monitoring of project progress. Meetings are held personally with the participation of all involved. If a team member is not available, synchronous communication tools (text mode or videoconference) can be used.

Real Customer Involvement

The customer, represented by the instructor, domain expert or instructional designer, actively participates throughout the OER development, being of fundamental importance in the definition and description of resources, as well as in the clarification of related doubts and issues.

Small Releases

Each release of the OER is composed of a small set of resources. First, a release must contain the value-added resources, i.e, those resources that are essential for teaching and learning from the customer's perspective. As development progresses, resources with lower priority are allocated to be created.

Complete Team

The team has a multidisciplinary characteristic, including professionals with different knowledge and skills, such as educators, designers, programmers, among others. Team members work cooperatively, constantly interacting and contributing to the development of effective OER.

Pair Development

Each stage of OER development, including modeling, instructional design, creation and adaptation of the resources, can be conducted by pairs of developers working side by side. This practice acts as a peer review, in which content can be revised constantly at the same time it is created, preventing errors and problems go undetected and being found as soon as possible and faster. It also acts as a way of balancing and dissemination of knowledge among team members, since the pairs of developers are exchanged during the OER development.

Collective Ownership

All team members have access to the various files that compose an OER, including text files, multimedia files and source code. Thereby, any member can make changes he/she consider relevant. However, it is necessary to manage and maintain a repository of versions and run the tests and verifications necessary every time a change is made.

Iteration Evaluation

The development team presents the work performed, demonstrating the OER or the set of resources that have been created. Users and customers have the opportunity to manipulate the OER release to check whether resources are in agreement with what was planned. Based on this, they can identify new perspectives for the OER, request changes and/or the addition of new resources and suggest improvements in a relatively short period of time, minimizing the cost of change. This evaluation occurs periodically to each delivery of the OER release.

Iteration Retrospective

After the iteration evaluation, the team has the opportunity to talk about the project. The aim is to analyze the problems and mistakes to decide what can be done to improve the performance of the next iteration. This retrospective works as a cycle of continuous improvement in which the team collects lessons learned to improve future iterations.

B. Roles

The team must include multidisciplinary characteristics and bring together all the knowledge and skills needed for agile development of OER. In this sense, we defined seven categories of roles, as shown in Table III.

TABLE III. AGILE METHOD FOR OERS: ROLES

Customer/ User	Collaborates effectively with the team, pointing out the problems, needs and key characteristics for the OER. He/she also assists in the understanding of the work to be done. Such role can be represented by the instructor, domain expert and instructional designer.
Project Manager	Manages the progress of the project, solving/minimizing the problems and obstacles faced by the team. He/she also specifies the OERs metadata and defines the validation mechanisms to be adopted.
Instructor Designer	Models the associated resources and designs the OER interfaces. He/she also acts in the validation and verification of the OER.
Instructor	Identifies the instructional needs. Plays a fundamental role in relation to the supervision and monitoring of the OER, helping to identify and record problems and improvements.
Domain Expert	Provides support for the determination of relevant parts and components of the OER, clarifying the main related doubts. He/she also helps in the resource modeling and in the validation of the instructional project.
Developer	Develops the resources associated with the OER, including content editing and integration of multimedia components. He/she also presents to the customer the work done during the iterations. He/she can assume different roles within the team such as instructional designer, tester and programmer.
Tester	Establishes implements and executes the validation and verification activities throughout the development process to ensure the quality of the OER. He/she also assists the customer to prepare the testing for the acceptance of the OER.

C. Life Cycle

The life cycle for the agile development and delivery of OERs is flexible, allowing the team to make changes they consider relevant during the development to optimize the project outcome. The cycle is composed of five phases, as shown in Fig. 2.

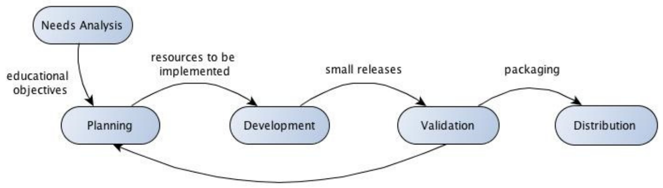

Fig. 2. Agile method for OERs: life cycle

Needs Analysis Phase

In this phase the needs to be addressed by the OER are established, including contextualized and clear definition of the educational objectives as well as the prerequisites and skills needed to use the OER. The resources of the OER are identified and summarized. At this stage, the first terms and metadata for associating resources may already be identified.

Planning Phase

In this phase the basic structure for the development of OERs is established. The resources of the OER are allocated to be created in the current iteration according to their order of priority. Customers and developers prioritize the resources to be implemented and establish the schedule for its creation.

The metadata management strategies must also be defined. The metadata specification should be standardized in order to provide reuse and facilitate the location of OER. The standardization of metadata also allows the use of OER in different educational environments and platforms. Besides that, licensing policies of OER should be defined. The use of open licenses is essential to provide reuse and benefit others users.

Development Phase

In this phase the OER is developed throughout repetitive and shorter cycles. The resources are elaborated through several iterations, culminating with the delivery of functional versions of the OER at the end of each iteration.

OERs can be developed from scratch or by combining existing resources. This phase can be divided in three steps following the development cycle proposed in [14]:

1. *Search* for resources that can adequately meet the needs, by using the Internet through search engines, databases and specific sites or searching materials previously used such as lecture notes, presentations, projects, exercises, assessments, etc.
2. *Create* a new OER in a fully way or combine the resources that were found during the search to compose a new OER.
3. *Adapt* the OER to meet the particular educational needs. In general, the composition of a new OER require adjustments to adapt it to a new context or domain, for example, translate the material into another language, make small fixes, add improvements, etc.

Validation Phase

In this phase the OER is prepared to be delivered for the learning environment. Instructors and learners are involved in the process in order to check how the OER meets the objectives initially proposed.

Extensive evaluating activities and inspections on the OER are needed, considering some quality characteristics such as: accuracy of the content, appropriateness of the content to the pedagogical objectives, resources accessibility for users with special needs, availability/location of the resources, stand-alone resources which can be reused in different contexts, among others.

Distribution Phase

In this phase the OER is available on platforms and repositories. The aim is to provide effective access to the OER according to its context and semantic meaning. The OER is packaged together with the associated metadata, in agreement with packaging standards. Such resources must be delivered according to licenses such as Creative Commons, providing few or no restriction on uses of these resources.

The distribution of the OER can be assisted through Web 2.0 tools, such as microblogging and social networking. The use of technologies such as RSS Feeds is useful to link related educational contents, and facilitate access to this OER. Moreover, media sharing can be accomplished through open tools such as Slideshare, Flickr and Youtube.

Web 2.0 tools, in particular, should be used throughout the process to provide the opportunity for those involved to effectively contribute to the development, making it more collaborative and serving as alternatives for customers/users to describe their needs.

IV. APPYING THE METHOD IN THE FLOSS DOMAIN

In this section we discuss the practical application of the proposed agile method in the development of a short course in the FLOSS domain – FLOSS OER.

Figure 3 shows the conceptual map illustrating the resources planned for the FLOSS OER during the *Needs Analysis Phase*. In this phase we also define the educational objectives, the prerequisites and skills to use the resource and the primary metadata.

The educational objective of the FLOSS OER is to clarify how specific characteristics of FLOSS may affect their use by individuals, companies, and governments. For this, some aspects need to be discussed: (i) problems related to proprietary software, and how FLOSS may become a good alternative; (ii) the emergence of the FLOSS movement, including history and perspectives; (iii) the peculiarities of the FLOSS development and the opportunities and difficulties in the interaction with their community; (iv) some major FLOSS licenses and their implications and consequences; and (v) major business models associated to FLOSS, with examples of successful approaches.

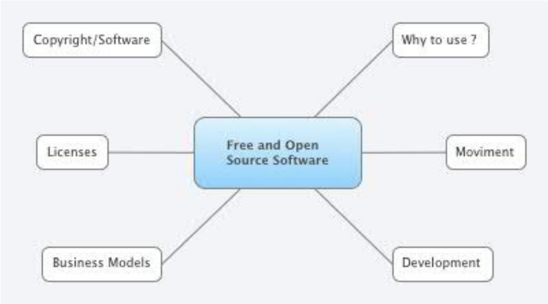

Fig. 3. Conceptual map of the FLOSS OER modules

In relation to prerequisites and skills, FLOSS OER was initially designed for graduate and undergraduate students in Computer Science and correlated areas. Specific knowledge and skills are not required.

In the *Planning Phase* we planned the iterations required to develop the resources, the media components, the metadata standardization and the licenses policies of the resources.

Four iterations were planned for the development of FLOSS OER. Two weeks of duration for each iteration was scheduled. In this paper, we focus on the first iteration planned. Figure 4 shows the conceptual map illustrating the *Licenses* resource, prioritized by the customer to be implemented in the first iteration.

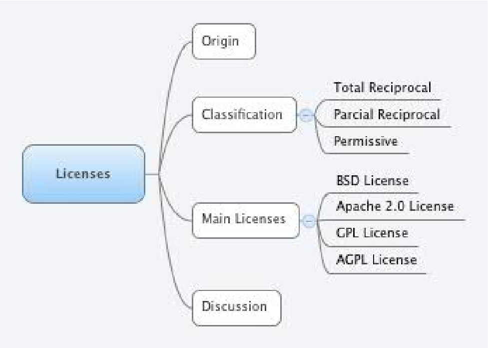

Fig. 4. Conceptual map of the Licenses resource

The *Licenses* resource was divided into small pieces (resources or topics) which were broken into smaller pieces (resources or concepts). It was chosen since licenses correspond to a key aspect regarding the FLOSS domain.

The media components planned to compose FLOSS OER were: text documents, hypertext, slides and podcast/streaming videos.

To formalize the resources description, an open metadata standard was adopted – *Learning Object Metadata (LOM)* [IEEE Standard Learning Technology Committee, 2002]. LOM was selected since it establishes an adequate set of elements to describe educational resources such as OERs. Furthermore, its hierarchical structure allows managing different kinds of metadata. Figure 5 shows an excerpt of the XML file containing the primary metadata for the FLOSS OER.

License policies of the FLOSS OER were defined in accordance with *Creative Commons Licenses* [21]. In this case, the OER will be delivered according to the license *Attribution-NonCommercial-ShareAlike – BY-NC-SA*.

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```

Fig. 5. FLOSS OER: primary metadata

In the *Development Phase*, we firstly searched for open materials which could be reused and adapted to our purpose. Open materials available from the FLOSS Competence Center (CCSL) [20] were used as a basis for developing the FLOSS OER.

Resources, topics and concepts were designed and implemented as a set of slides, integrated to HTML pages, text documents and multimedia files. Figure 6 shows some components of the FLOSS OER and their integration.

To edit the content associated to the FLOSS OER, some open tools were used: (i) *LibreOffice*, for creating the set of slides and text documents; (ii) *LaTeX*, for creating text documents; (iii) *XMind*, for creating conceptual maps; (iv) *SlideShare*, for providing the set of presentation slides; and (v) *Youtube Movie Maker*, for creating and delivering video. To support the communication among the members of the development team, we use asynchronous (electronic mail) and synchronous communications tools as (instant messaging system and videoconference).

In the *Validation Phase* the resources developed in the target iteration were evaluated by two specialists. The produced content as well as the educational goals were taken in consideration. Besides that, customer and users were involved to verify if the resources were in accordance with the objectives initially proposed. Criteria as accuracy and appropriateness of the content to the pedagogical objectives were considered.

Requests for changes and improvements were collected to be implemented in the next iteration. The next activities also include the development of the other resources planned for FLOSS OER.

Although preliminary, the results obtained so far reveal the feasibility of the practical application of the proposed method in the agile development of OERs. The next iterations planned to the development of FLOSS OER should be performed in short-term, acting as a validation mechanism to the method as well.

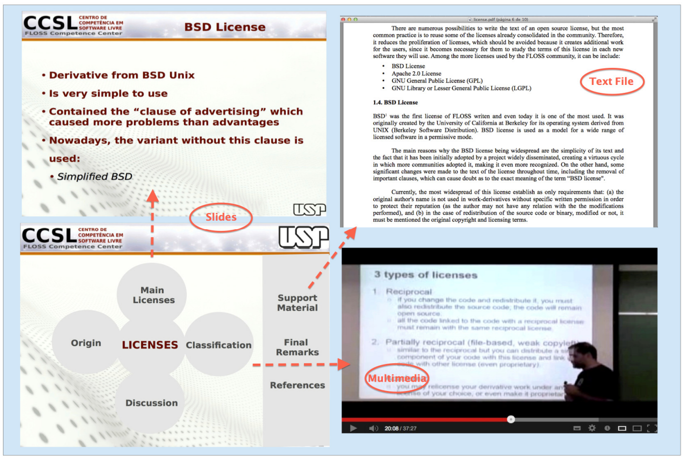

Fig. 6. Components of the FLOSS OER

V. CONCLUSIONS AND FUTURE WORK

In this paper we presented a preliminary version of a method for the agile development and delivery of OERs. The method was based on the main characteristics, principles and practices of agile methods for software, taking into account intrinsic aspects of OER development. The method has been applied (and validated) in the development of an OER for the FLOSS domain. It is worth to notice that the proposed method is also being developed in an incremental way, i.e., according to an agile approach.

The main contribution of this work is to encourage the adoption of systematic and (at the same time) flexible methods to develop and deliver OERs in a collaborative and agile manner. The idea is to create and deliver reliable and quality OERs, capable of being reused in different contexts of teaching and learning.

As a further work, we intend to keep evaluating and evolving the proposed method through the complete development of FLOSS OER. OERs for different knowledge domains should be produced in short term as well.

Aspects related to the distributed development of OERs should be also investigated and incorporated to the method, mainly regarding the geographical dispersion of the involved team. In this context, the monitoring activities and modules that comprise the OER and support for communication between teams are essential aspects to be considered.

Besides that, we intend to investigate the establishment of a repository/platform to support the creation, delivery and sharing of OERs, considering the aspects identified in the proposed method. A detailed analysis should be conducted to identify different tools to be used in order to effectively support the method in the development and delivery of OERs.

ACKNOWLEDGMENT

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A Model to support a Learning Object Repository for Web-based Courses

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***Abstract*—The demand for digital learning content has been increasing in the last years and the advent of the Learning Objects (LO) concept has the goal of mitigating some of the difficulties related to authoring such kind of digital content, by proposing a reusable model and an open metadata standard classifications for them. Nevertheless, digital learning content authoring is often an expensive and time-consuming task that requires many distinct professional skills. One attempt to overcome it is the adoption of Learning Object Repositories (LOR), in order to smooth LO manipulation experiences for teachers and content authors. Some of its keys characteristics are: to promote LO dissemination and reuse to users in a unified spot; and, to serve LO through flexible searches and enforce a metadata standard classification. This paper proposes an innovative repository model to support LOR and their use in web-based courses in the context of an specific LMS, the Moodle environment. The model is flexible, enhances digital content searches and can be fully integrated with an institutional LMS. Moreover, it offers a social environment for peer evaluation and, more important, information about the student performance, resulting in an efficient evaluation of the available contents.**

Keywords—Learning Object Repository; Learning Object; Authoring; Reputation; Dissemination; Repository and LMS integration; MOOC.

I. INTRODUCTION

The increasing availability of Web based courses has raised some demands in distinct distance learning fields. One of these consequences is that educational digital content production, storage and dissemination is continuously growing. Another related factor is the integration of these materials within *Learning Management Systems* (LMS).

Considering LMS in general, we could say that these family of tools are becoming ubiquitous in education [1], among them Moodle (*Modular Object Oriented Distance Learning*) is one of the most popular, since it is free software with a huge community of developers (http://moodle.org).

However there are several other LMS, some of them free (like Sakai, Claroline and Dokeos), others commercial (like Blackboard and Desire2Learn) [2]. This ecology of systems emerged another important question: "how to distribute learning contents?"

These digital contents have been frequently described by many authors during last years. In a general way, these materials are named by *Learning Objects* (LO) [3] and [4]. It could be found divergent definitions for LO, by usually a LO is a digital content tailored for educational purposes, that can be used, reused and combined for learning in education within interactive learning environments or just mediated by computers.

Nevetheless, LO adoption has some intrinsic issues that must be taken into account. Although the LO undelrying idea is to reduce production cost by cooperation [5], some researches relate several difficulties faced by teachers considering them. Some of them could be cited: *i*) high costs associated with LO authoring; *ii*) time-consuming processes; *iii*) lack of procedures and standards for sharing those materials; and *iv*) negative practical experiences for reusing their materials in an LMS environment [5].

Several organizations and government institutions have proposed and supported researches that aim to overcome these difficulties. Few years ago a new field emerged from these researches, considering LO and repositories, the reason why it was called *Learning Objects Repository* (LOR). One of the main goals of researches that address thos area are interested in facilitating the dissemination and reuse of LO in Web based courses [6], [7] and [8].

The use of LOR has reduced the problem of authoring since it provides for teachers ready to be used content that was already tested for other teachers. These content could be referenced and reused indefinitely to compose new sophisticated materials, from the composition of others LO.

Nowadays, there are a few hundreds of LOR systems, indexed by LOR public directories, like OpenDOAR and ROAR. Some of them are:

- DSpace (http://www.dspace.org);
- Fedora Commons (http://www.fedora-commons.org);
- EPrints (http://www.eprints.org);
- Merlot (http://www.merlot.org);
- Ariadne (http://www.ariadne-eu.org);

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Despite the progress already achieved, there are still a series of barriers that hinder their usage by teachers. Some of them are: lack of integration between LMS used by teachers and LOR systems; high learning curve for users and difficulty for creating packages; and logical dependencies among associated LO [9].

Another difficulty associated with LOR is the big amount of LO available. The teacher must select an adequate content considering the student knowledge and their context.

This paper presents a model to circumvent these problems and the deployment of this model to a particular LMS, the Moodle environment. The proposition is an innovative LOR, named *iRepository* (*Interactive Repository on the Internet*), which can be integrated with Moodle. Besides the usual LOR resource, *iRepository* brings important information from the content use by its users. Since it is integrated with Moodle, it has access to any internal data, including the assessments made by students. From these data it can produce a better evaluation of its LO, informing the teacher, e.g., what are the better ranked questions considering an specific school year of an specific subject.

The *iRepository* intention is to overcome some barriers highlighted before, promoting to the teachers the use of qualified LO. It is an evolution of previous work [10], *iDCR* system (*Interactive Digital Content Repository*). Both of them are integrated with Moodle data and provide reputation and recommendation for both LO and its authors.

Nonetheless, *iRepository* presents an improved method of reputation using the outcomes from the students with any item of the repository. In addition, *iRepository* provides a model to LO versioning [11].

This paper is organized as follows. Section II presents previous work of our research group that is related to the proposed model. Section III shows related work about LOR research field. Section IV exposes *iRepository* proposed model that justify this current work and next, section V presents its implementation supported by Moodle LMS. Last section discusses some possibilities for future work.

II. Previous Work

The research group hosting this project, *Laboratory of Informatics in Education* (LInE), has performing researches about the aforementioned difficulties. In order to increase interactivity while doing an assignment using Moodle environments, it were released the *iAssign* package [12]. On the other hand, to promote the cooperation between teachers it were done a proof of concept of a LOR integrated to Moodle 1.9, named *iDCR* - *Interactive Digital Content Repository* [10].

iAssign is a Moodle package conceived to integrate *Interactive Learning Modules* (*iLM*), that usually are Java applets (Fig. 1) into Moodle. Such integration provides means for Moodle users to have interactive intense experience with the learning content produced with the iLM. *iAssign* is available to Moodle from version 1.9 on and it is distributed as a free software (http://www.matematica.br/ia).

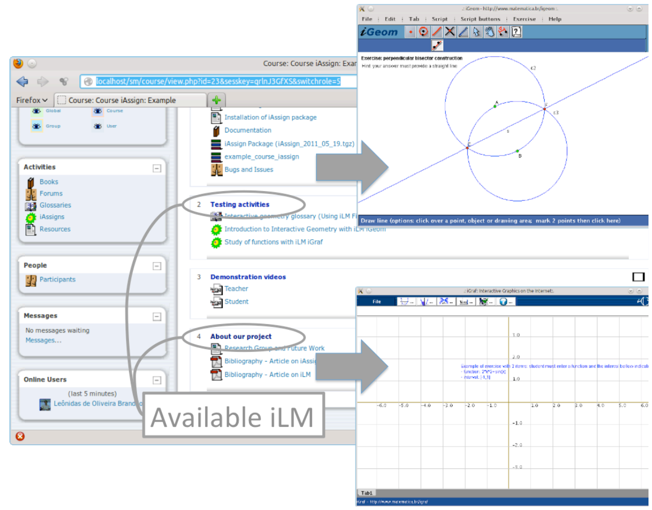

Fig. 1. The *iAssign* interface for Moodle 1.9 linking with two *iLM* (adapted from [12])

The second package, *iDCR*, had no public version made available. It was built to be integrated to Moodle 1.9 and by the time of its deployment, Moodle 2.0 was released and the adaptation of *iDCR* to Moodle 2.0 would lead to a lot of changes. The group leader decided by aborting that project and the *iRepository* is an evolution of *iDCR,* whose implementation is compliant to Moodle 2.0.

The *iRepository* and *iDCR* model allows communication with LMS internal data. This means that it can store LO in any level of aggregation, from a single text to a complete course. Both also provide reputation evaluation functionalities defined by the content's authors.

iRepository extends *iDCR* model in some aspects. The former presents evaluation of each content considering its use. If the content has automatic assessment, some measures could be performed to inform teachers how effective they classified it whenever it has been when used with a specific level of education.

III. Related Work

There are several work related to LOR and associated technologies. An interesting work is MEDUCA (http://gilt.isep.ipp.pt/meduca/) platform and the MELOR (http://gilt.isep.ipp.pt/melor) reposity [13]. The MELOR is based on DSpace and the MEDUCA platform integrates the MELOR repository to a Moodle environment. It is specialyzed in health learning and introduces a new layer of control to manage the submission, indication of referee and aproval to any submited LO.

Comparing this work with our, we could say that they use an external (and existing) repository, integrated to the LMS by web-service communication mechanisms. iRepository is integrated to Moodle and communication between them is transparent. In addition, they do not consider any information related to the student performance while consuming the content stored in the repository. Our proposal provides means for using information related to the student performance, as well as the ones related to the content's author.

The LORSE [14], is a multiagent system based on JADE (Java Agents Development Framework) to support teachers and students to reduce time in the process for searching learning objects in several LOR, such as MERLOT, Connexions, and Fedora Commons repositories. The approach of this work is also to integrate a LOR with the LMS, in this case the authors used the free system dotLRN (http://www.dotlrn.org).

The difference of this work with *iRepository* is the same when considering MEDUCA: they do not use internal information about the student usage of the repository items.

Another related work is [15]. Their goal is to provide information to LO based on crowd knowledge. They extended Fedora Commons repository and integrated it to a web site. In their extension, it is possible to put tag under the standard ISO/IEC 24751 (http://www.iso.org/iso/catalogue_detail.htm?csnumber=41521).

This work integrates the LOR with the learning environment (here a web site), but they do not have or use information related to the assessment of LO.

IV. Proposed Model

Considering Web-based learning, a common difficulty faced by regular teachers after finding suitable LO in a repository is how to integrate an specific LO to their electronic lessons. The proposed model supports most of the international standards for digital content description; it provides means for storing and retrieving LO from several levels of granularity (from a single text to an entire course); it supports versioning control and history tracking of LO; it supports the evaluation of LO reputation based on its use and its author and works as a peer-to-peer service provider. Nevertheless, since it integrates the repository with the internal assessment of an LMS, it has a bridge between the repository and the LMS database which is responsible for several of the provided functionalities.

In order to give some hints about how these functionalities are provided, some of *iRepository* key characteristics are described below:

A. Improved LO classification and searching

iRepository support major international standards addressed for digital contents, such as IEEE Learning Object Metadata (IEEE LOM) and Dublin Core. As a result, *iRepository* search engine will be more accurate. The LO could even be indexed in external LOR that supports same metadata standards, such as Ariadne (http://www.ariadne-eu.org) and Merlot (http://www.merlot.org).

B. Fine and course granularity of LO and dependency control

Since *iRepository* must be integrated to the LMS, an LO can be, for instance, a complete Web course or it could be an atomic LO, such as static texts or interactive activities. It is desirable that teachers could create and organize LO in such a way that they represent a logical arrangement of associated digital contents as a single self-contained package. Ongoing project supports granularity from a single text document to a complete course. It can facilitate author's composition, versioning, and distribution of more complex LO.

C. LO history tracking and versioning control

It's expected that LO contents could change over time – by adding, removing, or updating some of its core files as well as changing their metadata.

iRepository project keeps track of any change made by an author in such a way that all the LO's versions and data histories are automatically tagged and stored in the repository. This information can also be retrieved and checked by authors. They may also create new materials from any previous LO version.

D. LO reputation evaluation by other content authors and by content effective use

Usually a repository provides peer evaluation and reputation for LO and/or its author. This is an important indicator to the LO quality, and could be used in ranking searches: the indicators will be considered in search engines to promote good rated LO to the top of the search results.

In *iRepository*, a more interactive evaluation scheme is provided by the regular use of any item in the repository. This could provide information for accurate recommendation of digital content to a teacher during the search for a specific subject. The recommendation of content is, potentially, based on a large amount of the student experiences. For instance, it could involve: the number of correct answers to the item or mean time used by the students to answer that item.

E. Peer-to-peer service provider

iRepository has an architecture that provides peer-to-peer communication interface between distinct instances of the repository, as a federation of repositories. Any *iRepository* instance not only serves its environment, but also may be configured to exchange data with any other external instance. This feature could even bring new interesting possibilities in future, such as off-site LO backup, network balancing and inter-institutional collaboration projects.

The integration of these features could make *iRepository* an environment propitious to implement Item Response Theory [16]. The questions (or any assignment with automatic assessment) could be used to estimate the difficulty of the question.

V. Implementing The Model

In order to validate the model described in last section, we proposed an implementation prototype, supported by Moodle. There are many reasons for driving us towards the choice of this environment. The primary reason is that Moodle is a free software, allowing anyone to contribute. A second reason is its internal architecture, that is organized in such a way that a contributor can extend several of its features. A third reason is that the Moodle communities of development and of users. Moodle is used in more than 200 countries, by more than 40 millions of users [2].

The Moodle architecture allows a new package to extend some existent features. Usually it could be a plugin, a block or a filter. Mostly, *iRepository* is a Moodle block.

A. *Improved integration with Moodle Modules*

In this project the repository can exchange data with others modules besides *iAssign*, in a generic manner. This means that *iRepository* can register some information useful to evaluation of any of its item (LO). This is very important to promote a better scheme of content reputation. For instance, this can be used to identify a specific content for a specific curricular level or it can help teachers to find questions that present different levels of difficulty.

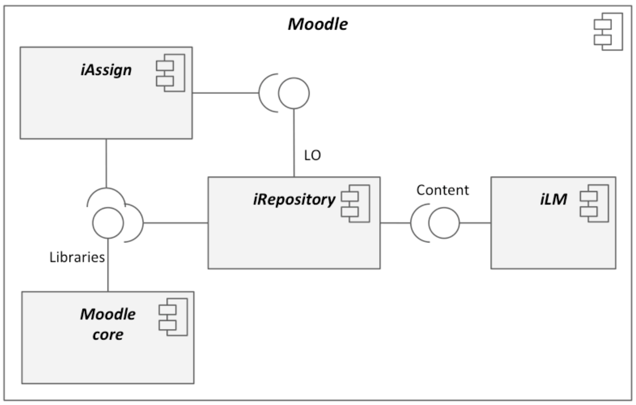

Fig. 2. UML Component Diagram for *iRepository* Moodle Environment

Fig. 2 shows a UML component diagram about an overview integration process between *iRepository* and Moodle Modules, using *iAssign* as an example. The last will act as a LOR client that have just to call repository methods to retrieve, update or store any content. Integration of iRepository with any Moodle package will be simple as is: the implementation of some inferfaces to retrieve, update and store content.

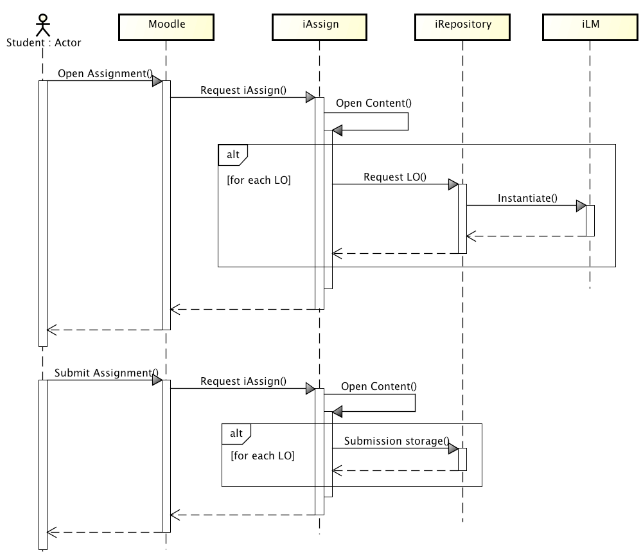

Fig. 3. *iRepository* as a LO provider for an *iAssign* and *iLM* modules

Fig. 3 shows a sequence diagram describing *iRepository* acting as an interface for *iAssign* and *iLM* modules. A student requests a Moodle *iAssign* activity. Each of its LO component (e.g. *iLM* module) is instantiated by the *iRepository* and returned back to the *iAssign*. After its submission to Moodle by the same student, *iAssign* can retrieve again its LO components and store each of them in the *iRepository*. The entire process is tracked and information related to te LO use from several point of views can be collected to be used further.

B. *Smooth learning curve for teachers and content authors*

Seamless interoperability between Moodle and *iRepository* is one of the key benefits of developing this new repository. Teachers and content authors do not have to switch between Moodle and any external LOR (e.g. Fedora Commons or DSpace), nor have to sign-up and login on distinct systems.

The *iRepository* is integrated with Moodle system in such a way that the its user actions can be called and executed through the LMS interface, following a familiar structure to the end user. Considering a regular teacher, not expert in technology, this feature could be sensitive to promote its use.

Authorization module for *iRepository* also shares Moodle user accounts, roles and privileges, so is not necessary to setup additional accounts besides Moodle's. The main interface of *iRepository* is presented in Fig. 4.

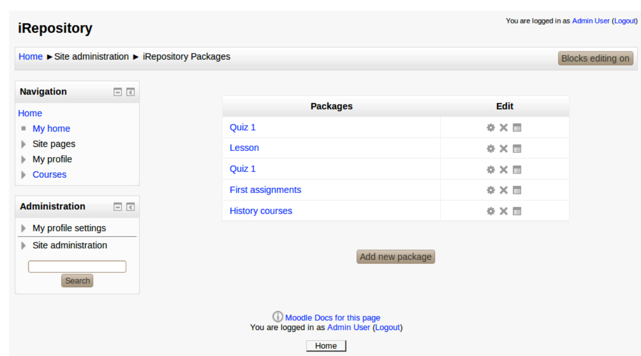

Fig. 4. *iRepository* main interface to Moodle

C. *The MOOC feature*

The previous features of *iRepository* results in interesting features from *MOOC* (*Massive Open Online Course*) besides preserving features of traditional e-learning courses.

Considering that *iRepository* allows the concept of federation of repository, can track the effective use of content item, and that several activities in Moodle allow automatic assessment (including *iAssign*), the proposed repository can leverage Moodle use to a higher position.

It can bring to Moodle's authors a kind of information typically gathered by MOOC: a massive collection of data related to the students outcomes. This data can be transformed into information to improve contents and courses. This kind of approach could be a partial answer to a question by [17]: "At this time MOOCs are fashionable and institutions are flocking into the business. Even though nobody has yet figured out how to make MOOCs profitable or at least financially sustainable". The use of any content item in several courses will provide important information about its quality: when use it? under what level of skills?

Also, it can produce a feasible model to implement *IRT* (Item Response Theory) [16].

VI. Conclusion and Future Work

This paper describes a project related to an innovative LOR that is integrated with Moodle environment, the *iRepository*.

In face of literature about educational authoring content, the *iRepository* was designed to reduce the difficulties of a regular teacher with e-learning environments.

There are several LOR available, each one with a huge number of learning objects. However these LOR environments are rarely used by teachers, e.g., in the last two years, in four courses with teachers or prospective teachers of Mathematics, no one had used a single LO to teach. In two of these courses, all the attendees were teachers with at least two years of experience and had about 15 students per class.

Although the proposed model is platform and system independent, an instance of it has been deployed to Moodle as a plugin. The Moodle was chosen because of its philosophy of open source code and its large amount users. This plugin will be available at Moodle Web page, so any interested user will be able to download and install it.

A future work must be an evaluation the *iRepository* with regular teachers. Another improvement would adopt agents to implement ontologies and semantic networks for accurate search results and interoperability among systems.

Acknowledgment

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Development of Educational Techniques for Computational-Experimental Analysis

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***Abstract*— A curriculum wide initiative to enrich course content and increase student engagement in experiential learning through the adoption of new learning modalities is underway in the Department of Mechanical and Manufacturing Engineering, Miami University, OH. The projects entail the development of online learning modules which interweave experimental and computational analysis. The modules incorporate multimedia content which has been prepared with undergraduate and graduate student participation. The ComEx website has been designed to enable easy uploading/updating of material. The distinctive feature of the ComEx studios is the thematic linking of the content which allows them to be used for multiple classes with a progressive advancement in technical content. This paper presents details of the studio model: motivation, methodology, implementation and assessment. The learning modules can utilized by faculty to introduce new lab derived content, which may be related to their research, into a traditional class only course format. Additional benefits of the modules include the ability to independently review specific topics in preparation of advanced courses or for a research project. Assessment of the efficacy of the modules is being performed by students surveys completed online, and by four external (faculty) reviewers. Continuous improvement of the modules is underway.**

Keywords—Learning modules; Matlab; Experimentation

I. Introduction

Miami University has an enduring and nationally recognized tradition of excellence in undergraduate education. U.S. News ranked Miami 3rd for undergraduate instruction among national universities in 2012. Preservation of this heritage has been achieved through the provision of myriad student resources, creation of a vibrant liberal arts culture, and, perhaps most importantly, through the creation of instructional methodologies that are informative, immersive, and permit an exploration of the quintessential *'what if'* ideas during the course of study. One tool the Department of Mechanical and Manufacturing Engineering (MME) has developed in response to this last challenge has been a set of online ComEx studios in five areas (name is derived from the computational-experimental nature of the activities). Each studio is comprised of at least two multimedia learning modules which are to be used in conjunction with MME courses or in research preparation. The project is described in more detail in the following section.

The use of online instructional material in engineering is by no means a novel approach, but it is revealing to examine the format and scope of some existing practices in order to contrast the objectives and methodology of the ComEx project. The use of simulation tools in various subject areas such as fluids, dynamics, and noise/vibration has been demonstrated in [1-3], with more advanced 3-D simulation methods being presented [4] in the context of power systems and manufacturing environments. The provision of various toolboxes and the ability to prepare graphical user interfaces (GUIs) in Matlab has been utilized, as in this project, by other faculty [5, 6] to create interactive learning tools in which the effect of changing various input parameters can be readily explored by students. Simulation tools can also be used to create virtual labs, which can enrich a course by animating and aiding in the visualization of key concepts. Such exercises are essential for sustaining student interest, exciting creativity, and instilling a sense of appreciation of the engineered world. Some examples of virtual labs have been demonstrated by [7-9] in areas such as robotics, materials testing, and mechanics of materials. The incorporation of assessment methods has been highlighted by several authors, see for example [8,10-15], and some significant observations have included a favorable impressions of the ability to complete online modules at one's own pace and the effectiveness of the modules, while some criticism was directed at the inability to receive immediate guidance and lags in virtual lab activities.

The ComEx grouped approach to the deployment of learning modules stands in contrast to the single course module structure seen in the majority of the aforementioned studies. Each studio serves as a repository for a group of courses which can be connected along thematic lines across the curriculum. An additional distinguishing trait is that the learning modules within each studio are structured such that students are introduced to a given experiment and provided several sets of emerging data which are then used towards the testing of analytical models associated with the experiment. This paper presents a brief outline of the five studio areas using the Materials studio as an example. The section following that is devoted to an explanation of the assessment process and its application towards continuous improvement of the modules focusing on the deployment of an interactive Java based applet as a case in point. Details of the assessment process and some significant findings have been included. The paper concludes

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with a discussion of the modifications planned for future semesters.

II. Project Structure

The ComEx project, projecting a two year development plan (key components being: creation of modules → assessment → revision), was initiated with support from the NSF-TUES. The motivation for the project emerged from a departmental student questionnaire which was designed to gather information on the level of student competency in being able to select, apply, and validate mathematical models against experimental data. Such skills are essential in myriad fields of engineering such as dynamics, thermodynamics, fluids, and manufacturing to name just a few, to ensure that product design and performance can be optimized by computer simulation methods while minimizing often prohibitively high experimentation costs and process lead times. This theme of computational-experimental juxtaposition established the guidelines for the organization, content, and presentation of the ComEx project. Key features of the project include:

1) Thematic grouping: The five ComEx studios are titled, i) Computational Core, ii) Design and Manufacturing, iii) Thermo-Fluids, iv) Materials, and v) Dynamics, Vibrations and Controls. With the exception of the Computational Core, all of the other studios feature a set of learning modules that span a set of courses. The Core studio has been populated with several tutorials and examples in a variety of mathematical platforms which students can adopt in their analyses. The ComEx homepage is shown in Fig. 1.

2) Longitudinal Utilization: The learning modules within each studio draw upon content from specifically selected courses. For example, the Materials Studio serves as an umbrella for the sophomore level Engineering Materials, the junior level Mechanics of Materials, and senior/graduate level Advanced Mechanics of Materials courses. The activities are designed to progressively introduce more advanced concepts and allow students to build upon previously learned concepts.

3) Content Expansion: The ComEx studios are designed to augment courses that lack a lab component by affording instructors the ability to use the multimedia content to familiarize students with specific experimental processes. The Materials Studio provides details of composite sample preparation and a video of the tensile testing performed to characterize the deformation properties. The data from multiple such tests is made available for download and can be used for various types of analyses.

Fig. 1. Image of the ComEx homepage.

III. Assessment

This section provides an overview of the project assessment mechanisms, and an example of how some of the first cycle assessment data has been used to implement changes to the project in preparation for the second cycle. The Ohio Evaluation and Assessment Center [16] at Miami University was contracted for creating and administering surveys in collaboration with the faculty using the studios. Input has been gathered from the following two sources.

1) External reviewers: Four senior faculty with prior experience in pedagogical research have served as external reviewers on this project. After completion of the first round in Fall 2012, a second round of assessment will be conducted in Fall 2013.

a) Process: The reviewers were provided student survey data from the first semester the ComEx studios (Materials and Dynamics/Vibrations) were used in MME courses. The two reviewers who visited the department also spoke with several students who had completed the learning modules, as well as the students involved in their preparation. Furthermore, they were asked to review the modules which had thus far been brought online, and complete a 25 question survey (with space for comments) which addressed various facets of the project. In addition to high priority characteristics associated with content delivery, user engagement etc, the questionnaire probed for evidence towards the attainment of the following outcomes:

- Recognize engineering concepts within multidisciplinary fields
- Apply knowledge of engineering and mathematics.
- Prepare systematic methodology for testing hypothesis.
- Select and utilize specific numerical approaches for simulating physical systems and phenomena.
- Engage in independent learning and research.

Some of these outcomes enable the fulfillment of certain ABET program accreditation requirements, thereby, incentivizing their adoption by departments and encouraging their use across the curriculum.

b) Findings: A sampling of the questions and results from the reviewer survey are provided in Fig. 2. The data in general suggested good progress towards the attainment of the project goals, and the comment, "ComEx would seem to be a nice environment that helps extend across curriculr borders such that one could begin a project or problem in one class, that can then be used in othe courses," captures very well the aspiration of the ComEx studios to be interwoven into the engineering curriculum. Two of the key reviewer suggestions pertained to making the student experience more interactive, and making the user experience more consistent across the various learning modules. Details of the efforts directed at fulfilling these requirements are presented in Section ABC to demonstrate continuous improvement through the use of assessment data.

2) Students: Online student self-assessment surveys based on their experience in completing a learning module(s) have been conducted each time a module has been used. The process began in Spring 2012, however, at that time the project website had not been completed which engendered a tepid response vis-à-vis the clarity and cohesiveness of the activities. An improvement of scores in these categories is anticipated.

a) Process: The online surveys are designed not only to elicit data for a given module, but sections of the form gather longitudinal data to gage the cumulative experience as students advance to higher level courses. In Spring and Fall 2012, 55 and 26 students, respectively, in a 200-level materials course responded to the survey. Data in other studios has been collected as well, but the presentation and discussion of data in this paper has been limited to one studio for brevity.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
The ComEx exercises/activities will improve students' understanding of the technical processes and approaches related to the module content.				2	1
The ComEx exercises/activities require students to review and/or apply previous learning from other engineering courses.				1	2
The ComEx exercises/activities will improve students' skills in using computational tools (Finite element software, Excel, MATLAB, etc.).				1	2
The ComEx exercises/activities introduce students to computational or experimental technology that may be unfamiliar to them.			1		2
The ComEx exercises/activities will strengthen students' interest in the content of this module.			1	1	1
The ComEx exercises/activities provide access to the learning modules within the institution and enable utilization by other institutions.				3	

Fig. 2. Excerpt from the reviewer survey form. The numbers indicate the responses received from three reviewers. Data from the fourth reviewer was not available at the time of this writing.

b) Findings: Some representative data from the 29 question form is shown in Figs. 3 and 4. As stated in the Project Description section, an important feature of this project was the introduction of new content in an independent learning format. In the context of the materials learning module, this meant learning about the preparation, testing, and analysis of composite materials. It is reassuring to see in the data that students were able to recognize this characteristic of the assignment. Mirroring the observation of the external reviewers, several students also suggested a more streamlined incorporation of supporting images and improved clarity in the instructions.

IV. Continuous Improvement

An example of the use of assessment data for introducing changes to the assignments can be seen in the development of new Java applets.

		Level of Agreement				
		Strongly Disagree	Disagree	Unsure/Neutral	Agree	Strongly Agree
a.	This ComEx module improved my understanding of the technical content necessary to be successful in this course.	SD	D	UN	A	SA
b.	This ComEx module improved my understanding of the technical processes and approaches related to the course content.	SD	D	UN	A	SA
c.	This ComEx module required me to apply previous learning from basic science (physics, chemistry and mathematics).	SD	D	UN	A	SA
d.	This ComEx module required me to apply previous learning from other engineering courses.	SD	D	UN	A	SA
e.	This ComEx module improved my skills in using computational tools (Excel, MATLAB, etc.).	SD	D	UN	A	SA
f.	This ComEx module introduced me to current or emerging computational or experimental technology that were unfamiliar to me.	SD	D	UN	A	SA
g.	This ComEx module strengthened my interest in the content of this course.	SD	D	UN	A	SA
h.	This ComEx module provided the opportunity to learn and apply new concepts (experimental and/or computational).	SD	D	UN	A	SA
i.	This ComEx module provided the opportunity to review content I had previously learned.	SD	D	UN	A	SA

Fig. 3. Section of student survey form.

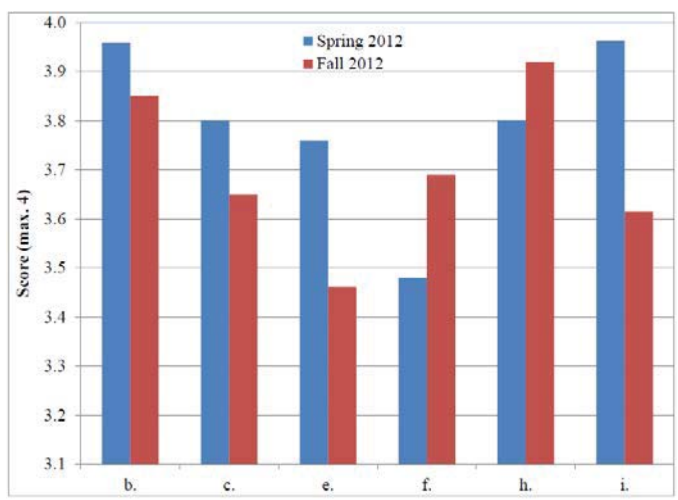

Fig. 4. Results of student survey (Fig. 3) for Composite Materials Characterization learning module. Data from six questions most relevant to the discussion presented here has been illustrated.

With the aim of making the modules more interactive, as suggested by the reviewers, and enabling students to investigate the effect of various parameters on process/model output, a simulation tool with a graphical user interface (GUI) has been developed for the Composite Materials Characterization module in the Materials studio. An image of this GUI is shown in Fig. 5. Students can change materials, from fiberglass to carbon fiber for example, and immediately perform a comparative analysis. For more advanced analyses, typical of a senior level course in advanced mechanics of materials or behavior of materials, a more advanced deformation modeling GUI is shown in Fig. 6. Both of these will be bundled into the Materials studio learning modules to achieve vertical integration of content.

In light of the intent to disseminate the ComEx content to other institutes, the development of the GUIs is also worth mentioning on account of the nature of the method of deployment. A GUI developed in a specific mathematical software typically requires local availability of that software for execution.

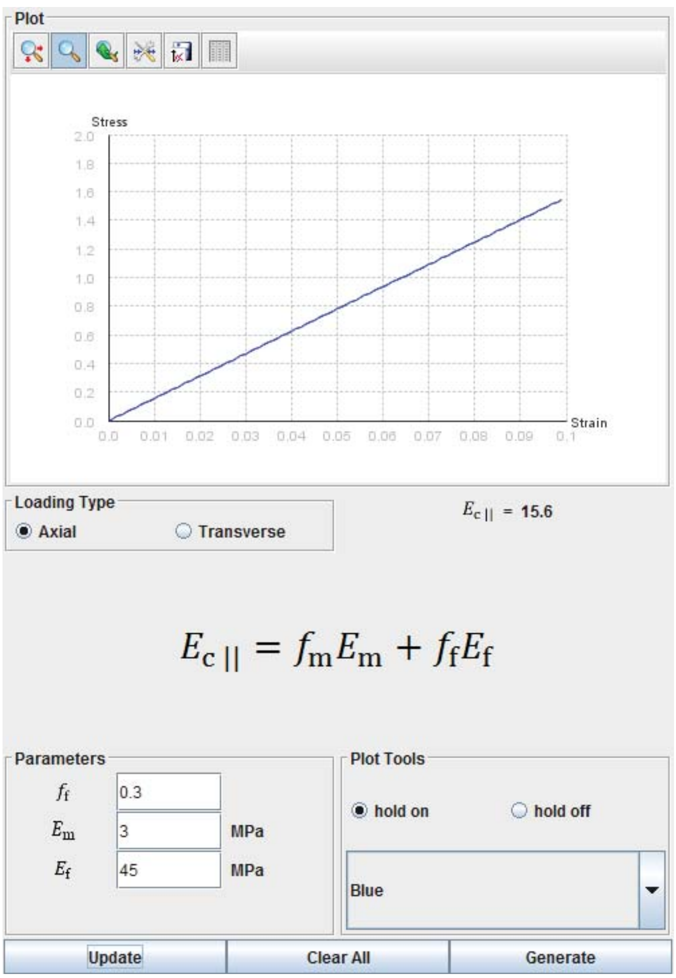

Fig. 5. Screen-capture of the Java based composite simulation tool.

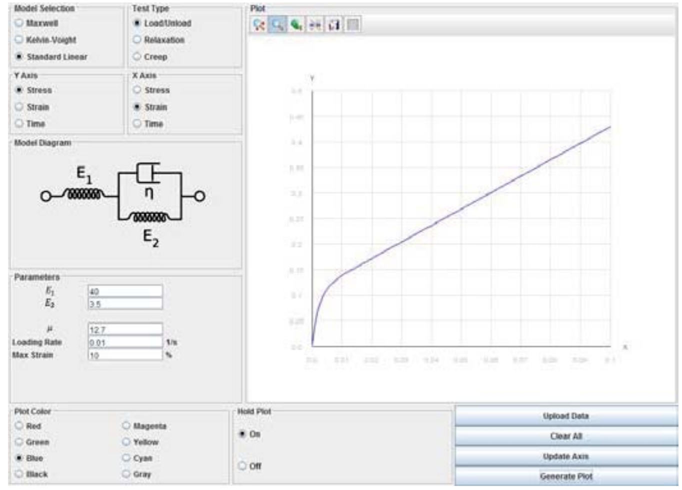

Fig. 6. Image of more advanced Java based interactive material property simualtion tool.

Since institutional preferences for software for faculty and research needs vary greatly among institutes, development of a universally operational GUI must shed it reliance on a specific software. Therefore, the preparation of the GUIs shown in Figs. 5 and 6, which even entails the solution of a first order linear differential equation, has been accomplished in a Java applet format which can run directly off the webpage. However, it is pertinent to add that more complex mathematical formulations (coupled or higher order differential equations etc.) may not be amenable to reduction to this environment, and the simulator shown in Fig. 7 does require the use of Matlab. The Java based GUIs can be used in sophomore and senior level courses in materials science and mechanics of materials, while the Matlab based tool is best suited for graduate students or use in research.

Other revisions to the modules include changes to the instructions, inclusion of more data sets for comparative studies, and greater consistency in style among the four subject specific studios.

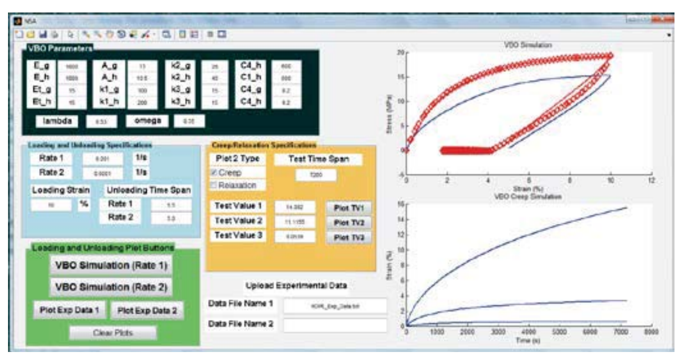

Fig. 7. Matlab based GUI enables determination of material parameters by enabling experimental data to be uploaded and juxtaposed against the numerical output. Multi-function capability allows various tests and experimental parameters to be input into the model.

V. Conclusions

The ComEx project was launched to address the need for greater proficiency in the use of computational methods in design and/or process analyses in areas of industrial significance. The computational methods are investigated in tandem with experimental data and packaged as learning modules with specific subject themes designed to allow progressive utilization across the curriculum. The learning modules have been found to be effective vehicles for the introduction of new content. A regular internal and external assessment process has been used to improve the quality and efficacy of the learning modules. Future work will comprise of increasing the number of learning modules, improving student interaction, and focusing of dissemination tasks.

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Using linked open data to improve the search of open educational resources for engineering students

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***Abstract*— In this paper, authors apply the Linked Data Design Issues to describe and retrieve information that is semantically related to open educational resources related to the Engineering Education, that are accessible via the OCW Higher Institutions. Linked data have the potential of create bridges between OCW data silos. To assess the impact of Linked Data in OCW, the authors present an interface of faceted search for open educational content. The authors demonstrate that OCW resource metadata related to engineering open courses can be consumed and enriched using datasets hosted by the LinkedOpenData cloud.**

***Keywords*— OpenCourseWare; Open Educational Resources; OCW; OER; Linked Data; Faceted Search Engine; Serendipity; LOCWD**

I. INTRODUCTION

The key idea the Open Educational Resources (OER) movement is that open educational content should be maximally shared [1]. Heterogeneity leads to problems of interoperability and accessibility of open content among institutions and within them. The lack of interoperability shows some disadvantages in the discovery, reuse, re-mix and adaptation of OER. OER Community must find a way to exchange quick and easy access to open educational materials.

Materials in OCW repositories are not usually described by metadata. Heterogeneity leads to problems of interoperability and accessibility of open content among institutions and within them. The lack of interoperability shows some disadvantages in the discovery, reuse, re-mix and adaptation of OCWs. OCW Community must find a way to exchange quick and easy access to OER.

Considerable work has been devoted to increase the interoperability between Learning Object Repositories that rely on different metadata schemas e.g. IEEE LOM. However, learning object metadata is typically not linked across repositories and not is possible navigate or interoperate between different data sources available on the Web. In this work, this problem is addressed through Linked Data by that describes how linked data has been integrated to data extracted from OCW repositories to navigate OCW resources.

Based on the perspective of Linked Open Data, free open OCW data also fosters interoperability and creates a basis on which the use, re-use, remix, and adaptation of open educational tools or commercial applications can be built more easily. In Section 2, we describe the OpenCourseWare domain, and the notions of Linked Data and Linked OpenCourseWare Data Vocabulary, which ensures that an OER of type OCW can be safely discovered and reused. In Section 3, we present Serendipity, our implementation as well as an experimental evaluation of it. Finally, in Section 4, authors present the conclusions.

II. THE OPENCOURSEWARE DATASET

A. Data Source and Coverage

There is not a standardized way to implement OCW initiatives. The internal organization, structure and technological infrastructure of an OCW project are diverse, and respond to the vision of each university. Current OCW initiatives are Silos of OER. These silos of OER have no way to link to a particular item, and so hinder the free flow of information [8]. In this respect, OCW data is locked away in independent data silos, making it much less useful than it could be.

In this work, the data source is provided by higher education institutions associated to OCW Consortium (www.ocwconsortium.org/) and/or OCW – Universia (ocw.universia.net/).

Our dataset contains data about the main OCW concepts: (i) OER, the OER are teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or re-purposing by others. (ii) OpenCourseWare, OCW is a type of OER.; (iii) repositories that contains OER and OCW courses; (iv) educational organizations; (v) users, creators or authors; (vi) branch of knowledge to which an OER belongs; and, (vii) open licenses or similar license that generally allows more liberal use, reuse, redistribution, re-mix and adaptation than a traditional copyrighted work.

B. Use of Linked Data from OCW content

Semantic Web technologies and, more precisely, Linked Data are changing the way information is stored and exploited. [5, 6]. The term "Linked Data" refers to a set of best practices for publishing and connecting structured data on the Web [4]. In summary, the Linked Data Design Issues, outlined by Tim Berners-Lee back in 2006, provide guidelines on how to use standardized Web technologies to set data-level links between data from different sources [3, 7].

The motivation behind creating the Linked OpenCourseWare Data (LOCWD) is threefold [9]: *Firstly*, data about OCW resources such as those stored in the Serendipity system are important for Educational decision makers, teachers, self-learners and other interested persons. We are particularly interested in courses related to engineering (see Table I and Table II). *Secondly*, although there are several open educational datasets, none provide the level of details that LOCWD does, nor are they available as linked data. And, *thirdly*, the current technology solutions used by OCW and OER sources are limited to offering data via diverse Web pages (not as raw data, but as embedded data within web pages) and very few services through APIs.

The selected open educational content were converted to Linked Data using the LOCWD vocabulary [9]. The resources described in Linked Data/RDF were stored in a RDF-Store. At this point, each resource was identified by a URI with a dereferencing option, and thus display the results retrieved as Linked Data.

TABLE I. OPEN COURSES RELATED TO ENGINEERING (EXTRACT)

University	*OCW quantity*
Massachusetts Institute of Technology, MIT	704
Universidad Carlos III de Madrid, UC3M	148
Universitat Politécnica de Catalunya, UPC	95
The Open University, OU	87
Universidad Politécnica de Madrid, UPM	56
Korea University, KU	38
Universidad de Alicante, UA	38
Universidad Politécnica de Valencia, UPV	33

TABLE II. OCW - KNOWLEDGE AREAS RELATED TO ENGINEERING

Knowledge Area related to Engineering	*Universities*
Electrical Engineering, Technological and Computer Sciences	MIT, UC3M, UPM, UPV, UPC, OU, KU, UA
Mathematics & Physics	MIT, UC3M, UPM
Mechanical Engineering	MIT, UC3M, UPC
Chemical Engineering	MIT, UC3M, UPC
Materials Engineering	UC3M, UPC, UPV

III. CURRENT USAGE

It's difficult to develop tools for consume data from multiple OCW silos. Searching OCW/OER across multiple silos means invoking each one's user interface, and receiving the results in separate groups. This severely impedes the development of applications to OER/OCW that wish to combine data from different sources. However, the use of linked data approach on OCW repositories provides the framework for its evolution into a more interoperable and integrated system to sharing, connecting and discovering data and metadata of OCW initiatives.

The authors have personalized a faceted search engine that consumes data from LOCWD: Serendipity. The first version of Serendipity is based on flamenco.berkeley.edu. With Serendipity we explore the potential of LOCWD in supporting discovering process to give assistance to use, reuse and remix OER and OCW resources. See fig 1.

A. *Serendipity a Faceted Seach for OpenCourseWare Content*

Serendipity is an interface of faceted search accessible from http://serendipity.utpl.edu.ec/. It is based on data extracted from OCW sites. Serendipity provides a search interface for allowing users to browse OpenCourseWare content in such a way that they can rapidly get acquainted with the scope and nature of the content, and never feel lost in the data. This interface exposes OCW metadata in such a way that users can build their queries as they go, refining or expanding the current query, with results automatically reflecting the current query. This interface also combines free-text search, it avoids complex search forms.

Faceted search, also called faceted navigation, is a technique for accessing content organized according to a faceted classification system, allowing users to explore a collection of information by applying dynamic and multiple filters. A faceted classification system classifies each information element along multiple explicit dimensions, enabling the classifications to be accessed and ordered in multiple ways rather than in a single, pre-determined, taxonomic order.

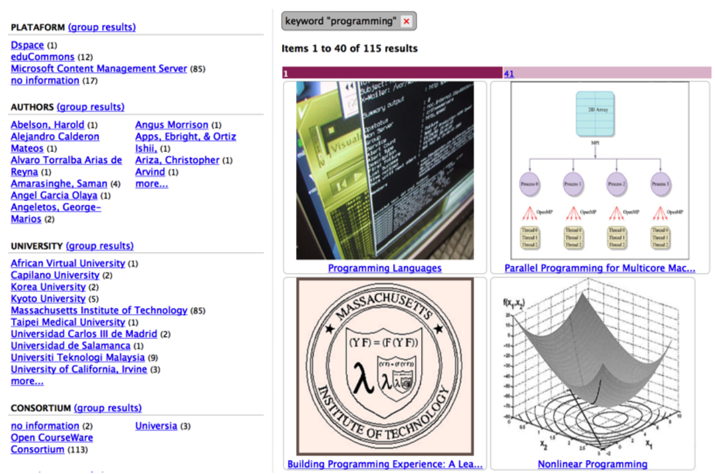

Fig. 1. **Explore OCW in an integrated and incremental manner**, from any of the repositories of institutions that publish OpenCourseWare.

B. *Data and Facets in Serendipity*

In Serendipity, facets correspond to properties of the OpenCourseWare content.

Any of the following cases might prompt to a teacher, student or self-learner to use Serentipity faceted search: (i) Users need to filter content using multiple category or taxonomy terms at the same time. (ii) Users want to combine text searches, category term filtering, and other search criteria. (iii) Self-learners don't know precisely what they can find on OCW site, or what to search for. (iv) Self-learners want to clearly show users what subject areas are the most comprehensive on your site. (v) Self-learners are trying to discover relationships or trends between OCW. (vi) OCW sites has too much content for it to be displayed through fixed navigational structures, but you still want it to be navigable. (vii) Self-learners want to use a faceted classification because a single taxonomic order or a single folksonomy is not suitable or sufficient for OCW content. (viii) Users often get empty result sets when searching your site. (ix) In cases that "advanced" search forms are not fun to use.

Fig. 2. Link from current OCW in Serendipity To Other LinkedData Source

C. *Navigation of OCW engineering courses*

In the search of OCW courses related to engineering, Serendipity demonstrates the following key features: Grouping search results by facet, displaying a total number of OCW per facet value, refining search results by facet value, update of the facet menu based on refined search criteria, displaying of the search criteria in a Bread Crumbs (navigation guides), ability to exclude the chosen facet from the search criteria, ability to improve ease of discovery open academic resources, ability to improve ease of consumption and reuse of OCW. ability to reduce redundancy in search of OCW, and Connect OCW Data with LOD data. Querying DBPedia, authors obtained additional information about universities such as name in different languages, label, comment, latitude, and longitude. From Geonames were extracted data about locations like continent, country, capital, city or state. To find and create external links, in this work were made directly SPARQL queries (see Fig 2). With Serendipity, we demonstrated that OCW resource data can be enriched using datasets hosted by the LinkedOpenData cloud.

We have verified that the data published in Serendipity is consistent and corresponds to the information obtained in various OCW sites and OCW Consortiums.

IV. Conclusions

The key idea the OER and OCW movement is that open educational content should be maximally shared. Any open educational data initiative should focus on providing data access permissions so that: provide non-discriminatory access/use/reuse/create derivate works/adapt/share to raw data, information and knowledge about the educational resource.

A lot of open educational resources ends up focussed on usage of open licenses, but not enough attention is paid to structure. Simply putting educational resources online under an open license is obviously not enough. Doing open educational resources data well depends on releasing key datasets in the right way. Moreover, with the proliferation of OCW/OER sites it has become increasingly hard to discovery and track what is happening in Open Educational Context.

In summary, we have shown that our implementation provides better results than other similar systems. Besides, we have also shown that our implementation, which benefits from linked data technologies, can be more appropriate to deal with interoperability and integration of OCW repositories.

Acknowledgment

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Latinos and Latinas in the Borderlands of Education

Researching Minority Populations in Engineering

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***Abstract*—We use the "borderlands of education" as a metaphor for studying processes of educational exclusion in engineering and the social forces that create them. Latinas in engineering education occupy intersecting borderlands. On the path to higher education, they face numerous societal obstacles. As women, they are on the margins of the masculine space of engineering. Though Latinas in engineering comprise a very small group, through their voices and experiences, we illuminate broader structural problems within engineering education.**

Keywords—Latino; Latina; Hispanic, engineering; underrepresented minorities, women in engineering

I. Introduction

We use the "borderlands of education" as a metaphor for studying processes of educational exclusion in engineering and the social forces that create them [1]. Latinas in engineering education occupy intersecting borderlands. On the path to higher education, they face numerous societal obstacles resulting from a legacy of racism. As women, they are on the margins of the masculine space of engineering. Though Latinas in engineering comprise a very small group, through their voices and experiences, we illuminate broader structural problems within engineering education.

How do Latino and Latina students navigate engineering education? We examine quantitative data to illuminate trends among Latinos and Latinas in engineering education. Using a large longitudinal data set with comparative information by race/ethnicity, we report six-year graduation rates disaggregated by ethnicity and gender. Similar to other researchers who examine retention longitudinally, we found that the paucity of Latinos and Latinas in engineering is related to recruitment more than retention. Our data shows that Latina transfer students are particularly successful and that geography and institution type affect academic persistence.

How do Latinas describe experiences of belonging in engineering education? We draw on qualitative research to examine the experiences of Latina students in undergraduate engineering education. We use the framework of "microagressions" in our analysis and describe how Latinas form counterspaces within the borderland of engineering education. This qualitative research, incorporating the rich, detailed perspectives through the women's voices, adds value to our understanding of the quantitative reality of engineering as a segregated space in academia.

Is there potential for radical change in engineering education? What might radical change look like?

II. Methods and Contributions

A. *Studying Engineering Education: Problems of Aggregation*

Research in STEM education tends to conflate racial/ethnic categories, aggregating and constructing a category called, "minorities". Disaggregation for social analysis, particularly in STEM higher education, is often difficult by discipline, because of the low population numbers. Much nuance, however, is lost in the aggregation of social groups. A notable example of the power of a single individual's story is the work of Foor, Walden, and Trytten [2] who described in-depth the story of female, multi-minority engineering student from a socio-economically disadvantaged background. In a similar methodological vein, Riley and Pawley [3] explore the experiences of a lesbian Latina engineering minor to critique myths of gender and race in engineering education.

In general, there is a paucity of disaggregated data on underrepresented groups, especially women of color, in STEM. Most studies aggregate by group, for example considering "women" or "underrepresented minorities," thereby assuming all women or all African Americans and Latinos share the same educational experiences. Because there are deep limitations to using a single category of analysis, feminists suggest the need to use an intersectional approach to best understand the multiple positions that combine unique gendered, racialized, social class, and sexuality perspectives that individuals inhabit [4]. An intersectional approach does not gloss over differences; rather, such an approach considers that not all women, for example, share the same experiences. The core of the intersectional paradigm suggests that relations of power are central in defining identities, and that identities may shift.

Similarly, many excellent studies also aggregate by field combining Science, Technology, Engineering, and Mathematics into STEM [5, 6], to the exclusion of studying a single discipline in depth. While there are important

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methodological and theoretical arguments for aggregating these fields (because of shared foundational course requirements, or because of historical similarities in these disciplines), there are also disadvantages. Aggregating by discipline can lead to hollow findings due to a lack of specificity. Glossing over differences buries diverse intracultural differences by discipline, leading to a silencing of voices that ultimately hampers our ability to understand the social positions of those on the border in engineering education. Engineering education is uniquely different from other categories aggregated in STEM.

B. *Importance of mixed methods*

One of the primary reasons that a book on the topic of Latinas in engineering has not been produced to date is because of the low numbers of women in the field of engineering, preventing systematic data analyses. Our large, multi-institution, longitudinal dataset provides quantitative data allowing us to disaggregate by race and gender. For the qualitative data collection, we used focus groups, given that this methodology provides rich descriptions of the participants' shared experiences. We focused on one large public university with a fairly diverse student body so that we could identify sufficient numbers of women of color in engineering and we used a case study approach to allow for intensive analysis [7, 8]. Together, our analysis of the voices of Latina engineering majors, obtained by our focus group research, breaks new ground in the literature on STEM education and provides an exemplar for future research on subpopulations in these fields.

III. Key Findings

A. *Quantitative*

Among Latinos and Latinas the proportion of bachelor's degrees awarded in engineering in the U.S. has marginally increased between 1991 and the present [9]. Of all engineering degrees earned in 2005, for example, 7.2% were awarded to Latinos and Latinas [10] and increased to 8.0% in 2010 [11]. Latinas have made gains in engineering, from comprising only 4% of the Latino engineering population in 1977 to 25% in 2005.

A serious issue in research on underrepresentation is the lack of data-driven studies. Although there is no national, longitudinal data for academic persistence tracking the trajectory from matriculation to graduation among Latinos, the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) [12, 13] database provides a unique resource for investigations of this type at ten institutions. MIDFIELD includes records for more than 130,000 first-time-in-college (FTIC) students matriculating in engineering and over 40,000 transfer students articulating in engineering at eleven U.S. institutions with nine of these in the Southeastern U.S. Race and ethnic categories are student-selected from institutional records. Results from the study of the MIDFIELD database are expected to generalize to the same type of institutions, large public universities with above average enrollment of engineering students, and therefore are relevant to institutions producing most engineering graduates nationally [14]. Since this dataset includes whole population data, statistical inference is unnecessary—all reported differences are accurate for the institutions and subpopulations studied.

Of the total MIDFIELD population, this analysis focuses on the over 84,500 FTIC students and over 27,500 transfer students who have sufficient data to calculate six-year graduation rates during the period from 1987-2010. Graduation is defined as having graduated by the sixth year from matriculation, following a standard of reporting by the Integrated Postsecondary Education Data System (IPEDS) [15].

The MIDFIELD data set allows for the examination of longitudinal trends over time, however, the former trajectory of transfer students (prior to entering a MIDFIELD institution) is unavailable. MIDFIELD permits analysis of transfer students once they enter a MIDFIELD institution and no information is available about a student's previous major. A student's progress is measured from a curricular progression standpoint to estimate how long they took to graduate. For example, if a transfer student comes in with sufficient credits to begin taking junior level courses and finishes in three years at the MIDFIELD institution, the student would be considered to have an effective five year time to graduation.

Note that this dataset permits calculation of true graduation rates following the same students from matriculation to graduation. Such calculations are not possible with other datasets such as that of NSF that provide enrollment and graduation data for given years but provide no way to track individual students.

B. *Recruitment, Not Retention, is the Challenge for Latino Engineers*

Latinos and Latinas who enter engineering education persist (i.e. do not switch majors or drop out) at numbers comparable to Whites and Latina transfer students are the most successful of groups. Table 1 shows the number and percentage of engineering matriculants and transfers who graduate in six years in Engineering. Of all Latinos who matriculate in engineering, 50% of the women and 48% of the men graduate in six-years. This exceeds the overall six-year graduation rate of 46.9% reported for FTIC Latinos in all majors at public four-year institutions in the U.S. by College Board College Completion Agenda: Latino Edition [16].

Often originating at community colleges, transfer students provide a potential source of many engineers and a more diverse population of engineers [17]. This potential is particularly true for Latinos in our dataset where 40% of the Latino students who are ever engineers are transfers, higher than the 30% for White students. For comparison, in national data from the U.S. Department of Education, in Fall 2007, 34% of White and 40% of Black college students were in community colleges while 51% of Latino college students were in community colleges [18]. As seen in Table 1, the high graduation rates of engineering transfer students may be due to these students having already successfully passed many lower division courses. Transfer students have firsthand experience with the rigorous curriculum of the major; they have already surmounted many hoops, are more knowledgeable about the major, and thus more invested in a commitment to success.

Latino transfers in engineering are particularly successful. Latino males have graduation rates in engineering only surpassed by Asian males. Latinas, are the most successful among all transfer students, having the highest six-year graduation rate in engineering. This success may be related to what several researchers describe as the “personal agency, or internal drive”, of women of color in college that contributes to their persistence [19] including Latinas in information technology [20] and Chicana and Latina transfer students in science and math [21]. Valenzuela called this "mi fuerza" or "inner fire to succeed" [19, p. 88].

TABLE I. NUMBER AND PERCENT OF ENGINEERING MATRICULANTS AND TRANSFERS GRADUATING IN ENGINEERING BY RACE/ETHNICITY AND GENDER. ORDERED BY TRANSFER GRADUATION RATE.

		Engineering Matriculants		Engineering Transfers	
		N	**% graduating in Engineering**	**N**	**% graduating in Engineering**
Latino	Female	494	50%	191	72%
Asian	Male	3799	57%	1687	63%
Latino	Male	1860	48%	848	63%
Asian	Female	999	57%	397	62%
White	Male	52501	53%	16159	57%
Black	Female	3404	46%	1004	55%
White	Female	12713	54%	3328	55%
Native American	Male	270	39%	136	53%
Black	Male	5617	38%	1834	49%
Native American	Female	84	43%	26	46%
TOTAL		81741	48%	25610	57%

C. Qualititative

Latinas are attracted to engineering for a variety of reasons. Given that there are so many more men who are engineers, it is not uncommon that often it is a male role model inspiring Latinas. Some Latinas described a long-time affinity toward math and science. Some feel a transnational affinity to their parental homeland and a desire to improve it materially and believe that work in engineering can make a difference abroad.

How do Latina women experience the climate of engineering undergraduate education? Our findings suggest that Latinas in engineering redefine ideas of success, which paradoxically, focus on learning how to fail. They described how they overcame inhibitions of failure, given forced curves, and effectively learned not to be psychically devastated by receiving a low grade, given they had been high achievers in high school. They also discuss how they cope socially, in the face of some adversity, in order to persist in undergraduate engineering courses.

Racialized microaggressions are “brief and commonplace daily verbal, behavioral, or environmental indignities, whether intentional or unintentional, that communicate hostile, derogatory, or negative racial slights and insults toward people of color” [22, p. 271). Researchers have found instances of microaggressions in the experiences of women of color in STEM classrooms including feeling unwelcome, unsupported, or invisible [19, 23, 24]. Microaggressions can be experienced by women in engineering in many forms. They can be experienced at the institutional level (such as through biases in the curriculum, structure, and type of assignments, and even in accepted canons of the knowledge base), at the interpersonal level (in the form of snubs, dismissive gestures, or seemingly innocent comments that are perceived as hurtful, inappropriate, or insulting), and as jokes and humor that subtly deride women’s place in engineering. Although there is somewhat of a shared experience among undergraduate engineering women, microaggressions are processed differently depending on race/ethnicity.

Latina engineering students experience detractors, people who second-guess their commitment to pursuing engineering. For example, students described with mixed emotion the sense that outsiders insinuate they are not a good fit for engineering and outsiders express shock or surprise that they are studying engineering. Some Latinas described the sense of feeling excluded in terms of a double oppression, first as a woman, second as a person of color. Some women felt displaced when men asserted sentiments such as “you’re only here because you are a woman.” For women of color, this displacement is compounded by assumptions of being an affirmative-action baby—highlighting not only subordinate status, but also a hint that they might not be academically qualified. In this example, a Latina student shares her response to such assumptions:

> In high school . . . my guy friends actually ended up going into engineering. [A] lot of them didn’t get into [this institution], . . . they were very, well, jealous of it really [chuckles], because they really wanted to come here. [They would say] “You’re a girl and you’re Hispanic, and you’re going into engineering. Dude, why would they not take you?” And I was like, “No, it’s because my GPA is higher than yours, my SAT scores are higher than yours, and I’m more involved in school than you.”

This Latina student explains how she has to establish her credentials because assumptions are made that she is unqualified based on her minority status as a woman of color in engineering. Another Latina had a similar experience. She related, “I’m in the honors program here. And one of my friends was like, well, the only reason you got in was because you’re Hispanic. And I [thought], ‘I do better than him in every single class, but somehow he is still better than me.’”

Some women suggested that at the interpersonal level, men in their academic work groups simply ignored them; they felt invisible. One Latina student laments that when she offers a solution she is ignored but when the same response to a problem is proposed by a male student, then others listen. “I don’t think they do it on purpose. It just—it shows.” Her deflated tone in the focus group, accompanied by her final comment, “it just shows,” suggests that she sees the disparity in how she is treated by male students, even though she does not clearly articulate it as an injustice.

Women's voices are unheard because there are so few, thus stereotypes about who is capable, and who is not, are reproduced. As one Latina suggests,

> I don't know if it's necessarily because they're [men], but I think it's the people that speak up in class, you know, they're the ones asking questions, and you think, "Wow. They must be really smart." And because of the ratios in our classes, most of the time it is guys, so you make that connection that, you know, you make that connection that guys really are smarter than that girl. But I think it's because we're so outnumbered.

Insightfully, in this quote this Latina reflects that her own perceptions of who is smart germinate from who is most likely to speak openly in class. Given that the classes are primarily filled with men, this produces a particular effect—one that perpetuates the stereotype that men are smarter, faster at composing responses, and more confident in their intelligence. The perception of the women that men are "smarter" or better at technical topics echoes the influence of "stereotype threat" -- As a result of stereotype threat, women are less likely to have confidence in their own abilities; they second-guess themselves and take longer to produce answers. These patterns of behavior reinforce false ideas about biologically determined intelligence, that men are innately more capable. A higher percentage of women would somewhat diffuse majority male voices. The situation can be so caustic for some women that they avoid group work altogether. This type of exclusion can be harmful academically given the importance of group work in engineering education and practice.

When Latinas were asked about stereotypes, they reflected in terms of gender, not ethnicity, and described stereotypes that emerge because of their low representation as women in engineering. The fact that men are responding in greater numbers, more quickly, contributes to the stereotype that women are not as smart. Women are keenly aware of this numerical bias, and address it in terms of stereotypes that challenge them. Thus the low numbers of women represented institutionally directly affect them through stereotypes.

Latina women differed from other women in focus groups in their emphasis on "learning how to fail." Latinas explained her early frustrations and learned that a key to persistence was adapting to the curve method of grading, "Learning to fail, learning that you're not good at everything. That was a huge shock to the system." Latinas adapt to the climate in engineering education by attempting to carefully navigate setbacks. Students explained how they learn to stand up for themselves when they feel ignored or marginalized. "Yeah… speak up. Because most of the time when you're right, and you know you're right, guys will fight you until the end. They'll [say] 'no, I think you did this wrong.' So just stick with your guns, I guess." As this Latina suggests, "sticking to your guns" is a warlike metaphor to suggest that it is a battlefield for some women. And yet, even with this powerful metaphor, her assertion trails off with, "I guess," suggesting she is not convinced of this potential. In these subtle comments we perceive the complexity of being one of few Latina women in the classroom, and the difficulty in having the confidence to have faith in your own work, knowing that others may put you down even before they themselves do the work. Among those who persist, they describe isolation, depression, and obsessive behavior as common territory for engineering students.

For one Latina, the consequence of this competition and sense of isolation, meant not having friends in her major. "I'm mostly friends with people that are not engineers. This is probably a gross stereotype, but they just want to talk about school and classes." Another adds, "Most of the people here just talk about classes instead." Another concurs, "Yeah, you'll meet them at a party, and then [chuckles] they'll be like, 'Oh, class . . . that test was so hard!' And you're like, 'Are you serious?' [She and others laughing]. 'It's Friday night and we're both drinking, an' you're telling me about the test' [laughs]." Another exclaims, "I'm like, 'What is this—we're at the party!'" Latina women describe their social life as bracketed between students with whom they can talk about their academics vs. "real friends." Latinas reported being more likely to join engineering societies that offer support to women of color (such as Society for Hispanic Professional Engineers [SHPE]). However, they cite professional development, not social opportunities, as the most likely reason for joining. The idea of having one peer group for academic interactions and one for social interactions was also found by researchers for women of color in college [25, 26] including Latinas [23]. Since academic peer support has been found to be an important contributor to persistence [19], the difficulty in finding such support is problematic for Latinas.

Our findings demonstrate that Latina engineering students continue to experience many of the same challenges faced by women and yet respond in unique ways. This work demonstrates a pattern across geographic location and through time as our findings are consistent with those of Hacker [27], Seymour and Hewitt [5], and Tonso [28] beginning decades ago.

IV. Radical Strategies for Recruitment

To fulfill the potential of Latinas in engineering, we propose radical systemic changes as well as targeted intervention and recruiting strategies. We highlight a few of these here.

A. Moving Engineering Off of the Borderlands

Over the last few decades, there have been numerous and valiant efforts to enhance the diversity of the engineering and STEM workforce and educational population. Despite these efforts, diversity in engineering has not changed significantly. Such stasis points to the need for significant fundamental change. As Heywood argues, most reform efforts have operated within a *convergent framework* where the past is seen as a guide to the future resulting in incremental changes [29]. To enact meaningful change, he advocates for *divergent visioning* as a more promising strategy. Others have called for revolutionary educational reform [30, 31]. We agree that revolutionary divergent visioning is needed -- the field of engineering education cannot remain a segregated elite enclave.

The re-envisioning of engineering, we argue, should include sweeping modifications to existing curricula with the intent of moving engineering off of the borderlands of education. Currently, engineering is largely absent from K-12 education. Exposure to and preparation for engineering must happen at the earliest levels of education. Doing so ensures that engineering will be familiar to young people, Latinas included, so that they can be accessed early, enveloped in the process of understanding the field, and guided towards pursuing engineering as a career. There are hopeful signs in this regard, particularly the promise of new science standards in K-12 education in California which will include engineering for the first time [32].

We propose that engineering should become a part of the core of the education of all college-educated students. Several leaders have called for the need for engineering to be recognized as part of the essential education of an educated person in the 21st century in the tradition of liberal arts. In today's world, engineering should not be the purview of a small minority. Given our societal infusion with ever-increasing technological capacities, a greater majority must share, understand, and begin to shape it.

Faculty and academic leaders need to be champions in re-envisioning the core. As institutions reflect on and modify their mission statements, they should consider their role in meeting the needs of students in an ever-changing technological world. Technical literacy transcends academic boundaries and should reach into its current borderlands. If engineering moves out of the borderlands of education and into the core, there are implications for all faculty. Also, this should be a reciprocal arrangement: engineering faculty and students need to be more broadly educated; similarly those in other fields (social science, science, arts and humanities) need to possess engineering/technical literacy so that they can work together to solve interdisciplinary problems.

B. Innovative Pedagogical Strategies in Engineering Education

Traditional engineering education has changed little in the last few decades in terms of pedagogy and content. Efforts to change have been motivated by "rewards" such as funding from NSF and "punishments" such as ABET accreditation requirements. Both sets of structural changes slowly continue to chip away at the rigid format of engineering curricula. Promising changes in pedagogy such as more collaborative and active learning, teamwork, and community service learning all could be beneficial for all students including Latinas. In addition, culturally responsive teaching and targeted approaches that address gendered and raced inequities may be helpful. Finally, reimagining the structural format and content itself of engineering curricula yields possibilities for radical change.

Even more radical changes may be necessary to reform engineering education. This involves self-reflection by engineering educators and could expand to questioning the engineering "canon." Is there an engineering canon? If so, is it negotiable? Who decides and who should participate in this decision making process? This extends into fields such as ethics and philosophy of engineering. What significant differences would appear in engineering curricula if these questions were considered? Considering curricular questions in light of the recognition of the gendered and racialized nature of engineering could lead to new breakthroughs.

C. Community College Pathways

For Latinas and Latinos, interventions to encourage and support engineering must consider community colleges since they "are the chief points of entry for Hispanic students who go to college" [33]. These institutions could potentially play a key role in advancing Latinos and Latinas in engineering, particularly for low-income students who may benefit from taking prerequisite classes at community colleges.

Enrolling in a community college is not a guarantee of transferring to a four-year institution. Researchers have shown that rates of four-year college graduation are less for students who start in community college than those for students who matriculate directly into four-year institutions [34]. The pathways from two-year to four-year institutions for Latino/as are often difficult with few students successfully making the transition [35]. In 2008, only 25.7% of fulltime Latino students at two-year colleges graduated in three years or less. This lagged behind Asians at 31.5% and Whites at 28.5% [16]. Many of the two-year institutions where Latinos go are Hispanic Serving Institutions (HSIs) [36]. In fact, 53% of HSIs are two-year institutions. HSIs are particularly important for engineering since forty percent of Latino engineering degrees were awarded by HSIs [37].

Geography plays a significant role in the institutions that graduate engineering students. O'Connor showed that Latino students who aspired to a bachelor's degree were more likely to enroll in community college than their Black or White counterparts [38]. However, Latinos who lived in states with high Latino populations, were more likely to go directly to a 4 year college than a 2 year college compared with White or Black students. She suggests that this may be linked to the preference of Latino students to live at home along with the higher availability of community colleges outside these four states. Because Latinos are not a monolithic group, and because Hispanic-Serving Institutions serve different populations that vary geographically, a more nuanced analysis that explores variation by Latino ethnic group is necessary to inform the development of specific and effective engineering recruitment strategies. Interventions designed to increase the number of Latinos in engineering education may have the best results if these efforts are targeted at HSIs, with special consideration in states with the largest populations.

V. CONCLUSIONS

In our collective disciplinary efforts to broaden the reach of engineering education and diversify our population of students, increasingly it is important to closely examine variation by disaggregating students. Researching minority populations in engineering is of value to better understand their experiences and conditions of their persistence. We advocate for more studies that use multi-methods of investigation, quantitative and qualitative, to understand small populations in engineering. We also suggest that there is value and a need for more book-length projects in engineering education. Much research remains, and particularly more qualitative investigation is needed to understand the in-depth experiences of underrepresented groups in the borderlands of education.

Acknowledgment

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Minority Student Informed Retention Strategies

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Abstract—**Diversifying engineering programs is a major goal for almost all universities because expanding the diversity of students will broaden and enrich the knowledge and experience associated with the science, technology, engineering and mathematics community. This study looked to explore those factors that contribute to minority students' success and more precisely what contributed to their success the most so that recommendations could be made on how universities can improve their minority student retention. In order to do this, African American, Hispanic American, Asian American, and Native American undergraduate engineering students of various disciplines were interviewed using theoretically grounded qualitative methods. The transcripts were coded for patterns using NVivo qualitative analysis software and the patterns found are described in detail within this paper. These patterns gave us insight into the factors that contribute to minority students' success and therefore lead to recommendations on ways for college campuses to encourage and foster their minority students' success. The insights reported in this paper will hopefully help universities make changes that will greatly improve the success of their minority students in engineering majors.**

Keywords—diversity; retention; minority students; narrative

I. INTRODUCTION

Among minority races, interest in obtaining an engineering degree has grown, but given low retention and graduation rates of these students, completing a degree appears more difficult than for majority students. Nationally, the graduation rates in engineering of underrepresented minority students are lower compared to majority students [1]. According to St. Omer, by the year 2050 minority students will constitute the largest segment of the college population [2]. If the graduation rate of minority students remains the same, then the number of minority engineering students who fail to graduate will continue to increase. Over the last decade research has been conducted to identify factors contributing to this lower rate of degree completion. These studies have shown that the main factor affecting minority student persistence tends to be limited access to the resources and support needed to graduate.

Examination of the research reveals that lack of interaction with student organizations and technical societies, as well as with peers and faculty can have a significant impact on higher-education degree completion [3]. However, among minority engineering students at predominately white institutions, limited social networks reduce their access and utilization of these resources.

Two undergraduate engineering students enrolled in an honors research project to answer the research question "**what can institutions do to support retention and graduation of minority engineering students?**" In collaboration with their faculty advisors, the student researchers interpreted the narratives of undergraduate minority engineering students to respond to this research question with a set of recommendations. This paper is written in the voice of the students, both the honors research students through their theory-based interpretations and the research participants through their quotations.

II. METHODOLOGY

The factors contributing to successful graduation of minority engineering students at a large predominately white public research university were investigated through a study consisting of interviews of 138 undergraduate minority students. The engineering students belonged to one of four ethnic groups: Asian American (AsAm), African American (AfAm), Native American (NAm), and Hispanic American (HAm). Most of the students were juniors and seniors, and those who participated as sophomores were often interviewed again in a later academic year. All research participants successfully graduated with a bachelor's degree in engineering. We believe that the lessons to be learned from successful students are more valuable toward promoting future success than those derived from attriting students. The interviewers were given an outline to follow during the interview that included questions about the student's background, college experiences, and motivating factors. The individual interviews were open-ended questions, partially concerning what barriers the students encountered, but mostly what programs, processes, and practices helped on their paths to graduation. The interviews were transcribed and then coded using NVivo qualitative analysis software.

Analysis for this paper used a theoretical perspective grounded in an intersection of social capital [4] and heuristic knowledge theories [5]. Padilla defines heuristic knowledge as that obtained through experience in local context. As Padilla states, heuristic knowledge is most commonly passed from experienced students to new, inexperienced students either through individual or group interactions [5]. The social networks embedded in social capital are one way for students to acquire that heuristic knowledge [5]. Social capital is defined as the "aggregate of actual or potential resources linked to possession of a durable network of essentially institutionalized relationships of mutual acquaintance and recognition" [4 p.33]. Bordeiu further suggests that the quantity of social capital a particular student obtains depends on the amount of network connections the student assembles

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and the amount of capital possessed by each network to whom the student is connected [4]. Examining the students' strategies with this dual lens, we will build a model for how minority students identify and build their social networks to gain heuristic knowledge supporting success within the context of a specific academic institution.

The findings presented here are supported by quotes from the participant interviews. Student's responses are designated with their race/ethnicity and sex. Words or excerpts that appear in *italics* represent the actual language of the students. Words or phrases inside parentheses ( ) have been added by authors to add context or clarify participants response. Words or phrases inside square brackets [ ] replace or delete identifying information and are used to ensure anonymity of participants and other entities.

III. RESULTS

Developed from the data to follow, Figure 1 illustrates our model for how minority students' social networks contribute to the development and use of relevant social capital. This figure visually depicts how heuristic knowledge builds social capital. Minority student research participants are at the core of the social network. Oval and diamond shape nodes represent examples of the larger institutional bodies defined in the rectangles. Each arc connecting the participants to nodes represents a channel of communication. Through these communication channels, heuristic knowledge is transmitted from these university constituents to students. Students who build larger social networks enable more of these channels of communication and thus accumulate stronger social capital.

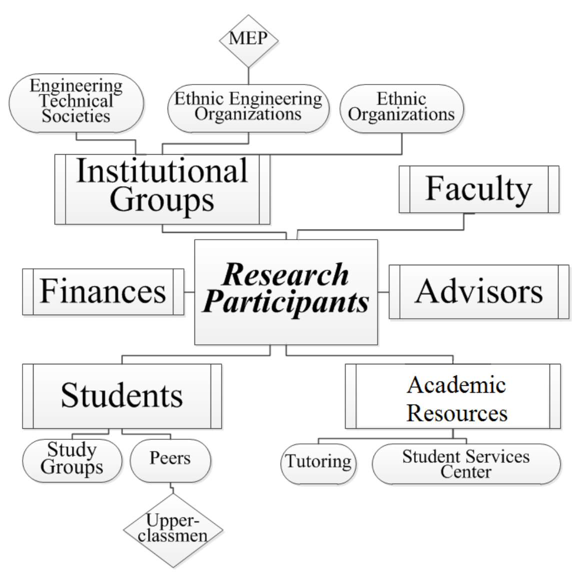

Figure 1. Model for minority student social networks of institutional bodies enabling accumulation of social capital

A. Institutional Groups

According to the minority engineering students in our study, supporting and accepting communities come in the form of ethnic organizations, and ethnic or technical engineering societies. Research reveals that minority students are culturally uncomfortable in predominantly white institutions, however, when available, ethnic-specific subcultures help students of color cope with this issue [6].

Students from all ethnic groups find that organizations like these help nurture their success during their academic career. Unlike the assumption that extracurricular and co-curricular involvement "diverts or distracts students from their academic studies" [7 p.402], our study, along with others, reveals a direct positive relationship between academics and involvement outside of the curriculum [7]. Belonging to an organization, program or society allows students to interact and socialize, to gain a support system outside their classroom. Specifically, ethno-centric organizations help minority students by providing the opportunity to build relationships with students and faculty of similar culture. For students of color at higher-education institutions, being involved in ethnic organizations was a way to "retain and nurture a sense of ethnic identity on campus" [5 p.134], which enhances the "interest, determination and aspiration of the students" [2 p.10]. Witnessing others' success encourages them to pursue their goal of graduation. One student describes the encouragement that the African and African American studies (AFAM) program gave her in pursuing her degree.

It gave me a sense of pride…helped to cure any type of inferior complex…that helped honestly in seeing other students that are successful in engineering that are black. AfAm Female

Also, involvement gives minority students access to other networks such as study groups, teachers, and upperclassmen, all contributors to success [3]. This student describes how being involved in Engineering Club (E-club) allows her to branch out, meet faculty and learn how to work within groups:

I think it's a really great way to meet people and get to know people and get to know some of the people in the college and some of the staff…so it's a really good way to get involved and it teaches you how to work with people and trying to get the best out of what little money you've got and all that stuff. HAm Female

One concern expressed by AsAm students is over-involvement with outside activities creating interference with their academics. Even with this concern, they still find that the organizations they join are a positive aspect of their college career. A minority student describes the conflict he feels regarding his involvement with his fraternity:

It gave me a lot of stress. I don't know, again it helped me work with people. It helped me prioritize and time management. Also it's an outlet it balanced engineering, a lot of times I'd get overburdened with engineering and I'd want to just give up and something that took my mind off of it for at least a couple of hours a day or hours a week. AsAm Male

Like the AsAm student describes, research has found that over-involvement outside of the classroom can sometimes lead to lower achievement in academics [7]. Further research found that students who are devoted to academics and are not involved in out-of-class activities tend to isolate themselves from peers, which can cause "smaller than-average changes in personalities and behaviors" [7, p. 392].

One of the largest support programs at this university is Multicultural Engineering Program (MEP). This program for underrepresented students includes a freshman engineering orientation class, a scholarship program, tutoring services, and other opportunities. Most participants in our study were involved with MEP. However, AsAm students use MEP only as a resource for tutoring. Students from the other minority groups are more engaged with MEP, enrolling in the class where they had the opportunity to meet successful minority professionals and diverse institutional groups. The most active students find MEP to be most beneficial, allowing them to interact with ethnic peers while simultaneously gaining heuristic knowledge about other organizations and societies. One student emphasizes how helpful MEP is in increasing their involvement at the University:

And that program has been so important to getting me involved right now, I'm in the E-Club and I'm in all of these different clubs, and DLC, and I would've never gotten involved in any of that. NAm Male

B. Peers

Foor and Shehab concluded, "the ability to find or create supportive peer communities is critical to student success" [8 pg.1]. We believe this interaction is most important for gaining heuristic knowledge when the peer community includes both upperclassmen and lowerclassmen. Many students discussed the help they receive from fellow students in their classes as well as the advice they receive from upperclassmen. The need for a relationship and help from peers is relatively equal across all four minority groups. When this NAm student was asked what advice he would give to a student entering the College of Engineering, he responded,

I'd say talk to as many kids as you can because it doesn't matter how much you think you know, there are still some things you don't know and it helps to know the people that have some idea about it, especially the older kids. NAm Male

Rarely is help from upperclassmen associated with class work. Instead, relationships with upperclassmen provide advice from someone who has already been through what these students are about to go through. The idea that the upperclassmen have recently completed what the younger students are hoping to achieve, makes them a more desirable advisor than teachers or the advising staff.

Many students recognize the need for interaction with peers. Museus found that involvement in organizations was often valued because it "provided undergraduates with opportunities to spend time with peers who they perceived as similar to themselves" [6, pg.580]. Interaction with peers is especially important because most minority students feel more comfortable asking classmates than professors or TA's when in need of help with their coursework. The help classmates can offer includes homework help as well as social outlets to relieve the stress of school. Huang supports this assertion that college students who are too focused on their academics become isolated from their peers, which hurts their social development [7]. When an AsAm student was asked where he goes for help, he responded:

Academic matters, usually this group of engineering friends. I mean we have the same classes and we always study together and end up taking the same classes together. And then in my fraternity, I've got a lot of guys who are like electrical engineers or computer engineers taking the same classes so I ask them. AsAm male

C. Study Groups

Although competition is high in the discipline of engineering, faculty should encourage cooperation as well. This cooperation can come in the form of study groups. Students who join small peer groups committed to academic success perform better in school, have a higher desire to learn, and more easily excel in their engineering courses [9]. Also, "research shows that students who work in groups develop an increased ability to solve problems and evidence greater understanding of the material" [10 p.4]. In our analysis, study groups exhibit similar importance on students' success. All participants saw cooperative learning as key to their success. Study groups facilitate student success by allowing them to interact with peers facing the same issues. Also, the impact of witnessing strong work ethics within these peer groups encourages the student to succeed. When asked if interaction with his peers contributes to his success, one student responded,

Some of them work really hard to get where they're going and that motivates me to do, you know, to try and do my best. NAm Male

There are numerous benefits for all members of peer study groups. Some in the group benefit through their role as peer instructors [9]. Furthermore, some students find that their peers can describe a solution to a problem better than their instructor. The student can work at their own pace, and when needed ask their peers a question. For example, these students describe the benefits of working in peer study groups.

I don't usually go to office hours too often. I'll see if I can find the answers through my peers. They can describe it, because they're just learning it too. So they can kind of describe in a better manner than somebody who has done this their whole life saying, 'Why don't you understand? It's so easy.' It's easy for you, but not for us new guys. AsAm male

It's a little bit tougher to get one on one help, so in study groups it's a lot better because you can work at your own pace and with people that are your peers. AfAm male

Although study groups most commonly enhance heuristic knowledge, and accumulate social capital, study groups intermittently have negative effects on the development of a successful engineer. The minority students recall feeling like an outsider when their study group is predominantly white. When speaking of the white majority, one AfAm female said that for this majority "*they [have] more people for them to associate with of their own kind*". Also, study groups can bring on adverse effects including underrepresentation of effort from certain teammates or study group partners [11].

D. Academic Resources

Although the details differ among minority groups, they agree that many of the resources offered to aid students, such as tutoring and student services centers, are rarely helpful. AfAm students report that student services centers are only helpful to meet advising requirements. However, they did find that the tutoring offered by the engineering college is a great way to show teachers your commitment to learning and to meet classmates that can help. One minority student accredits tutoring for his survival in the College of Engineering:

Basically, you have to really show the teacher you are trying, you know kind of get to know them and let them know you, and you know where you are coming from and all that. You have to have some people in there helping you out, and you know working with you taking their time and stuff like that, groups are great, stuff like that, getting tutoring was real good. AfAm Male

AsAm students, on the other hand, mention neither tutoring nor any other student service when discussing what helps them as an engineering student. However, when asked directly about helpful resources, most describe tutoring and service centers as helpful resources, but not critical to their success.

NAm students also report that the provided academic resources are part of formal requirements for advising and information dissemination. One engineering student describes a perspective shared by multiple students on how the advising resources provided within the engineering student services center do not meet the students' individual needs:

Well I noticed the last time, whenever I was here last fall because I was over in the honors advising center and then I got switched over to [engineering student services center]. But I like the honors advising college because you know they sat down with you and it's like they took the time to try to see what you want to take and give you advice about you know whether or not you should take even though you weren't the engineering and so whenever I went over there it was pretty much OK, let me see what you have and OK I think that will work and then they sign you off. NAm Female

However, many NAm students discuss the benefit they receive from the engineering tutoring available. NAm students find the tutoring beneficial because it is free and accessible to all engineering students. In particular, they value information provided by the college about available tutors and subjects. The following student found tutoring especially helpful:

Here is a list of the people that are actually hired to tutor. They are available but they (are) paid, basically. So if I have to, and I have done that once with a programming course. I got a tutor and it was excellent. NAm Male

HAm students have the most positive outlook on both university services centers and tutoring, and use these resources more than the other minority groups. In particular, most HAm students find the tutoring required by the MEP program to be very helpful. Some did report that tutoring was only as good as the preparedness of the student tutors. This HAm student offers the following advice for incoming students of similar background:

Definitely find a tutor as soon as you fail your first test. Or if you are having trouble within the first week, definitely find a tutor, find a group of people that will help you and motivate you, that is the key to surviving. HAm Female

While all four minority groups express wide ranges of opinions on academic resources, we were able to find trends among the groups. First, although services centers are considered helpful in the enrollment process, they lack in all other services they supposedly provide. Second, tutoring appears to help students who participate, however the students only value tutoring if the tutor is competent in the academic subject.

E. Finances

Financial resources appear in the model because they allow or limit a student's access to social networks. In particular, students from financially disadvantaged families must choose between working part-time jobs and engaging the social networks that facilitate college success. HAm students in our data set discuss financial issues and the need for scholarships more than others. Many HAm students believe that financing college tuition and other expenses is the biggest barrier to overcome, even more so than academic challenges:

Academically, I've always been able to succeed with the help of the professors or whatever, so that's really the money has been the only problem or the only challenge I have seen in front of me. There's nothing else that seems to stop me to go anywhere so. HAm Male

Some of our AfAm students find that financing college is often difficult and can be the determining factor in whether they stay in engineering or even in college. Those who work during the academic year to pay their college expenses, feel they have fewer opportunities to build social networks that could make them more successful. One AfAm engineering student comments on how financial concerns have affected him and his friends:

Me and my friends started off as Engineering. One of them he left after his freshman year. Uh, it's more of a money issue with him. I just worked. That is one thing I wished I didn't have to do is work while in engineering. I probably would have you know a better grade or whatever. AfAm Male

However, all minority students do not equally express such financial struggles. For example, many AsAm students appreciate the extra money scholarships and financial aid offers, but they don't discuss financial support as a challenge that must be overcome to continue to persist in engineering.

I really didn't have too much of an issue being able to get here. A lot of that was because they (my parents) could afford OU and I actually had a few scholarships to help out with that. AsAm Male

Huang recognized that employment limits campus involvement and therefore the benefits associated with involvement [7]. Although our students express different levels of financial need, most students recognize the help scholarships or other financial aid provides and recognize that financial difficulties prevents graduation for many students. One AsAm study participant provides this advice for other minority students:

Definitely apply for all the scholarships you can because I've seen how other people who are paying for school and it seems like they're the ones that tend to drop out more often. AsAm Female

NAm students differ from the other three minority groups because many receive financial support from their particular tribe. For some it has allowed them to focus more on school, and less on trying to find other outlets of support. The following students express some positive attributes of receiving tribal support:

I mean it's a blessing. We really benefited just from the fact that we had Native American background and things like that. [Those scholarships] helped us out. NAm Male

"*Yeah I get a tribal grant, a thousand dollars a semester, it's to kind of to keep it where I don't have to work during school, and pay bills, it helps me out a lot.*" NAm Male

While the need for financial help is present among all the minority students interviewed, many express frustration with the financial aid process. Within each group interviewed, there are individuals who discuss the need for financial aid but who found it difficult to locate scholarship and financial aid resources. On the other hand, those who are more involved and connected seem to be more aware of financial aid available. Below a student describes how his attentiveness to emails has made him more aware of scholarship availability:

They keep on sending me emails and I have been noticing that there are more opportunities for Hispanic where you can get different scholarships. HAm Male

F. Faculty

The importance of professors to students' success is broadly understood. "Peer and faculty networks include resources such as guidance, support, information and encouragement with coursework, and information and contacts for post-graduation endeavors" [3, p.4]. However, not all minority students report feeling comfortable with professors. HAm students in our study appear to be the most comfortable with their professors and gain the most help from them. Many discuss feeling comfortable talking to their teachers about school and coursework and other topics as well. The following quotes from a HAm student describe how he feels his professors are encouraging:

Sometimes they point out if they knew of a position they think I might be able to (apply for, or when) the company needed some help or (there were) some work opportunities. And they send me an email and tell me who to go talk to or something like that or a letter of recommendation, they are always helpful

You know just friendly, just kid about classes and if we're really going to pass and everything and graduate. Or if we understood the material they were teaching us. HAm Male

This feeling of natural comfort with professors was not as strong for the other participants. For example, many NAm students discussed that while they knew the importance of getting to know their professors well, they did not always feel comfortable doing so. The following quote from a NAm student talks about the benefit he received when he finally did find a teacher he knew on a more personal level.

Every other instructor that I have ever had has been strictly just an academic relationship. I am in your office because I have a problem with homework or I have a question from a test or something presented in class. Very rarely does it go beyond that (except) with a guy that I work with; we have had some real personal conversations. That is something that I really like, that he feels I am somebody that he can talk to like that. I am not just a student or I am not just somebody that works for him. NAm Male

The reluctance to get to know professors often seems to come from a feeling of intimidation. Many students find that some of their professors seem superior and unwilling to help. One AsAm described this feeling often in her college experience:

I don't know. Sometimes some of them come across as they're better than me. If I ask a question they are like oh, that is a stupid question…This one professor. He was kind of a jerk. You'd go in and ask a question and he didn't really know the answer and so he kind of blew me off. AsAm Female

All the participants recognize the benefits a relationship with a professor provides. Museus reports that AfAm students find that the biggest advantage of involvement with student organizations is the opportunity to form relationships with professors [6]. The students in this study report only few issues with the structural considerations of office hours, but more so with the attitudes from faculty that students encounter when attending office hours. Students also encounter some faculty with teaching styles that they feel are ineffective.

G. Advisors

The college advisor is instrumental in helping students achieve their degrees [9]. Minority engineering students in this study describe the value of a personable advisor who is knowledgeable of the engineering curriculum and truly cares about the students' future. However, many participants in our study mention limited access to this kind of advisor, thus creating a roadblock to their success. Faculty-led student advising is often variable and dependent on the perspective and experience of the faculty member. Some advisors do not advocate extra-curricular involvement, nor do they suggest how to access and utilize resources for success. These students express what they believe is important in the faculty-student advising relationship:

That little bit of encouragement goes a long way. You can do this and this is how we're going to do it...I mean just have that background voice saying this is where you need to go to get this information and not just brush you off. AfAm Female

I didn't like it when I came. ... I felt like [advisors] could have helped me a lot more in my decisions about my classes and where to take them and what teachers…. They helped a *little bit but I would have wished the college of engineering stepped in to guide us in a different way.* AsAm Male

Another key attribute of a good advisor is communication and the opportunity to form a relationship [12]. Many of our students find their advisors to be unapproachable. One HAm student mentions that their advising appointment "*wasn't anything too personal, and [it was] basically what I went in for and left*" (HAm Male). Many students express that they "*would feel more comfortable meeting with an advisor of the same ethnicity"* (NAm Male). The availability of an advisor with similar ethnicity and cultural perspective creates opportunities for students to find community [9].

IV. Recommendations

Critical cultural theory-based qualitative research forefronts the voices of the less-empowered members in an organizational culture. As faculty mentors, we recognize that student voices need to be included in the discourse of retention in engineering education. Thus, after their analysis of student experiential narratives, our undergraduate researchers offer these student-perspective recommendations for engineering faculty and administrators to consider.

From the view of the undergraduate researchers, all of the following recommendations would benefit engineering students. They believe that implementing anywhere from one to all of these suggestions will broaden access for more students to the social networks and social capital that enabled graduation for these minority student research participants. An additional focus of these recommendations is for institutional actions to address or remove issues that the research participant students encountered in their experiences. Supporting students' social networks using these recommendations will help future students attain heuristic knowledge and increase their retention as undergraduate engineering students.

A. Encouraging Peer Interaction

Study groups expand a minority-engineering student's social network and all the students in our analysis find it easier to communicate with their peers than faculty. Study groups are a way of forming relationships with people who will further the student's success. These relationships are an important aspect to a student's social network in college because the more connections that are made, the easier it is to form study groups in the future and therefore gain beneficial advice and help. An AfAm undergraduate female believes that "*professors should always encourage people to work in groups, and to do group work, even if not for the homework.*" Therefore, we recommend that professors encourage students to participate in study groups; we suggest this be done in a variety of ways. Professors should be encouraged to hold optional study sessions outside of class time. The advantages of these sessions are that faculty are present to monitor and supervise: 1) the exclusion and silencing of minority students within majority groups; 2) students not fulfilling their individual responsibilities within the group; and 3) groups lacking structure and focus. These sessions could be held once a week or even just once before the test. These sessions support collaboration within the class and help students get to know each other outside of class time. According to Springer in *Effects of Small Group Learning*, study sessions outside of class had greater effect on students than inside. It is also beneficial because the professor is there for consultation and guidance when needed [11]. These study sessions encourage developing social networks with their classmates and with their professors without the extra time commitment of being involved in an organization.

B. Faculty

Since minority students can more easily approach minority faculty, increasing the diversity of faculty will enable easier communication for both advising and teaching. Also, MEP and the freshman-engineering seminar class should include testimonies from teachers and upperclassmen about their success stories. These resources are meant to be a place where success is encouraged and taught. Knowing how others achieved success advocates this idea.

The students who experience successful teaching know the techniques most helpful to their success; therefore, we recommend that the university hold student-led workshops. These workshops would encourage professors to teach with students in mind. Finally, we believe that outside of office hours, faculty should have an "open door policy". Professors would encourage students to stop by when their door is open to just say hi, get advice, and get to know the professors. This takes away the pressure to only go to the professor's office for homework help and makes the professor more accessible on a personal level.

C. Accessibility of Information

Easy access of information about the college of engineering is vital for minority engineering students' success. Because every engineering student at our studied university has access to the Internet, we believe all information regarding anything associated with the college should be posted on a central webpage there. If all student support information is centralized, then students will know where to go to look for needed resources. Students should be able to easily access the different tutoring times within the college of engineering, as well as the tutors names and numbers. Ranking the tutoring programs from students' reviews, specific to subjects could help students pick out the tutoring services that would be most helpful. Also, accessibility to information regarding institutional groups should be available on the website as well. Possibly this webpage should provide a link to each institutional group's websites, or if a website is unavailable, someone to contact about this group. All scholarships available to minority students should be posted on the website, because sometimes scholarships can be hard to locate on the Internet. Not only should all of this information be online, but the student services center should also make all information available at the actual building the service center is located.

D. Mentoring

Connecting younger students to older students is one of the most important aspects to creating an academically-centered social network. Establishing one centralized mentoring program that is well-organized and advertised fosters the beginning of an academic branch for a young engineering student's social network. This mentor program would allow students to be immediately coupled with at least one older student. Connecting this mentor program with engineering organizations could encourage the younger students to get involved with their mentor's organization and meet even more people therefore expanding their social network.

E. Scholarships

Universities must recognize the positive impact scholarships and scholarship requirements have on undergraduate minority engineering students. If possible, the number of scholarships given to minority students should be increased, helping the students to stabilize their college financial situations. Covering more of students' financial costs can give students more time for school by reducing their amount of time spent having a job. Tied in with these scholarships should be requirements of students to attend different events, programs, and classes within colleges of engineering. Although students may find these participation requirements to be a hassle, participating in different events, programs, or classes could help the student become more involved which could expand their social network. Receipt of these scholarships should come with more information on the benefits of the program, the advisors and mentors that are leading it, and most importantly, success stories from others, which could instill more motivation for minority students to actively participate. For example, attaching participation requirements to scholarships is a technique the American Indian Scholars (AIS) Program tried and found successful [9]. When NAm students received a scholarship from AIS, they were required to volunteer at an event sponsored by AIS, which helped connect them to other Native students. From our research, we believe that expanding scholarship programs with participation conditions will reduce the financial burden for students and enhance social networks, which could increase those students' chances of graduating.

When Padilla looked at how financial barriers affected minority students, he recommended that minority students should be educated on financial aid options and processes in order to be successful [5]. Padilla's findings are similar to ours. We recommend that universities should make scholarships more well-known by having all applications online and on one webpage. Emails with dates that can be automatically added to the students' calendars would serve as reminders of the scholarship due date.

F. Advisors

In order to increase the positive impact advisors have on students, advisors must meet with students more frequently. More frequent meetings would mean more time spent together, hopefully creating a connection between advisor and student. The advisor must be able to encourage students academically, and give them guidance on strategies to utilize other resources to complete their studies. At each advising session the advisor can give a list of specific tutoring services or other outside resources that can be of use if needed. Further, taking time to personally email the student during the semester to see how their classes are going might allow the student to comfortably approach the advisor for advice and questions. Also, by identifying the student's strengths and weaknesses, the advisor should suggest the discipline that best fits the student [9]. Advisors must also connect what the students are studying to the real world, pushing these engineering students to have the desire to reach this real world [10]. Providing an ethnically diverse group of advisors within colleges of engineering could also help students to feel more culturally understood and comfortable with the advisor [10].

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The Elephant in the Room

First-year Engineering Students Discuss Diversity

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Abstract— This work in progress presents a developmental model representing the ability of students to negotiate shared meanings with cultural others in order to build sustainable and mutually beneficial partnerships .The goal of this research is to locate students within this continuum and provide a student-centered starting point in the ways students construct meaning around cultural differences. This paper uses a qualitative inquiry and analysis methodology with a focus on first-year engineering students at a large Midwestern public university and a similar large public university in Australia. The data collected were interviews and focus group discussions probing their experiences with cultural differences. Initial findings demonstrate that in order for students to be able to acknowledge and express their understanding of differences, they need and want models, tools and techniques to be able to communicate their thoughts about cultural differences and to negotiate bridges of mutual understanding. Student interviews in the US reflected more polarizing messages while focus groups in Australia generated more minimizing messages. Engineering educators encourage students to approach and explore both their own cultures (self-knowledge), internal dialogues and other cultures (perceived through the student's own cultural lenses), and the language they use to describe others.

Keywords—cultural humility, cultural differences

I. Motivation

The engineering education literature on the attributes that students need to develop in order to participate in the multicultural, global workforce has grown exponentially over the last 15 years. Yet many engineers still struggle to see the importance in understanding and appreciate cultural differences relevance to engineering projects. Engineering is an applied science to benefit people from varying cultures. A firm understanding and appreciation of cultural differences impacts not only how engineers will interact with other teammates and stakeholders but also directly impacts the engineering process from conception to delivery and whether or not the product and partnerships will be sustainable [1]. Industry has stated the appreciation of diversity and other attributes necessary to create and build sustainable, multicultural partnerships are in high demand but the least frequently seen in those graduating and just entering the workforce [2,3].

In 2006, Lohman, Rollins, and Hoey discussed the difficulties of defining, developing and assessing these attributes [4]. Many of these attributes are represented within ABET's general criteria 3, student outcome h, "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context", the least researched area of the ABET criteria [5].While other academic disciplines have used a variety of theoretical models to define, guide pedagogical practices and assessment practices, within engineering education theoretical models used to understand this attribute have largely been classification models focusing on knowledge, skills and attitudes alone [6,7].

Engineering educators need to understand the attributes of first-year students' communications, discussion and negotiations of cultural differences. Therefore locating students within a developmental continuum is necessary to create and assess appropriate curricular activities and pedagogical approaches. This research is part of a project that seeks to offer a multi-faceted portrait of the ways that first-year engineering students communicate and share meaning around cultural differences. Initial findings show that these students collectively and individually fall within the first half of Bennett's Developmental Model of Intercultural Sensitivity (DMIS). These results indicate that first-year engineering students need structured, active learning opportunities that focus upon developing appreciation of and being comfortable with cultural differences. These attributions are integral progression in terms of developing their cultural humility.

II. Introduction

The research considers Bennett's DMIS through the lenses of Politically Attentive Relational Constructionism (PARC) [8, 9]. DMIS offers six phases of development.: Denial, Polarization, Minimization, Acceptance, Adaptation, and Integration [8]. These six phases are illustrated in Figure 1. The first three are considered ethnocentric viewpoints and the final three are considered ethnorelative viewpoints [8]. PARC is a cluster of communication theories that asks people to consider interactions from the viewpoint of "person-in-the-world-with-other-moving-toward-a-future/past" (p. 41) [9]. Communication is not just a list of skill to be mastered but rather a relational endeavor embued with caring and hinging on the ability to create and sustaing prosocial connections with others [10]. Through this communicative and relational lens, the DMIS becomes a means of considering the development of communication with cultural others through a socioculturally mediated process, a Vygotskiyan approach to development [11]. As such, those who use language that predominately denies the recognition or existence of otherness would be in the Denial phase. Those whose language describing otherness is

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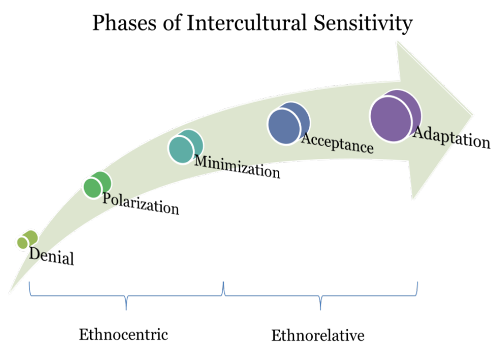
judgmental characterized by the usage of words like "weird" and "strange" or within a context of "liking or disliking" end up in the Polarization space. Students whose language minimizes differences, "it's all good, in the end we are really all the same" land in the Minimization space. Students whose language describes otherness with words of neutrality are located in Acceptance. Students whose language predominately indicates an ability to connect to otherness and negotiate differences are located in Adaptation. Research has not indicated that the final stage of Integration exists and so the language patterns for Integration have not been identified [12, 13]. Together these theories offer insight into critical aspects of the negotiation of cultural differences: the communicative character of the understanding of otherness, the relational origin of the negotiation of meaning, political nature of encounters with cultural others, the historical and socio-cultural context of the encounter as well as the notion that these attributes are a part of a lifelong, developmental process.

Fig. 1. Phases of Intercultural Sensitvity [8]



III. Methodology

The focus groups and interviews were conducted between May and November of 2012 at a large Australian public university and a similarly large Midwestern public university. Seventeen first-semester, first-year engineering students from the Australian campus participated and 27 first-semester, first-year engineering students from the US campus participated. Students' genders and ethnicities were varied, though most grew up as a member of the majority ethnicity in the countries where these students spent their formative years.

Focus groups were initially conducted to understand how students communicated about cultural differences in a group setting. Because students were so reticent to talk about obvious differences such as race, the researchers wanted to hold individual interviews as well to see if students remained hesitant to discuss obvious cultural differences.

This portion of the research focused on a qualitative inquiry and analysis. While the methodological approach of the larger work uses Bruner's functional approach of narrative analysis to understand the ways students construct stories to create meaning around their encounters with others, the research presented here focuses on themes in the specific language students used to describe the notions of diversity and otherness [14]. Once the focus groups and interviews were transcribed, researchers read and reread the transcripts for thematic elements. This work focus on speech acts and how those speech acts would work to build mutual understanding or could potentially create misunderstandings. These speech acts were then categorized based upon their appropriateness to a developmental level. Speech acts that indicated a lack of understanding or awareness of how cultural differences might be impacting the interaction were classified under Denial. Speech acts that indicate negative judgments around otherness were classified under Polarization. Polarizing speech acts are divisive and may either favor or disparage students' culture of origin. Minimizing speech acts lump all peoples experiences together and minimize the impact of cultural difference. Accepting speech acts indicate an understanding of how culture impacts an interaction and, as the word indicates demonstrates acceptance of difference. Adaptating speech acts demonstrate ways mutually understandings are negotiated cross-culturally. As all qualitative work is, this work is necessarily interpretive and requires the acknowledging that the researchers are inherently a part of the interpretive process and the relational construction of knowledge.

IV. Discussion

Students vacillated between polarizing speech and minimizing speech when describing otherness. Frequently though, students found themselves without words. The following two vignettes are exemplars of the two most frequent phases demonstrated, Polarization and Minimization.

A. *Polarization*

This vignette shares a particularly obvious example of polarizing speech. A young Chinese man enrolled at the US university sits across the table from the interviewer intently discussing diversity. In earnestness, the student has shared how he initially thought his Resident Assitant (RA) was "gay" because he hugged him on his way back from the shower wearing only a towel, but in the end it turned out he [the RA] was not. The student shared, " [My RA] was in fact very nice". The polarizing speech is demonstrated by juxtaposing the term nice with a term to describe someone's sexual orientation. This student's language choice communicates the message that the idea of nice and a homosexual orientation are mutually exclusive. The interviewer keeps a non-reactive mask in place as the young man continues his story. He explains how this RA has made his experience in the US so much more comfortable. How he has introduced him to all kinds of new places and new religions. When asked what kind of diversity the young man has observed, with all sincerity he runs his right hand across his left forearm and asks if we can talk about skin color.

B. *Minimization*

An important example of minimization is shared in this next vignette. Seven students of multiple ethnicities enrolled at the Australian university are clustered around a table sharing pizza and conversation about cultural otherness. Two women, one domestic and one international, and five men, four domestic and one international are discussing the cultural differences they encountered upon arriving at the university. A young woman shared her reaction at seeing a woman in a "full burqa" for the first time. The students went on to discuss other differences they had observed. They concurred that what they liked best was that despite the different ways of dressing and acting, in classes and with their engineering teams what they discovered was in the end they were more alike than they were different. They all wanted their team to succeed so they would do well in the class. The minimization was typical. With first year students, there is a collective echo of the notion that at the end of the day we are all human and that is what is important.

This part of the discussion was not surprising: the surprise came after the focus group was coming to a close. A young Malaysian man who had been a quiet but supporting part of the conversation, nodding along with his fellow students', agreeing that in the end they were more alike than different asked if he could stay after the group to share some more of his experiences with cultural differences since arriving in Australia. He wanted to share that he did not really feel like a part of the team and that he did not know how to connect with them across the cultural differences. He shared he did not feel like he was included; and he did not feel like he could share this in front of the other students. He did not have the communication attributes to engage his classmates in a productive conversation on how he experienced things differently than they have without believing that he might be further isolated.

C. The Elephant in the Room

The researchers would like to say that these types of interactions were novel, but unfortunately, they were not. While these two vignettes are more colorful than most, they are examples of the ways first-year students communicate difference creates barriers to engaging and building mutually beneficial relationships with cultural others. Polarizing and minimizing messages permeate the conversations. These polarizing and minimizing speech acts impede students' ability to connect cross-culturally in meaningful ways. At the same time, inadvertently committing a cultural faux pas and unintentionally offending others was a pervasive concern for students on both sides of the Pacific. This mix of polarizing and minimizing communication patterns and fear of making a mistake impedes students' growth toward cultural humility. No one wants to talk about the elephant in the room for fear of looking foolish or worse.

V. IMPLICATIONS

This work provides a glimpse into how students communicate their understanding of cultural others. Students need tools and opportunities to discuss cultural differences and negotiate new meanings with cultural others within the engineering curriculum. Completion of this work will lead to locating first-year engineering students along this developmental continuum. Knowing where students are and what these phases look like in terms of students' constructions of meanings allows engineering educators to create student-centered, active learning approaches for student growth such as asking students to consider their relationships with various stakeholders when introducing the notion of user centered design, asking students to

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Common Configurations for Engineering Student Support Centers

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***Abstract* — In response to the persistent issues of retention and diversity, many colleges offer Engineering Student Support Centers (ESSCs). However, little is known about ESSC design or how these centers function alongside the engineering curriculum and within the larger systems of engineering education. Based on the current literature, there is a need to better understand ESSC design and how such centers influence the institutional experience of undergraduate engineering students. Our research seeks to address this gap by examining ESSCs of varying structure and configuration at multiple institutions. The overall study will use a multi-case study approach, which includes interviews and open-ended surveys with center administrators and engineering students. Preliminary results from the first phase of the project reveal a variety of ESSC structures and will assist us in representing the assortment of centers in the later phases of the study.**

Keywords—recruitment; retention; student support; diversity

I. Introduction

In response to the persistent issues of retention and diversity in engineering [1, 2], many colleges offer Engineering Student Support Centers (ESSCs). ESSCs serve a variety of purposes and are found in various structures. Common structures include Minority in Engineering Programs (MEPs) and Women in Engineering Programs (WEPs). However, little is known about ESSC design or how these centers function alongside the engineering curriculum or within the larger systems of engineering education as much of the existing research is around individual programs (i.e. summer bridge programs) and typically focuses on program outcomes and student satisfaction - e.g. [3, 4]. Since few studied have examined ESSCs holistically (i.e. as individual entities) [4-7], the literature offers very little insight into the design of such centers or the advantages and disadvantages of the numerous approaches. Through previous studies, researchers have found: engineering faculty to be less supportive of programs and activities offered by MEPs that physically segregate students based on race or gender [5]; low financial cost and the ability to help numerous students academically and socially to be important factors when determining which activities to offer through a WEP [6]; female faculty to be more supportive of WEPs than male faculty [6]; and the impact changing the mission and physical space associated with an MEP can have on the relationship a center has with underrepresented students [7]. While these findings are useful, they underline the extent of our knowledge about the design of ESSCs and the scarcity of research that has investigated the diversity in structure and function of ESSCs across universities. That is to say, previous studies have not simultaneously examined the similarities and differences between an assortment of ESSCs with respects to how they are designed and influence the undergraduate experience. Based on the current literature, there is a need to better understand ESSC design and how structure and configuration impact the influence an ESSC has on the institutional experience of the undergraduates being served. Understanding the implications of the various structures and configurations will allow colleges to ensure they have an ESSC that best meets the needs of their students.

Our research seeks to address this gap by closely examining ESSCs of varying structures and configurations at multiple institutions. This work-in-progress describes the overall project and then focuses in more detail on the first outcome of the initial phase of the study - identifying and describing current ESSC configurations.

The overall study will use a multi-case study approach [8, 9], which will include data from interviews and open-ended surveys with center administrators and students respectively. Through this project, we will answer the overall research question: How do individual student support centers function alongside the engineering curriculum to promote positive institutional experiences for undergraduate engineering students? The project is a multi-phased qualitative study that will result in (1) descriptions of current ESSC practices, (2) descriptions of how students and center administrators experience and view these practices, (3) the identification of supports and hindrances to programmatic changes, and (4) strategies to overcome revealed barriers.

Specifically, this paper focuses on answering the following sub-question: What kinds of student support centers do engineering colleges commonly offer? This important first step will enable us to determine which types of ESSCs to include in the subsequent project phases for

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closer examination. In this phase, we examine the common ESSC types, providing examples of how centers are structured at multiple institutions. Since there has been minimal research in engineering education regarding ESSCs holistically, this paper fills a needed gap by examining how colleges have attempted to support engineering students, particularly those from underrepresented populations.

II. Overall Research Project

To engage in examining ESSC structures, we will use a qualitative multi-case study approach including interviews, open-ended surveys, and document artifacts to gather a variety of information. We will interact with center administrators and undergraduate students at multiple institutions. Research findings will be grounded in Tinto's Longitudinal Model of Institutional Departure [10]. Tinto defines the institutional experience as a combination of: (1) academic performances, (2) faculty/staff interactions, (3) extracurricular activities, and (4) peer interactions. Tinto's model asserts that these experiences influence the level of academic and social integration a student achieves. Tinto's model further suggests that higher levels of integration lead to greater institutional commitment and retention. Looking at college students in general, research using Tinto's model has supported the underlying premises of the model [11-13]. The results of this study could potentially confirm or result in a modified version of Tinto's Model specifically geared towards ESSC design.

III. Current Status

To ensure the cases selected for the subsequent phases of the research study are representative of the common ESSC structures, we completed a preliminary Internet search to develop a database of common ESSC types. To gauge the commonness and variety of ESSCs offered across institutions, we compiled a list of universities and investigated whether or not they had a student support center specifically for engineering students and, if so, in what format.

To ensure we included a variety of schools, we intentionally sought out schools ranked high in engineering as well as schools graduating a large amount student from underrepresented groups by using the following lists:

1. Best Undergraduate Engineering Programs Rankings from the 2012 U.S. News & World Report (where doctorate is highest degree)
2. Best Undergraduate Engineering Programs Rankings from the 2012 U.S. News & World Report (where doctorate not offered)
3. Bachelor's Degrees awarded to Black or African-Americans (2010-2011) from the ASEE School Profiles
4. Bachelor's Degrees awarded to Women (2010-2011) from the ASEE School Profiles
5. Bachelor's Degrees awarded to Hispanics (2010-2011) from the ASEE School Profiles

From lists 1 and 2, we selected schools ranked in the top 10. From list 3-5, we selected schools ranked in the top 15. This resulted in a list of 50 universities from multiple regions of the US with a range (based on the Carnegie Classification) from very small to large, public to private, and undergraduate focus to very high research activity. Many institutions were represented on multiple lists, so the total number is less than adding the number of schools from each list together. For example, Georgia Tech has a highly ranked undergraduate engineering program and enrolls a large population of women and underrepresented students.

IV. Preliminary Findings

The results from searching the websites of each of the 50 universities revealed five ESSC formats across institutions and they are listed in Table I. The formats included:

- Minority/multicultural engineering programs (MEP), which focus on ethnic diversity without a specific focus on gender diversity
- Women in engineering programs (WEP), which focus on gender diversity without a specific focus on ethnic diversity
- Diversity in engineering programs (DEP), which focus on engineering students in general while targeting underrepresented populations; this includes centers that focus on broadening participation by targeting students from underrepresented populations or under-resourced high schools communally
- Women & minority engineering programs (WMEP), which separately focus on ethnic and gender diversity but under common leadership (i.e. one director); and
- General engineering support (GES), which focus on engineering students in general without a specific focus on broadening participation or diversity

It should be noted that 8 schools offered both a WEP and MEP separately so the percentages in Table 1 will not add up to 100% (i.e. each university that had a WEP also offered a MEP).

In looking for patterns in type of ESSC by school, we found that each large, public, research-intensive university (n = 16) offered an ESSC in some format. ESSCs were not as prevalent in schools under different Carnegie classifications and no patterns were found by setting (i.e. residential or non-residential) or geographic region.

TABLE 1: COMMON ESSC FORMATS

ESSC Format	Universities Identified
Minority Engineering Program (MEP)	10 (20%)
Women in Engineering Program (WEP)	8 (16%)
Diversity in Engineering Program (DEP)	10 (20%)
Women & Minority Engineering Program (WMEP)	3 (6%)
General Engineering Support (GES)	3 (6%)
No ESSC Identified	25 (50%)
Total	50 (100%)

Half (n = 25) of the institutions included in the Internet search do not offer an ESSC. At first we were surprised because a large part of our sample are schools that graduate a large number of women, Black/African Americans, and/or Hispanics. However, through closer examination, we found that a majority of the schools without ESSC were highly ranked non-PhD granting universities, Historically Black Colleges and Universities, or schools with very high Hispanic populations. There are several exceptions that we believe warrant further examination to understand if support is offered in a way that we were unable to identify during our Internet search. For example, perhaps these schools have strong support centers for students in general that were not identified through our initial search criteria.

V. Future Work

Our preliminary findings suggest that we should sample schools from these five configurations for subsequent phases of the project. However, to verify that we have not missed important alternative configurations, we are developing a survey to be administered nationwide. This survey will include schools in our present sample for confirmation of our classifications as well as a broader sample, allowing us to verify and/or modify the ESSC classifications identified herein. ESSCs will also be surveyed with regards to the specific programs, activities, and services they provide and invited to participate in the larger study. Once a more complete picture of the ESSC landscape is developed, centers that represent the variety of formats will be selected and more closely examined.

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Engineering Culture and LGBTQ Engineers' use of Social Change Strategies

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Abstract – **In this paper, I describe the theoretical framework for an investigation of the ways that engineers who identify as LGBTQ navigate engineering cultures. Previous work by Cech and Waidzunas, Bilimoria and Sewart, and Riley describe strategies that LGBTQ engineers use within highly heteronormative engineering cultures. The strategies described in the previous work fall into what Cox and Gallois refer to as *social mobility* strategies. Because Cox and Gallois assert that these strategies ultimately prove inadequate, I call for investigation of the use of *social change* strategies within the context of engineering.**

Index Terms – Diversity, LGBTQ, Sexual Orientation, Social Change

INTRODUCTION

Within engineering education, there is significant discussion of women and racial and ethnic minorities as underrepresented or marginalized groups in the field. A significant corpus of research on the subject, as well as engineering-specific community resources exist [1]–[7]. Lesbian, Gay, Bisexual, Transgendered, and Queer (LGBTQ) individuals in the engineering community are another, less visible (both literally and figuratively), marginalized group in engineering on which there is considerably less research or resources available.

Cech and Waidzunas' [8] 2009 conference paper and follow-up [9] journal article on the subject argue that engineering culture has "a strong propensity for dualistic styles of thought" where from the beginning of their training "engineers learn to differentiate between people-focused / technological-focused, detached objectivity / emotional connectedness, etc," These dualisms are valued differently in engineering culture, with technological-focus, and objectivity more highly valued than people and emotions. Furthermore, they noted that previous work on gender inequality showed that in engineering culture "technical/social dualism is often mapped directly onto a corresponding masculinity/femininity binary, having consequences for women within the profession." They extend this framework to LGB engineers and show that a similar dualism exists in engineering culture: the "heterosexual / homosexual binary." The main conclusion of their work was that in order to cope with this environment, their LGB participants utilized various strategies such as passing, covering, and compartmentalization, where students essentially feel the need to hide their sexual orientation or downplay its salience in engineering contexts.

Donna Riley [10] noted that within engineering workplaces, even in companies with LGBT-friendly policies, engineering workplace culture can undermine efforts to create a warm climate. For participants in that study, fear of the social repercussions of being out in the workplace can make work a "fearful and isolating place" for LGBT individuals, many of whom use covering, passing, and compartmentalization to cope with workplace culture.

Bilimoria and Stewart [11] conducted interview research with LGBT science and engineering faculty in academia with the goal of modeling the effects of academic workplace climate on the careers of LGBT faculty. Similarly to Cech and Waidzunas' [9] findings with engineering students, they found that engineering faculty work in a climate where heterosexuality is assumed, and that non-heterosexual identity is invisible. Informants in the study reported both direct and indirect hostility towards LGBT sexual orientation. This climate leads many faculty to remain closeted for fear of negative social or career consequences, and consequently experience their academic work environment as an isolating and fearful space.

THEORETICAL FRAMEWORK

In this work, I adopt social identity theory as a theoretical framework, specifically the work of Cox and Gallois [12]. The heart of their social identity perspective of sexual identity development lies in the fact that members of non-dominant groups have a harder time building self-esteem through social comparison (positive distinctiveness) than dominant groups. "Because of the inequalities in the power relations between groups," non-dominant groups must employ certain strategies so that the social comparison process builds positive distinctiveness rather than negative. These are referred to as Identity Enhancement Strategies, and are used by non-dominant groups to overcome the fact that dominant groups, through their position of power, determine the dimensions by which social comparisons are made and ensure that the chosen dimensions cast the dominant groups in a positive light. The Identity Enhancement Strategies that Cox and Gallois posit may aid the process in gay and lesbian individuals are: Social Mobility Strategies, and Social Change Strategies.

Social Mobility Strategies rely on the fact that (some) social groups have fluid boundaries. By joining a dominant group, a member of a non-dominant group can increase self-esteem. In the case of homosexual identity, this can involve capitulating, passing, covering, and blending. Capitulation, in this case, would be where a homosexual individual discards all aspects of homosexual identity. Passing is where an individual lives with a homosexual identity in one social circle and a heterosexual identity in another, hoping that the circles do not intersect (Don't ask, Don't tell is an example of passing). Covering is when an individual is "prepared to disclose their sexual orientation if asked, but does not actively demonstrate it." Finally, blending is when an individual views their sexual orientation as irrelevant to all other aspects of life, and avoids disclosing it while acting as a member of the dominant (heterosexual) group. (In the preceding sentences, I used homosexual as an example identity for illustration, but any non-dominant sexual identity could be substituted). Cox and Gallois posit that when individuals interact in social situations, sexual orientation can move from being seen as a personal identity to becoming a salient identity in group situations. As this happens, it becomes less possible to use social mobility to enhance self-esteem because as sexual orientation becomes more salient in group dynamics, it becomes more apparent to the individual using social mobility strategies that they have not, in reality, joined the dominant group. Cox and Gallois are also careful to point out that because social mobility maintains the status quo comparison between the dominant and non-dominant social groups intact, "the most that can occur via social mobility strategies is for individuals to leave the subordinate group and join the dominant group. Social mobility is a strategy for individuals, not for groups."

The other type of strategy described by Cox and Gallois is Social Change Strategies. There are two types of social change strategies, social creativity and social competition. Both strategies can increase positive self-esteem in the non-dominant group. Social creativity takes three forms: creating new dimensions for comparison with the dominant group where the non-dominant group is evaluated positively (homosexuals are artistic); redefining the value of existing dimensions; and comparing with other non-dominant groups (homosexuals are superior to polygamists). It is important to note that while social creativity increases self-esteem, there is no fundamental change in the social structure. Social competition, on the other hand, aims to effect change in the relationship between non-dominant and dominant groups where both groups accept the shift in status differential. Examples of social competition include lobbying for official government recognition such as the right to marry, or holding civil rights protests.

Each of the coping strategies used by LGBTQ engineers described in the previous work [8]–[11] in an engineering context can be as what Cox and Gallois called Social Mobility Strategies. While the previous work on sexual identity found ample evidence that LGBTQ engineers use these Social Mobility strategies, there is a lack of reported evidence of the use of Social Change Strategies.

As an initial inquiry, I am using in-depth open-ended qualitative interviews to explore 3-5 case studies of LGBTQ-identifying engineers to look for evidence of the individuals' use of social change strategies within engineering schools and workplaces. As this research is ongoing, the exact demographics of the participants are unknown. This work will contribute to a fuller understanding of the ways that LGBT engineers navigate engineering cultures, with a larger goal of identifying new directions for research on sexual identity in engineering. Preliminary results will be shared at the conference.

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AUTHOR INFORMATION

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Tools to Facilitate Development of Conceptual Understanding in the First and Second Year of Engineering

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***Abstract*—We want our students to understand and apply the concepts in each course. Therefore, we work hard to help our students master often-difficult concepts; however, our evaluation of their conceptual understanding often occurs simultaneously with evaluation of other learning goals through use of traditional problem-solving tests. Seldom do we measure pre-to-post learning gains. Often, instruments that would facilitate pre-to-post learning evaluation are not available. Creation, development, and use of such instruments would likely promote constructive conversations between engineering students and faculty members. Assessment instruments that have been designed to evaluate only conceptual understanding are often referred to as concept inventories, following a convention established by the Force Concept Inventory. Concept inventories have a range of possible uses, e.g., a pre-course diagnostic to understand conceptual understanding of students at the beginning of a course, early course formative assessment to guide instructional planning, summative assessment to evaluate conceptual understanding at the end of the course, and pre-post assessment to aid evaluation of instructional strategies. Concept inventories have been used at both course and program levels. What distinguishes concept inventories from typical engineering course assessment methods is focus on a small set of key constructs, focus on a specific domain of academic content, and focus on conceptual understanding or qualitative reasoning, as opposed to computational problem solving. Considerable scholarship informs selection of the situations, formulation of the question, and development of plausible distracters.**

During the workshop, participants will (i) be provided an overview of research on conceptual understanding, (ii) be provided an overview of the historical development of concept inventories, (iii) engage in activities to describe effective uses and some misuses of concept inventories in their courses, (iv) learn how to access existing concept inventories via the developing ciHUB.org platform, (v) discuss psychometric properties of existing instruments, (vi) learn how psychometric analysis can aid development of concept inventories, and (vii) have opportunities to become active members in a growing community of users.

Keywords—assessment; assessment instruments; conceptual understanding; formative assessment

I. Introduction

Most engineering faculty members will agree with this statement: "Students should understand engineering concepts." However, a much smaller percentage actually assesses the extent to which their students have developed conceptual understanding, apart from performance on course exams. Unfortunately, course exams assess complex combinations of knowledge and skills, so separating out development with respect to conceptual understanding is difficult. Also, small numbers of engineering faculty members track gains in conceptual understanding from the beginning to the end of their courses. In cases where faculty members have tracked pre-to-post development, many have been surprised at the small size of the gains that were achieved [1, 2].

Instruments to assess conceptual understanding have been developed or are under development for several engineering subjects [3-6]. Other subjects could benefit from development of such instruments. Therefore, this workshop at FIE 2013 provides an excellent opportunity to engage many engineering faculty members in constructive conversations about applying and developing these instruments, often referred to as concept inventories.

II. Assessing Concept Understanding

Although conceptual understanding of the course subject may be necessary to solve problems on course exams, many other areas of student learning and development contribute to their ability to solve these problems. As a result, scores on the exams may indicate the extent of mastery of conceptual

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understanding, but they may also indicate the extent of mastery of many other sets of knowledge and skills. In order to assess and evaluate conceptual understanding, many instrument developers have turned to questions that do not require students to complete calculations. Instead, questions, sometimes referred to as concept questions, pose a scenario for students and ask them to reason qualitatively to develop or select an answer to the question. Further, many of the concept questions are often multiple choice questions that allow a faculty member to identify potential misconceptions. An appropriately developed, appropriately organized, and appropriately refined set of concept questions may form a concept inventory.

In the case of multiple choice questions, selection of the situation on which each question is based, formulation of the question, and development of distracters is based on research about how students understand the concepts that are the focus of the concept inventory. For a particular concept, research often reveals that many learners have completely incorrect understanding while many other learners have partially correct understanding. Use of this research allows development of distracters that can reveal much about alternative conceptions that learners hold and suggest approaches to repairing these alternate conceptions.

III. Brief History of Concept Inventories

Concept inventories, which began in 1985 with the Force Concept Inventory (FCI) [7, 8] in physics, seek to produce valid, reliable data on conceptual understanding and foster constructive conversations among STEM educators. The FCI provided a snapshot of student conceptual understanding of force and motion that fostered a "cascade of CI development initiatives" in many different subjects [9]. Use of the FCI in many different settings illustrates how a well-developed instrument can evaluate instructional strategies [1], catalyze educational change in a science field [10], and influence education in other STEM fields.

IV. Workshop Overview

Workshop facilitators will use a set of interactive activities and short lectures so that participants will:

(i) Be provided an overview of research on conceptual understanding,
(ii) Be provided an overview of the historical development of concept inventories,
(iii) Engage in activities to describe effective uses and some misuses of concept inventories in their courses,
(iv) Learn how to access existing concept inventories via the developing ciHUB.org platform (http://www.ciHUB.org),
(v) Discuss psychometric properties of existing instruments,
(vi) Learn how psychometric analysis can aid development of concept inventories, and
(vii) Have opportunities to become active members in a growing community of users.

V. Workshop Facilitators

A. *Jeffrey E. Froyd, Texas A&M University*

Dr. Jeffrey E. Froyd received the B.S. degree in mathematics from Rose-Hulman Institute of Technology and the M.S. and Ph.D. degrees in electrical engineering from the University of Minnesota, Minneapolis. He is a TEES Research Professor in the Office of Engineering Academic and Student Affairs at Texas A&M University, College Station. He has been an Assistant Professor, Associate Professor, and Professor of Electrical and Computer Engineering at Rose-Hulman Institute of Technology. He served as Project Director for the Foundation Coalition, a National Science Foundation (NSF) Engineering Education Coalition in which six institutions systematically renewed, assessed, and institutionalized innovative undergraduate engineering curricula. At Rose-Hulman, he co-created the Integrated, First-Year Curriculum in Science, Engineering and Mathematics, which was recognized in 1997 with a Hesburgh Award Certificate of Excellence. He has authored over 70 papers on faculty development, curricular change processes, curriculum redesign, and assessment. Prof. Froyd is a Fellow of the IEEE, a Fellow of the ASEE, an ABET Program Evaluator, the Editor-in-Chief for the IEEE Transactions on Education, and a Senior Associate Editor for the Journal of Engineering Education. He has served as the general chair for the 2009 Frontiers in Education Conference and a program co-chair for three other FIE conferences.

B. *P. K. Imbrie, Texas A&M University*

Dr. P.K. Imbrie, the Director of Undergraduate Programs and an Associate Professor in the Department of Engineering Technology and Industrial Distribution at Texas A&M University. He holds B.S., M.S. and Ph.D. degrees in Aerospace Engineering from Texas A&M University. An advocate for research-based approaches to engineering education, curricular reform, and student retention, Dr. Imbrie conducts research in epistemologies, assessment, and modeling of student learning, student success, student team effectiveness, and global competencies. He helped establish the scholarly foundation for engineering education as an academic discipline through lead-authorship of the landmark 2006 JEE special reports "The National Engineering Education Research Colloquies" and "The Research Agenda for the New Discipline of Engineering Education." He co-led the creation of the First-Year Engineering Program's Ideas to Innovation (i2i) Learning Laboratory, a design-oriented facility that engages students in team-based, socially relevant projects. Directly building on the enhancements to the first-year experience, he led the First-Year Honors Program toward an enabling environment that attracts and retains the highly motivated and academically successful student with a broader and more enriched educational experience promoting scholastic achievement, breadth of knowledge, global awareness, and leadership development. He has been involved with various research projects sponsored by NSF, NASA, and AFOSR, ranging from education-related issues to traditional research topics in 3D stress measurements using photo-stimulated luminescence spectroscopy (PSLS) and environmental effects on titanium-based metal matrix composites. Prior to joining Purdue, Dr. Imbrie was involved with NSF's Foundation Coalition, during which time he established himself as one of the nation's experts on collaborative learning and teaming. He is co-author of a text on teaming called *Teamwork and Project Management*.

C. Teri Reed, Texas A&M University

Dr. Teri Reed is assistant vice chancellor of academic affairs for engineering (TEES), assistant dean of academic affairs for the Dwight Look College of Engineering, and associate professor in the Department of Petroleum Engineering at Texas A&M University. She received her BS in petroleum engineering from the University of Oklahoma and spent 7 years in the petroleum industry during which time she earned her MBA. She subsequently received her PhD in industrial engineering from Arizona State University. Dr. Reed's teaching interests include statistics, interdisciplinary and introductory engineering, diversity and leadership. Her research interests include statistics education, concept inventory development, assessment/evaluation of learning and programs, recruitment and retention, diversity, and equity. She has received funding from the National Science Foundation, Department of Education, various foundations, and industry. Professor Reed is a member and Fellow of the American Society for Engineering Education (ASEE), and a member of the Institute of Electronics and Electrical Engineers, the Institute of Industrial Engineers, and the American Society for Quality. She serves as an ABET Engineering Accreditation Council evaluator for ASEE and is the co-chair of the Undergraduate Experience Council. Dr. Reed served as a reviewer of the United States' National Academy of Engineering's (NAE) 2008 report Changing the Conversation: Messages for Improving Public Understanding of Engineering and 2010 report Standards for K-12 Engineering Education? and was an invited participant in NAE's Committee on Curriculum Reform and the NAE workshop Curriculum: Understanding the Design Space and Exploiting Opportunities. She recently joined Texas A&M University from Purdue University, where she received one of Purdue's highest honors given by the University President in the fall of 2012, the One Brick Higher Award. She has two boys, one is a first-year student at Purdue and the second is a sophomore at Allen Academy in Bryan, Texas.

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Building an Inclusive REU Program

A Model for Engineering Education

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***Abstract*—Faculty, staff, and students from Colorado School of Mines' Renewable Energy Materials Research Science and Engineering Center (REMRSEC) will discuss several strategies that have allowed REMRSEC to host a successful Research Experiences for Undergraduates (REU) program over the past five years for more than 100 students. The REU has consistently attracted highly qualified, diverse applicants and participants from a broad range of educational institutions that include Doctoral/Research Universities, four-year liberal arts colleges, historically black colleges and universities, Ivy League schools, tribal colleges, and two-year colleges. The program has received a significant amount of national recognition and international visibility due to its strong mentoring component that spans a variety of engineering and science disciplines while engaging students in authentic research tasks. Audience members attending this panel discussion will learn how our REU has successfully connected faculty mentors and undergraduate student researchers together in experiential education activities outside the students' primary research endeavors that include extracurricular activities, field trips, hands-on laboratory investigations, interactions with other REUs, professional development opportunities, student-driven "snapshots" sessions, and weekly technical seminars.**

Keywords—community; inclusive; mentoring; renewable energy; research experiences for undergraduates; REU program.

I. INTRODUCTION

This panel session features a spectrum of speakers from the Colorado School of Mines' (CSM) Renewable Energy Materials Research Science and Engineering Center (REMRSEC) who will discuss several strategies that have allowed REMRSEC to host an extremely successful Research Experiences for Undergraduates (REU) program over the past five years for more than 100 students. The REU has consistently attracted highly qualified, diverse applicants and participants from a broad range of educational institutions that include Doctoral/Research Universities, four-year liberal arts colleges, historically black colleges and universities, Ivy League schools, tribal colleges, and two-year colleges. The program has received a significant amount of national recognition and international visibility due to its strong mentoring component that spans a variety of engineering and science disciplines while engaging students in authentic research tasks. REMRSEC's interdisciplinary team of approximately 30 science and engineering faculty from Mines, as well as staff from the Center for Oil Shale Technology and Research, the Colorado Energy Research Institute, and the National Renewable Energy Laboratory, mentor students in a ten-week summer research program addressing fundamental materials issues related to the science and technology of renewable energy. These highly interdisciplinary studies focus on multiple areas that are open to all chemical engineering, chemistry, computer science, engineering, materials science, mathematics, and physics majors. Audience members will learn how our REU has successfully connected faculty mentors and undergraduate student researchers together in experiential education activities outside the students' primary research endeavors that include extracurricular activities, field trips, hands-on laboratory investigations, interactions with other REUs, professional development opportunities, student-driven "snapshots" sessions, and weekly technical seminars.

II. PANEL SESSION FORMAT

Our panel format will allow our diverse group of speakers (energy educators, engineering research faculty, graduate student mentors, REU leaders, and undergraduate student researchers) the opportunity to present a holistic view of our program. The panel will feature viewpoints of faculty and administrators who developed the REU structure, its curricular themes, and multifaceted research components, as well as students who have participated in the program over different summers. The first half of each 15-minute time block will allow panel members to share their remarks, while the second half of each 15-minute time block will be open to audience members to discuss best practices at other institutions. These multiple perspectives will provide panelists and audience members a rich landscape of successful REU qualities, as well as factors that contribute to robust energy engineering and energy education programs. We hope this session will extend our methods to existing and new REUs in an effort to provide more students with high-quality undergraduate research experiences that will give them clearer perspectives on academic coursework, a better appreciation for graduate studies, and the need for a highly-trained workforce in the field of energy engineering.

The panel session will address the following key areas in six, 15-minute time blocks:

A. Recruiting Strategies and Tactics that Resonate Well with Underrepresented Populations

The REMRSEC REU has been successful in recruiting women, underrepresented minorities, non-traditional students,

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and persons with disabilities in research. Underrepresented minorities are African Americans, Hispanics, American Indians, Alaska Natives, and Native Hawaiians or Other Pacific Islanders. Since the REU began in 2009, female participation has ranged from 29% to 59%, while underrepresented minority participation has ranged from 12% to 29%. Strategies to foster interest in the REU have included faculty attendance and student presentations at conferences targeted for underrepresented groups. A majority of our applicants freely interact with our faculty and staff via email communications, conference calls, personal phone calls, and campus visits.

Throughout the recruitment and selection process, as well as the entire REU program, students have a consistent point of contact through Chuck Stone, our REU Program Director. Stone tirelessly promotes our student recruitment efforts, establishes collaborative research groups on- and off-campus, and facilitates successful student-mentor interactions. He travels to about six scientific meetings each year to discuss research opportunities in renewable energy, advertise our REU summer program, and recruit underrepresented students. He follows-up on all contacts, completes direct mailings to interested students, and promptly responds to all telephone and email inquiries. He also signs offer letters and responds to acceptances. Upon arrival at the CSM campus for the REU experience, Stone introduces participating students at our Orientation Session and Welcome Luncheon. During the Orientation, Stone provides an overview of the REU program; introduces faculty mentors, post-doctoral scholars, and graduate students; discusses the role of REU alumni mentors, external collaborators, and visiting scientists; and highlights key features of REMRSEC. He also introduces REU students to the members of the project management team, the administrative support staff, and their own research teams. Although direction of the students' research is transferred to each project's primary faculty mentor, Stone continues to be an important point of contact and acts as a resource to both students and faculty mentors throughout the summer.

B. How to Encourage Faculty Mentors and Prospective Students to Structure Preliminary Research Teams

Each year, the REU recruits approximately 30 CSM faculty to mentor REU students. During our recruiting period, students are openly encouraged to contact REMRSEC faculty and staff to discuss research opportunities. A typical applicant may speak to three different research teams with work efforts that require analytical, computational, experimental, or theoretical expertise. Stone serves as an unbiased advocate and coach for those applicants that contact him seeking to best match their interests and skills to appropriate research teams. Since he is uniquely aware of each research team's activities, and always leaves the final student selections to individual faculty mentors, Stone helps match strong, deserving students to the most appropriate research endeavors. Renewable energy projects typically address the performance of next-generation photovoltaic devices; microstructural design of composite membranes; hydrogen storage in clathrate hydrates; social and ethical implications of climate change, renewable energy, sustainability & education; hybrid energy systems for oil shale production; and optimizing computational tools for energy science. In the end, the goal is to create a "win-win-win" situation for each student, each faculty mentor, and REMRSEC's unique research agenda.

Most REMRSEC research teams consist of a primary faculty mentor, postdoctoral scholars, graduate student researchers, and CSM undergraduate students. A visiting scientist may also be on the team. When an REU applicant is selected to participate in our REU, he or she is assigned a near-peer mentor (usually a CSM undergraduate student) within the team, and often begins interacting with team members six to eight weeks prior to the start of our REU. This gives a participant valuable lead time to get to know team members, an opportunity to contribute to group discussions, survey reports on team activities, and preview relevant papers on the research topic. Consequently, most REU students are able to make preliminary headway in their research pursuits before they arrive on campus. These types of preliminary interactions make students feel they are already an integral part of the research enterprise before our REU begins, and prevents many students from declining our invitation, even after they have committed to our program. Yes, students can be fickle at times and change their minds when least expected!

C. Community-Building Activities within Students' Research and Social Environments

REU students are encouraged to connect with each other as much as possible outside of their research teams and individual projects. Opportunities for community building include weekly technical seminars that span photovoltaics, energy storage materials, the role of catalysts in fuel cells, computational energy science, and challenges & opportunities with biofuels. These technical seminars expose students to a renewable energy curriculum that provides them with appropriate depth and breadth in the subject. Students demonstrate an appreciation for how and why an advanced degree in an engineering or science discipline is beneficial to further advances in renewable energy. Each week, hands-on laboratory investigations expose students to processes and techniques used in engineering and physical sciences. Professional development sessions cover Ethics and the Responsible Conduct of Research; Learning, Teaching, & Working Across Generations; Being a Role Model, Finding a Mentor; Careers in Renewable Energy; and Graduate Schools & Fellowship Opportunities. Student "Snapshots" Sessions allow participants to informally share their research results in a weekly open-learning environment. Additional community-building activities include field trips to the nearby National Renewable Energy Laboratory, visits to local renewable energy businesses and a sustainable energy museum, outdoor concerts at Red Rocks Amphitheatre, evenings at Colorado Rockies baseball games, afternoon soccer matches and ultimate Frisbee competitions, mountain biking, horseback riding, summiting 14ers (mountains with elevations over 14,000 feet), overnight backpacking trips, whitewater rafting excursions, shopping at the local farmer's market, exploring downtown Denver, and sightseeing throughout the Rocky Mountains. In addition, all students are housed in the same on-campus residence hall, which also fosters community.

D. *Nurturing Collaborations with Other Nearby REU Programs*

REMRSEC REU students participate in research discussions, laboratory tours, social activities, and an end-of-summer joint poster session with other nearby REU students in the Advanced Metallurgical Design for Transportation, Infrastructure, and Energy REU at CSM; the Advancing Polymer Materials by Integrating Chemistry and Chemical Engineering REU at CSM; the National Nanotechnology Infrastructure Network (NNIN) REU at the University of Colorado, Boulder; and the Science Undergraduate Laboratory Internship (SULI) program at the National Renewable Energy Laboratory.

For the past two years, the Advanced Metallurgical Design and Advancing Polymer Materials summer REUs have been established on the Mines campus. Since the REMRSEC REU is the older and more established program of the three, the faculty managing these two other REUs have looked to our REMRSEC REU for guidance. In turn, the REMRSEC REU has included these other REUs in its various community-building and professional development activities, allowing students in all three programs to benefit from additional networking structures.

E. *Post-REU Tracking and Measuring Long-Term Student Outcomes*

During the summer of 2012, REMRSEC surveyed its past REU participants in its 2009, 2010, and 2011 summer programs. Questions addressed issues like the influence of the REU on career aspirations and what former REU students are currently doing. The survey had a 64% response rate (54 students) and provided data that has helped the REU program understand its strengths and areas for further development.

F. *Retention with the Fields of Renewable Energy, Energy Engineering, and Energy Education*

One of the goals of the REMRSEC REU program is to encourage people from underrepresented groups in science, technology, engineering, and mathematics programs to learn more about renewable energy research in hopes of motivating them to stay in the field. Our survey data indicates some success with this goal, with almost 1/3 of the students continuing to graduate school.

III. Summary

The thrust of this panel, and the very nature of it, is that we have a model program at one institution. Students in our REMRSEC REU participate in research discussions, laboratory tours, social activities, and an end-of-summer joint poster session with two other REUs at CSM (the Advanced Metallurgical Design REU and the Advancing Polymer Materials REU) and two other nearby groups at the NNIN REU at the University of Colorado, Boulder and the SULI program at the National Renewable Energy Laboratory. Although we considered inviting personnel from these four groups to join our panel, these partner REUs are still maturing and are not yet vested in the model program we describe. In the future, we would like to offer a panel session featuring presenters from different institutions, in addition to the breadth of perspectives from our REMRSEC REU stakeholders. This discussion could focus on strategies for effectively assessing and evaluating REUs as well as describing best practices for tracking short-term and long-term student outcomes. First, however, we see benefit to the engineering education community in featuring a singular (yet still collaborative) model, which has inclusion as a core value and outcome.

Acknowledgment

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References

[1] National Science Foundation award number DMR-1063150, *REU Site: Research Experiences for Undergraduates in Renewable Energy*.

[2] National Science Foundation award number DMR-0820518, *Renewable Energy Materials Research Science and Engineering Center*.

[3] National Science Foundation award number DRL-0814364, *A Phase II Trial of the Systems Evaluation Protocol for Assessing and Improving STEM Education Evaluation*.

Improving STEM Classroom Culture: Discourse Analysis

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***Abstract*— Every classroom constructs its own culture through the interactions of all participants, students and instructors. This culture, often covert or invisible, has a direct impact on students' opportunities to learn. Therefore, it is critical that instructors understand their classrooms' interaction patterns and their effect on student learning. We suggest that discourse analysis may serve as a tool to enhance instructors' understanding of their classrooms and to serve as an intervention particularly useful for junior faculty as they are beginning their teaching career. To this end, this paper (1) describes the theoretical foundation of discourse analysis and (2) demonstrates its application, effectiveness, and applicability in STEM classrooms, particularly at the introductory level, the time when students make their first steps in negotiating 'academic literacies'.**

***Keywords*— discourse analysis; qualitative methodology; academic literacies; first-year engineering courses**

I. Introduction

In the last few years, an increasing number of scholars have called upon the engineering education research community to expand the predominant quantitative and positivist paradigm to include a broader and more diverse range of epistemologies, theories, and methodologies [1]-[8]. Broadening engineering education scholarship will allow access to a larger spectrum of possible research questions and ensuing understandings about ways engineering is taught and learned. By including a range of research perspectives, the engineering education research community may delve deeper into the fundamental questions about engineering students' learning experiences and extend the current discourse about student learning from a purely cognitive enterprise to a socially constructed endeavor [8, and the literature cited therein].

This paper presents discourse analysis method as a way of exploring the question of students' learning experiences situated in various socio-cultural contexts. We maintain that discourse analysis, albeit underutilized to date in engineering education research, allows for understanding classroom culture as it is being created through the interactions between all participants, students and instructors. Specifically, the focus on the classroom use of language provides a lens to understand students' learning opportunities [8]-[14].

To this end, we situate our discussion in the research on 'academic literacies' while also co-opting this term to embrace ideas that go beyond the traditionally defined boundaries of the engineering education research field. Epistemologically, literacies are considered social practices, in which students negotiate, often conflicting, academic and experiential discourses [8],[14],[15]. Literature on the subject maintains that it is through this process of negotiation that students work towards finding their professional identities [8]. We propose, however, that the term 'academic literacies' need to encompass students' understanding of 'the rules of the game' in each classroom context, i.e., the micro-actions and micro-discourses embedded in each classroom's activities that serve as opportunities to learn [2]. We argue that in the absence of knowing 'how to play each classroom's game,' students do not take advantage of opportunities to learn, preventing them from further learning particular academic discourse needed for realization of professional identities.

Thus, in this paper we draw on the work of Courtney Cazden (2001) to describe the academic literacies developed in classrooms by focusing on micro-actions and variations in discourse features [10]. As such, in addition to describing qualitative features of the classroom discourse that form the cognitive basis of students' professional development, we employ quantitative methods to measure the ability of all students to gain access to learning. By using this mixed-methods framework, we demonstrate how the effectiveness of comprehending communication may be measured through the ability of all participants, at any given moment, to actively share in the co-creation of classroom culture and for students "to know what they are talking about and feel confident that all the parties involved refer to the same things when using the same words" [16].

In Cazden's framework, the classroom culture is created by all participants through actions such as obtaining speaking turns, gaining the floor, active listening, pacing and sequencing, classroom routines, etcetera [10]. We demonstrate how these actions, which serve as a source of quantitative data, along with qualitative observations can be used to generate a holistic picture of the classroom's culture. Specifically, we do so in the context of introductory mathematics courses, which serve either as a gateway to a technical degree or a requirement for a non-technical one. In all cases investigated, the courses are situated at the critical time in students' overall development as they are making their first steps in negotiating 'academic literacies' [14],[15]. Therefore, understanding the cultures of those specific classrooms becomes of particular importance. Moreover, we illustrate how discourse analysis method may be used as an early intervention for junior faculty as they are beginning to shape their pedagogical identities and skills.

We conclude with a description of how discourse analysis method allows for identifying what students have better opportunities to succeed in the specific classroom cultures investigated and how faculty perceive their post-intervention evolution with an emphasis on the ways in which they can then take concrete steps to make overt the classroom culture, otherwise invisible to students, and reshape it to expand learning opportunities for all participants.

II. Discourse Analysis Method

A. Methods

We investigated three introductory mathematics classrooms at three different undergraduate institutions: one at an engineering school, another at a liberal arts college, and the third at a business school. All classrooms were led by an early-career instructor (either in his second or fourth semester of teaching). Three classroom meetings of each course were videotaped and one videotaped session from each was chosen for transcription and further analysis [17, and the literature cited therein]. Analysis began with the creation of broad categories typical of discourse analysis studies: the number of interactions initiated by the instructor and students, the amount, "density," and quality of instructor's and students' discourse, etc. This was achieved by breaking transcribed discourses into message units, interaction units, and instructional units (defined below). Multiple passes through the data allowed for enumerating and qualifying various items of interest (e.g., quantity and quality of faculty feedback, type of questions, etc.), which revealed specific interaction patterns. To summarize our findings for each classroom, we used three representations: graphical visualization of the numerical data; short narratives describing a typical student's experience; and a 'taxonomic map' of the classroom's culture. These representations allowed a holistic understanding of each classroom's unique culture and, moreover, identification of these cultures' aspects that students ought to have understood to take full advantage of learning opportunities.

B. Nomenclature

In what follows, we present the discourse analysis terminology used throughout the paper.

Interaction units are defined as "turn-taking" between classroom participants [2]. For example, the following episode contains three interaction units. For visual identification, interaction units are separated by horizontal lines:

Instructor: *First, tell me the type of curve it is. It has a name, right? We know that?*
Student: *Parabola.*
Instructor: *It's a parabola.*

Instructor: *And it opens up or down?*
Student: *Up.*
Instructor: *Up.*

Instructor: *So, the coefficient of the x squared term is positive or negative?*
Student: *Positive.*
Instructor: *Positive.*

In this episode, the instructor begins each interaction, the student then responds, and the instructor follows up with feedback. This is a typical example of what is called the IRF pattern (Initiation-Response-Feedback). Many interactions, however, do not fall into such a neat arrangement. For example, an instructor may ask a student a series of questions to elicit a desired response. A turn-taking may then be considered to be "complete" either after each student's response, or after the instructor moves on to a new line of questioning or to a different student altogether. The way interaction units are identified is subject to the information sought in specific classroom discourse.

A message unit is defined as "the smallest unit of meaning." In practice, this can be interpreted as the smallest portion of speech that evokes a complete image or thought. For example, in the previous example, message units, delineated by slashes, may be defined in the following way:

First tell me / the type of curve it is. / It has a name, / right? / We know that?

Finally, the largest unit of analysis identified in discourse analysis is that of an instructional unit. An instructional unit is usually defined as a change of interaction pattern and/or of content. For example, in a class session that has three instructional units, a teacher may start by lecturing, then allow time for group work, followed by the group report-outs. In this example, the lesson moves in a very linear way and the instructional units, sometimes known as lesson phases, are clear to all participants. Other classrooms may follow a different pattern. For example, an instructor may choose to shift from topic to topic based on student feedback or spiral around a central class theme; yet other classrooms may have loose instructional units whose transitions are obscured by frequent, off-topic interruptions.

To some extent, identification of interaction, message, and instructional units is subject to the specific analytical practices used by an analyst. The robustness of the results lies in the analytical consistency and high inter-coder reliability.

C. Analytical Representation

The results of the analysis may be represented in several different ways. Used together, these representations allow for a comprehensive in-depth description of quantitative and qualitative results. For example, data can simply be represented in terms of raw numbers of interaction, message, and instructional units. Alternatively, a series of bar charts or other graphical representations may be used to capture major patterns in classroom discourse. A short narrative of what an analyzed class might look like from a student's perspective may serve as yet another illustration of classroom discourse.

This particular portrayal of data usually supplements quantitative results and allows for a detailed description of qualitative findings. Finally, a taxonomic map allows for a visual depiction of the classroom culture with ensuing understandings about a type of student that might thrive in a given classroom environment. A taxonomic map can also be used to understand the processes necessary to support students' success in each classroom culture and serve as an intervention for instructors' professional development.

In this particular study, the taxonomic map incorporated both quantitative and qualitative features along with some open questions. This allowed us to use the taxonomy to generate a conversation with the instructors about their classroom culture and the processes they follow to co-create interactive contexts in their classrooms. In our dialogue with participating instructors, we were able to identify important aspects of each classroom that students need to understand in order to successfully take advantage of learning opportunities.

Ultimately, discourse analysis has several benefits when used in the appropriate context. Breaking down a classroom's discourse into countable units allows an analyst to quantifiably answer questions about the procedures and processes that govern classroom interaction. Those objective results can reveal an overall picture of the classroom's culture, and various methods of data interpretation may be used to help the instructors understand that culture from many angles so that they can overtly communicate their unique interaction "rules" to students.

III. Our Study

To give context for our results we first offer a description of the format and content of each of the three classes analyzed. Next, we present the results of the study by first explaining emerging catgories for all three classrooms and sharing an illustration and interpretation of one taxonomic map. We also include a cross-class comparative analysis of our findings for each classroom and present them as models-in-use, i.e., examples, but not generalizations, of similar classes.

A. Abbreviated Class Narratives

All three mathematics classes investigated were introductory in nature and prerequisite either for attainment of a major or as a distribution requirement. As well, early-career faculty, all men, taught all three classes. Set in the context of different institutions, however, each class had its own unique structure, pattern of interactions, and overall discourse. Below are much abbreviated narratives about each observed class.

At the *engineering school*, the classroom was significantly larger than the other two with 72 students and an approximate ratio of 50/50 men to women. This class ran 100 minutes and was held in an auditorium, with a single large white board at the front of the room. The distinctive feature of this class was that three mathematics instructors were always present in the room. For each lesson, one of the instructors was designated as a "main lecturer," while others chimed in to either clarify an answer to a question or to expand on the material presented. The lesson analyzed for this study was presented by the most junior instructor in his fourth semester of teaching at the school. The lesson took the form of an interactive lecture that began with a discussion and clarification of the course format and expectations, quickly transitioning to the presentation of the main topic, differential equations. Guided by students' questions, the instructor briefly reviewed and clarified content presented in previous lessons and homework assignments. When students had no further questions, the instructor moved to introducing new content: linearization, phase plots, and phase planes. The instructor frequently solicited and entertained students' questions, often taking him away from the lesson's focus. However, he quickly realigned himself with the class agenda while still responding to students. (His colleagues occasionally spoke up as well.) On several occasions, students' questions were only briefly or partially answered under the premise that the full answers would be included in later portions of the lecture. The interactive nature of the lesson was established by frequent exchanges between instructor(s)' lecture and student questions/comments. These exchanges were either instructor-to-individual student or instructor-to-student group. There were no student-to-student interactions during the lesson, that is, we did not observe any partner- and/or small-group work. Throughout the entire lecture, the instructor allowed for no deviations away from the main lesson's content.

The *liberal arts college* classroom was the smallest of the classes observed with only 14 students, all women. The lesson ran 75 minutes and took place in a room that had individual desks arranged in two rows, all facing a "smart" interactive white board. The instructor was in his second semester of teaching at the college. The content of the analyzed lesson included convergence of power series. The instructor taught the lesson in a traditional lecture format. There was some individual and pair work. The instructor began the class with a review of a quiz taken by students during the previous class session. He then moved into sharing the results of a student feedback survey regarding the course. The instructor then transitioned into the day's lesson by stating the lesson goal, representing functions as power series, and recapping what the class had learned about the topic up to that point. He gave an example of a function the class was familiar with, and asked questions beyond the students' knowledge to justify the importance of what was to come during the lesson. Although the instructor frequently solicited questions, they were usually met with silence; yet, for simple questions that required (dis)agreement, students seemed to respond through nodding of their heads or other non-verbal cues. During a short period of individual work, the instructor asked students to solve a problem on their own. As students did so, the instructor checked individual student progress and answered questions, making sure to stop by each desk. At the end of this individual seatwork, the instructor brought the students back together and stepped through the problem with the entire class. The instructor concluded the lesson by solving an additional example problem. The interaction during the presentation of both sample problems consisted of lecture interspersed with instructor's questions, infrequently followed by students' answers. Throughout the entire lesson, the instructor's focus remained on presenting the relevant material allowing for no social language and little teacher-student interactions.

Similarly to the classroom in *liberal arts college*, the class in *business school* was relatively small, 17 students, with a male to female ratio of 12:5. The class was 80 minutes and was held in a classroom arranged in two semicircular arcs centered on a series of white boards at the front. A new faculty member, in his second semester, taught the class. Similarly to the lesson in liberal arts school, the class took a form of a lecture with a group work component. The lesson began by the instructor reviewing a recent quiz with a detailed presentation of each problem on the board. The lecture then moved to a discussion of a simple and compound interest. At each step, the instructor made a point to differentiate between an asset's present and future values based on certain interest rates and initial investments. Following the presentation of the new concepts, the instructor asked the class to work on a problem in small groups. During this mini-session of problem-solving, the instructor walked around the classroom answering students' individual questions. The instructor did not solicit questions from student groups; rather, he spoke only to the groups that had specific questions. In the final few minutes of class, the instructor quickly presented the process of solving the problem at hand and demonstrated the correct solution. Students in this course frequently interrupted both the instructor and one another. These interruptions ranged from questions about problems that had already been discussed earlier in the lesson to questions about grading. Some students' questions were unrelated to the course and were of a personal or social nature. These interruptions required the instructor to suspend the flow of the lesson, go back to previously presented material and/or discuss content tangential to the lesson's objectives.

B. Comparison of Variables

After multiple passes through the data coding the *quantity and quality* of each set of units (interaction, message, and instructional) from the transcribed classroom discourses, we arrived at ten emerging categories. These categories were: (i) overall interaction units (both initiated by the instructor and students); (ii) overall message units (both those of the instructor and student); (iii) questions asked by instructor; (iv) instructor feedback; (v) student name use; (vi) instructor use of "I" vs. "We"; (vii) social content vs. pedagogical content; (viii) interruptions; (ix) student participation (i.e., "density" of student message units); and (x) theoretical vs. "real life" application content. The above categories served as a basis for ensuing quantitative and qualitative analyses within and across the classes. Below we describe most prominent categories as a way to understand social interactions of the classrooms studied.

1) Number of interaction/message units

In what follows we report quantitative data and analyses; statistical methods are not used in reporting our analytical findings as data demonstrated refers to specific units counted in one class at each school. Fig. 1 compares the number of interaction and message units per instructional hour initiated by the instructor with those started by students in each class. With only 80 interaction units/hr commenced by the liberal arts instructor in comparison to 124 and 135 in the engineering and business lessons, respectively, this seems to be the least "interactive" class. The number of interaction units/hr initiated by the students in each class, with only 16 in the liberal arts college in comparison to 23 and 83 in the engineering and business schools, respectively, supports the description of least "interactive" class as well.

When paired with the message units "density" data (the number of message units per instructional hour), however, the following picture emerged. With the 1749 instructor's vs. 134 students' message units/hr, the lesson in the liberal arts college remained the least "interactive" of the three. The corresponding numbers in the engineering and business school lessons were 1507 vs. 361 and 1974 vs. 449, respectively. This indicates that the low density of interactions in the liberal arts school does not correspond to a decreased number of message units, i.e., the density of the information shared by this instructor was quite significant, in fact, even larger than that at the engineering school. What this implies, however, which is what we qualitatively observed as well, is that the liberal arts classroom had the least student participation, solicited or otherwise. This qualitative observation bears out in the quantitative finding that only 7.1% of all message units in this class came from the students.

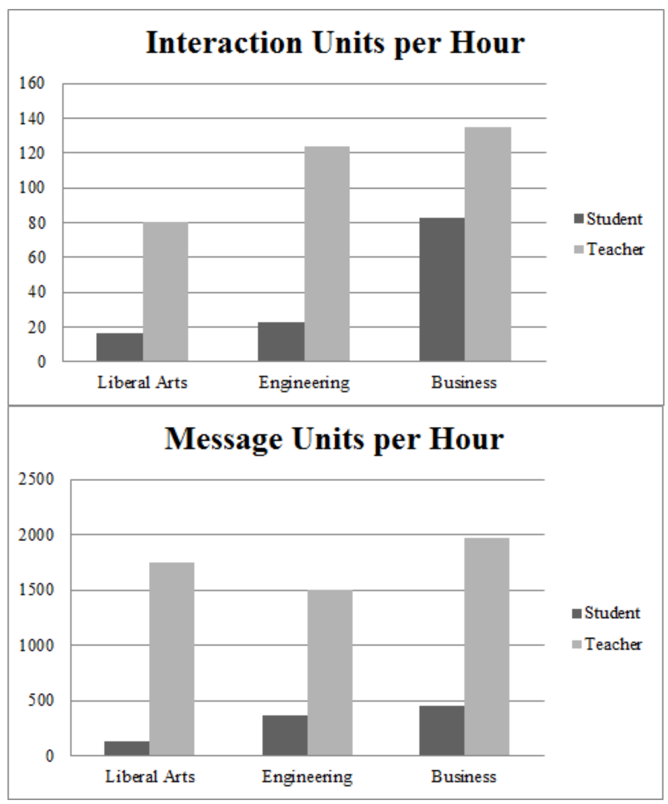

Fig.1. Number of interaction and message units per instructional hour initiated by the instructor and students in each class.

In the business and engineering courses, 81.5% vs. 80.7% of all message units were faculty discourse. This implies a high students' participation rate, which was both observed qualitatively in the two classes and bears out in the quantitative findings, i.e., 18.5% and 19.3% of all message units in these classes, respectively, come from the students.

2) Student vs. teacher initiated interaction units

In comparison to the classrooms at the liberal arts and the engineering colleges, the classroom at the business school boasted the largest density of both interaction and message units initiated by the instructor and the students. In fact, students initiated 38.1% of all interactions in this classroom. This is in comparison to 16.7% in the liberal arts and 15.6% in the engineering lessons, respectively. By this measure, the business school class was the most interactive of the three in terms of the student initiations. Measured by the instructor's message unit density, the overall information shared by the instructor in this class was comparable to that of the instructor at the engineering school.

The classroom "interactivity" may be also measured by the participation rate, i.e., the number of students participating in the classroom discourse. From this perspective, the lesson in the liberal arts college remains to be the least "interactive" with only 20% of students engaging in the overall classroom discussion (3 out of 14). On the other hand, using these quantitative data, the lesson at the business school continues to be the most interactive with 70% student engagement (12 out of 17), and the class at the engineering school having intermediate level of student participation at 38% (27 students out of 72).

3) Interruptions

Classroom "interactivity" measured simply by the interaction unit density, whether initiated by the instructor or the students, or by the students' participation rate, however, is a poor measure of what goes on in the classroom. This is because interaction units initiated by the students are not the same qualitatively. The quality of contribution to the classroom discourse differs greatly from classroom to classroom and from student to student. For example, the lesson at the business school had the highest number of student-initiated interaction units, but most were categorized as interruptions. An example of such interruptions, indicated by dashed horizontal line, is demonstrated below:

Instructor: *Okay. / So, i equals prt. / I'm going to leave it here. / And we're going to move on to compound interest. / Because/ this is, this is a pretty, / a pretty straightforward idea. /*

\- -

Student Larry: *Professor, /what did you do for RIM? /*

Instructor: *Um, we'll talk about it after class, / because/ we have to get through a lot. / But/ not much. /*

Student Elsa: *What? /*

Instructor: *I worked for Blackberry/ – the, the company that makes Blackberry phones. / Um, but/ I only worked there a semester during grad school. /*

At 30 such interruptions per hour, or one interruption every two minutes, the quality of this lesson's "interactivity" is pedagogically questionable. The quantitative data, taken with the qualitative observation, indicate that the class seemed to have developed a culture wherein students had learned that interruptions are acceptable. Some students had come to understand they would receive a response, either from faculty or a fellow student, notwithstanding the time, content, and suitability of the questions.

In comparison, interruptions were either small in number (6 per hour) or non-existent at the engineering and liberal arts schools, respectively. Combining these data with the qualitative observations, we find that these two lessons were highly focused on the subject matter with the emerging culture of the speaking rights belonging to the instructors who nevertheless welcomed students' content-centered input.

4) Questions

In terms of the questions asked in each classroom, the instructors presented a differing number of inquiries (85 in the engineering school, 75 in the liberal arts, and 143 in the business school classes). The instructor in the liberal arts school asked 85% of all questions during the class session, while the percentage of all the questions asked by the instructors at the engineering and business schools were, respectively 65% and 63%. These quantitative findings combined with the qualitative observations of the three classrooms indicate an interesting set of cultural paradigms.

In addition there were interesting qualitative differences observed in the type and format of the questions. The instructor in the liberal arts school tended to ask multiple questions before receiving an answer – sometimes as many as four questions were asked in sequence before a student responded. The students seemed to expect multiple questions, each increasing in focus in terms of content solicited. To ensure "the correct" response, therefore, a student may have developed a strategy of waiting until the last question to better understand what the instructor wanted to hear:

Instructor:

So, / what we see/ here in black/ is the actual curve 1 over 1 minus x./ Right…/and it makes sense, / because/ it seems like / it has an asymptote at x equals 1./ Um, so it seems like/ it's the right curve./

Instructor: *So, / can anyone tell me/ what they think this thing /in red is?* ***[4 sec silence]*** */ Any ideas?* ***[4/5 sec silence]*** */ First tell me / the type of curve it is./ It has a name, /right?/ We know that?/*

Class: *Parabola./*
Instructor: *It's a parabola./*

At the engineering school, the quality of questions asked seemed to indicate high instructor expectations in terms of both students' preparation for the class and the instructor-student dialogue for constructing new understandings:

*Instructor***:** *So, let's try to figure out /what is the behavior /around the equilibria/ in this system of equations. / Is there anything we have to do /preliminary to that investigation?* ***[1 sec]*** */*
Student B: *Find the equilibria. /*
*Instructor***:** *We definitely need /to find the equilibria / so systems of equations. / This is an example /of a system of equations. / And let's find the equilibria.* ***[6 sec]*** */*

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*Instructor***:** *Okay. / So, how do we/ go about doing that? /*
*Student M***:** *Set x-dot equal to zero / and y-dot equal to zero? /*
*Instructor***:** *Yeah. / So, if I'm at equilibrium, / and I'm not moving, /neither x nor y could be moving/ at equilibrium. / So, I have to solve / now / two equations and two unknowns. /*

The predominant culture of high density of interaction units and multiple student interruptions at the business school seems to indicate that students in this context needed to ask and respond quickly before another student interrupted the flow of the discourse.

5) Instructors' use of students' name

Interestingly, quantitative measure of students' class participation is correlated with quantitative measure describing the number of students called by name. At the liberal arts college, with the lowest number of students and the lowest percentage of student participation, no student was called by name. In contrast, at the engineering school, the instructor used the names of 10 students of the 27 participating; the instructor at the business school called all 12 participating students by name. We may attempt to infer an unspoken message that students in each of the three classes may have received as a result of either being called by name or not. Remaining nameless, may decrease the responsibility for participation in the class, while being called out prevents one's ability "to disappear," i.e., a student must be present and participating in such an environment.

6) Feedback

Differences in quantity and quality of feedback message units were also significant. In fact, in the business school, students received instructor feedback 216 times (i.e., 27 times every 10 minutes) compared to only 54 and 90 feedback responses at the liberal arts and engineering schools (i.e., 7 and 9 times every 10 minutes), respectively. In the engineering classrooms, feedback messages were more numerous but brief in quality (e.g., "*Yeah!*" or "*Yes!*" or "*Absolutely!*") in comparison to the class in the liberal arts school, while in the business classroom, the feedback was personal and positive (e.g., "*It gets…yeah, / right. / Wow. / I can't believe you just, / you just, uh, understood that. / It's um… /").*

7) Type of Content

One of the most interesting categories was the number of message units dealing with the type of content in the three classes. In the liberal arts college, the class contained mostly message units coded as mathematical theory (e.g., "*This function has the same slope at 0,/ the same y value at 0 /and what else?/"),* while at the engineering school most message units contained visualization-related content (e.g., "*Who has, / who has a Matlab window open? / It's just 2 by 2, / but/ we're that lazy. / What are the eigenvalues and eigenvectors? /*"). Yet, in the class at the business school, most message units were based on real life applications (e.g., "*The next year, / we're going to get interest/ on our original investment/ and interest on the interest. /*"). What is significant in this finding is that each class reflected the values and missions of the three institutions.

8) Taxonomic Maps

Discourse analysis allowed us to look at the three mathematics lessons by de-constructing them into distinctive coding variables and then restructuring the variables to uncover the hidden interaction of each context.

A taxonomy is map of the identified patterns that constitutes the "rules of the game" for each class. An example of such map is presented in Fig. 2. This map summarizes various quantitative and qualitative findings while placing them in the context of students' experiences. In addition to the summary, such a map prompts a participating instructor to think about the questions related to classroom culture (e.g., "Who creates classroom culture and how?") and ensuing student experiences. Empty blocks are left specifically for the participating instructors to fill in during and following the debriefing session with the researchers.

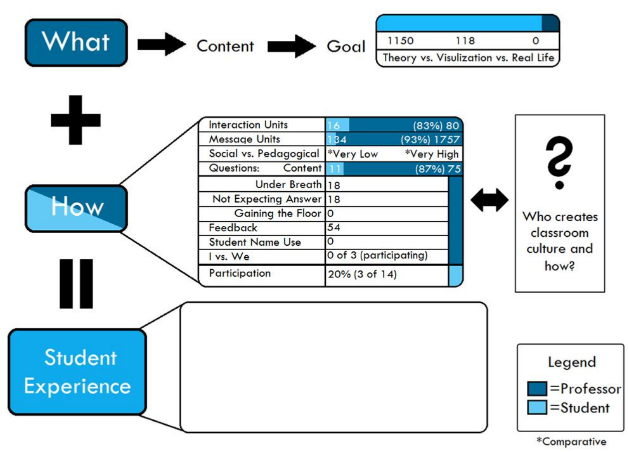

Fig.2. An example taxonomic map.

The liberal arts classroom was one in which students' responsibility for the classroom interaction was minimal and the instructor was in control of the lesson. In sharp contrast, in the business school, students participated actively, however, much of the participation was in the form of interruptions changing the topic. In the engineering classroom, students were expected to co-construct the classroom content and culture. Each classroom had constructed its own distinct culture through the interaction of instructor(s), students, group dynamic, and text Students who were able to understand the culture and live within its rules, gained more learning opportunities.

Although not in the scope of this paper, we also investigated the patterns of pedagogical units (change of topic) of each instructor and the variation of interaction types within pedagogical units. This topic will be discussed in our future work.

IV. Concluding Remarks

To complete the research-to-practice circle, our methods and results were shared with participating instructors during a follow-up meeting the subsequent semester to determine the research and program's efficacy. The main question discussed during these meetings was about a type of student that may thrive in each class and how the instructors may actively work to change the classroom culture to benefit all students. We also helped instructors identify 'academic literacies' that students must develop in their classrooms in order to succeed. Two instructors found that their classroom discourse changed drastically due to their participation in the research. The third instructor felt his participation in the program confirmed what he had already known about his classroom discourse.

One semester after the program completion, participating instructors were presented with an opportunity to reflect on the efficacy of the program and its effect on their teaching. The two instructors, who originally found the program beneficial to their teaching, remained positive about their participation and found that their teaching improved dramatically:

> *Discourse analysis helped me see exactly how my lessons were falling short of my intended learning outcomes for them. I've since used the results of the analysis to better pace my lessons, improve the time I wait for student responses to questions, and adjust my lesson outlines to better foreshadow upcoming new material.*
>
> \- Instructor from Liberal Arts School

While the original study design did not include a longitudinal piece, in the future we intend to conduct follow-up interviews with participating faculty over a course of several semesters post-program to allow for a rigorous analysis of the impact and efficacy of the discourse analysis "intervention" on participants' classroom teaching.

Our findings indicate that discourse analysis, a rigorous yet straightforward method of researching classroom interaction, may be used by any educator who wants to uncover, understand, and shape their classroom's culture to offer all students the most effective opportunities to learn .

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PBL-Test: a Model to Evaluate the Maturity of Teaching Processes in a PBL Approach

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Abstract—**The increasing application of student-centered teaching approaches to solve real problems, driven by the market´s demand for professionals with better skills, has prompted the use of PBL in different areas, including in Computing. However, since this represents a paradigm shift in education, its implementation is not always well understood, which adversely affects its effectiveness. Within this context, this paper puts forward a model for assessing the maturity of teaching processes under the PBL approach, the PBL-Test, with a view to identifying points for improvement. The concept of maturity is defined in terms of teaching processes adhering to PBL principles, taken from an analysis of the following authors: Savery & Duffy (1995), Barrows (2001) Peterson (1997) and Alessio (2004). With a view to validating the applicability of the model, an empirical study was conducted by applying the PBL-Test to three skills in the Computing area. Results showed that although the model has shown it needs further enhancement, it has already been possible to identify improvements in PBL teaching processes that clearly affect the effectiveness of the approach.**

PBL; Evaluation of Teaching Processes; Process Maturity.

I. INTRODUCTION

Professionals in highly dynamic areas such as Computing, face the need to be familiar with and know how to apply new concepts, methods and techniques for specific situations that may arise in the labor market, if they are to keep up with the pace of rapid change in this market. In seeking better ways to formally train these professionals, the instructional teaching method called Problem-Based Learning (PBL) has been adopted with very favorable results as in [1, 2, 3, 4]. In general, PBL makes use of real problems to start, motivate and focus on the acquisition of knowledge. In addition, it encourages professionals to add to their skills and it fosters positive attitudes in the professional environment. It is considered to be a student-centered educational strategy, which helps to develop reasoning and communication. These are skills which are essential for professionals to possess if they are to be successful in the labor market [1].

PBL is becoming increasingly effective in a variety of disciplines in higher education [5]. Many studies have shown the efficiency of the PBL method in helping learners to absorb the content of learning. In [6], the authors conduct a systematic mapping of the use of PBL when teaching computing, from 1997 to 2011. They analyzed 52 studies in this field, taken from sources such as IEEE, Scopus, Science Direct and ACM databases. This study shows that this method has been adopted with the objective of improving the effectiveness of teaching and learning processes.

Despite the potential benefits of the PBL approach, it is also evident that its use implies a profound educational change and a new culture of teaching and learning [7, 8, 9, 10]. Thus, managing a process of teaching and learning based on PBL is a great challenge, especially with regard to implementing a methodology which adheres to PBL principles [7]. Thus, if such adherence is absent or partial, this could have an adverse effect on the effectiveness of this approach.

Faced with this challenge, this paper seeks to answer two important questions: "*How can it be certified that a process of teaching and learning is adhering to the principles of PBL approach?*" And "*At what level of maturity is the process of teaching and learning in a formal training course which uses the PBL approach, in accordance with PBL principles?* '.

As to the first question, Oliveira et al. [6] stress that there is a wide variety of educational methods, referred to as being PBL. According to Norman and Schmidt [11], "*anyone who knows more than one institution in which PBL is used will verify that in each of them, the methodology is applied in a different way.*" Very often, teaching organizations/ institutions start to work with PBL without their having the necessary theoretical foundation on which to bring about educational change. Therefore, the method ends up being confused with practical experiments or other methods of active/ collaborative learning, thus jeopardizing the success and authenticity of the methodology [3].

Additionally, some intrinsic characteristics of PBL, such as the unpredictability and flexibility in the practical assimilation of learning, entail that the teaching coordinators lose control of the actions and constantly improvise [11]. Experiences undergone as in [2, 3, 4] show that adopting this method is made difficult when there a lack of appropriate support from content, processes and human capital in order to implement PBL. PBL demands flexibility, continuous assessment and cooperation. It is against this background that this paper argues that for PBL to be adopted effectively, it is of fundamental importance that the learning and teaching processes be in conformity with the basic principles that guide the practice of this approach.

As to the second question, in view of the variety of PBL formats, it is important to check at what level of adherence these formats are. This visibility enables faults in the process of teaching and learning to be identified as well as the corrective actions or improvements needed in this process.

In this context, this article proposes a model for assessing the maturity of processes of learning in the PBL approach, deemed a PBL-Test. The concept of maturity is defined, based on the teaching processes that adhere to PBL principles. These principles have been set out by authors such as Savery & Duffy [7], Barrows [8] Peterson [9] and Alesssio [10]. With a view to validating the applicability of the model, an empirical study was conducted by applying the PBL-Test to three formal training courses in Computing. Results showed that although the process of analysis of the model may already shows signs it needs to be further improved, the model is a valuable tool for evaluating the maturity of teaching processes in the PBL approach, thus demonstrating its applicability.

II. The Principles of PBL

PBL is based on educational principles and on results from research in cognitive science, which show that learning is not a process of passively receiving and accumulating information, but one in which knowledge is constructed [6].

In [7], Savery & Duffy set out a set of eight instructional principles for PBL, namely: (SD.1) *Anchor all learning on activities to a larger task or problem*; (SD.2) *Provide support for engaging the student on the task or problem*; (SD.3) *Design an authentic task*; (SD.4) *Design the task and the learning environment to reflect the complexity of the environment for which the students should have the skills to interact in, at the end of the learning*; (SD.5) *Give the student ownership of the process used to work out the solution*; (SD.6) *Design the learning environment to support students' thinking while challenging them*; (SD.7) *Encourage the testing of ideas against alternative views and contexts*; (SD.8) *Give opportunity for reflecting on learning and what has been learned*.

In the review of the literature conducted for this research, which includes the systematic mapping of the use of PBL in teaching Computing [6], no records were found of other authors who have set out principles for PBL, using this nomenclature for this purpose. However, the authors Barrows [8], Peterson [9] and Alessio [10] define criteria and characteristics that are key to PBL, which, for comparison purposes, in this paper, are also referred to as *PBL principles*. These studies were chosen with a view to having practical guidelines for this teaching approach that, to some extent, derive from or complement the principles suggested by Savery & Duffy [7] for PBL.

In Peterson [9], the author draws attention to three important criteria that foster more effective learning when PBL is used: (PT.1) *Learning takes place in an environment where students are immersed, in practice, in activities in which they receive feedback from their fellow students and teachers*; (PT.2) *Students receive guidelines and support from their peers such that this encourages multi-directional teaching involving other students, teachers and monitors, unlike conventional teaching which is usually unidirectional (teacher to student)*; (PT.3) *Learning is functional, with real problems as the starting point*.

To Barrows [8] the features essential to PBL are: (B.1) *The student must take responsibility for his/her own learning*; (B.2) *The problems used in PBL should be scantily structured and allow free research*; (B.3) *Learning should be integrated into a wide range of disciplines and subjects*; (B.4) *Collaboration is essential for the learner to develop the security needed to be responsible for his/her own learning*; (B.5) *What students learn during their self directed learning should be applied when resolving the problem through interactive discussions, in order to promote in-depth understanding*; (B.6) *A more accurate analysis is essential about what concepts and lessons were learned in working with the problem*; (B.7) *Students should be able to assess their own learning progress and to evaluate that of their peers*; (B.8) *The activities conducted in PBL should be the same as those performed in the real world*; (B.9) *Assessments should measure the learner's progress as per the PBL objectives*; (B.10) *PBL should be the pedagogical basis of the curriculum and not a part of the didactic curriculum*.

The author Alessio [10], in her study on the perceptions of students and the performance of PBL, stresses three key characteristics of PBL: (A.1) *Learning in context, in which real-life problems are presented*, (A.2) *Extending knowledge through social interaction, in which students work together in small groups, and* (A.3) *Metacognitive reasoning and self-directed learning*.

The model for evaluating the maturity of PBL put forward in this paper is at bottom based on PBL principles. Given the variety of definitions, the study included a mapping of the principles and characteristics of PBL previously mentioned with the aim of identifying the correlation or possible differences between them (Table 1). This mapping enabled both the concepts of PBL to be more clearly understood and for it to be seen that the values and proposals suggested by Savery & Duffy, compared with those of Peterson, Barrows and Alessio, express practically the same ideas. To the extent that there are differences, these complement each other. Thus, it was concluded that two other principles can be added to the list of PBL principles described by Savery & Duffy, and which, as per the study by Santos [12], were described as follows:

- *Principle 9 - "PBL lays down a process of multi-directional teaching and learning*" (Peterson's Principle 2): which foresees collaboration through social interaction between students, and between teachers and students, unlike conventional teaching in which learning is largely unidirectional, from teacher to student, and;
- *Principle 10 - "PBL is supported by planning processes and continuous monitoring*" (includes Barrows' Principles 7 and 8): an effective PBL methodology is strongly oriented to process, since it needs to be planned. This ensures that theory and

practice go hand-in-hand and are aligned to each other, while learning should be monitored by instruments that can evaluate its effectiveness [1].

Therefore, the result of this mapping indicates that the PBL may be defined in 10 basic principles as shown in Table I. The correlation between the principles/ characteristics of the authors Savery & Duffy, Barrows, Peterson and Alessio is also presented in this Table, using the indices of the respective principles. For example, considering the principle PR1, Savery & Duffy says "Anchor all learning activities to a larger task or problem." Peterson reinforces this principle when he affirms that "the learning is functional - based on solving the real problem," corroborated by Alessio when he says that "PBL include learning in context, where real life problems are presented".

TABLE I. PBL PRINCIPLES

PBL Principles	Correlation
PR1. All learning activities are anchored on a task or a problem;	SD.1, PT.3, A.1
PR2. The learner should feel he/she owns the problem, and is responsible for his/her own learning;	SD.2, B.1
PR3. The problem should be real;	SD.3, B.2, B.3, B8, PT.3
PR4. The task and the learning environment should reflect the reality of the professional market;	SD.4, PT.1
PR5. The learner needs to own the process used so as to work out the solution to the problem;	SD.5, A.3
PR6. The learning environment should stimulate and at the same time challenge the learner´s reasoning;	SD.6, PT.1
PR7. The learner should be encouraged to test his/her ideas against alternative views and contexts;	SD.7, B.5
PR8. The learner should have the opportunity and support to reflect on the content learned and the learning process;.	SD.8, B.6, A.3
PR9. The learning is collaborative and multidirectional;	B.4, PT.2, A.2
PR10. PBL is supported by planning processes and continuous monitoring.	B.7, B.9

It is important to stress that the mapping undertaken in Table 1 was based on an interpretive analysis from the meaning and descriptions of the principles discussed in the studies mentioned above, which are subjective in nature. However, the practical and research experiences in PBL of the authors of this paper have contributed to adding reliability to this process, as shown by cases in [2, 3, 4].

III. THE PBL-TEST MODEL

Based on the principles set out in Table 1, the PBL-Test consists of a model for assessing the maturity of the teaching processes based on PBL. This model includes an assessment tool and is structured into five maturity levels. Additionally, the model lays down conditions and steps for its implementation.

A. Definition of the PBL-Test Model

The PBL-Test includes an assessment tool, which consists of a form which contains questions, comprising: a header section, comprising data to be collected, viz., name of participant, training program, the participant's status (student, professor or tutor), and period of his/her training; a section consisting of 10 objective and standardized questions, made up of exclusive alternatives as shown in Table II.

TABLE II. PBL-TEST QUESTIONS.

PR 1 - Problem (s) at the core of the educational proposal.
0.0)The learning activities are carried out regardless of tasks or problems. 0.5) Not all learning activities are associated with the resolution of a problem or task. 1.0) All learning activities are initiated, directed and motivated to solve a specific problem or task.
PR 2 - Learner as the owner of the problem.
0.0) Totally passive posture on the part of the learner about the problem. 0.5) The learner engages with the problem, usually on delivery of partial results required by the teacher or tutor. 1.0) The learner is fully involved with the problem, demonstrating engagement in seeking to solve it.
PR 3- Authenticity of the problem or task.
0.0) The learning tasks do not reflect real-world situations. 0.5) The problem or task is real, but the client and his context aren´t. 1.0) The actual learning tasks are defined and monitored and the client and restrictions are real (scope, delivery time and effort spent).
PR 4 - Authenticity of the learning environment.
0.0) The learning environment is defined by the teacher. 0.5) The learning environment is a simulation of the real world. 1.0) The learning environment is real, with the same challenges as those in the labor market.
PR 5 - Driving the solving the problem process.
0.0) The solving the problem process is fully driven by the teacher or tutor, without the learner understanding the process. 0.5) The teacher or tutor defines the solving the problem process, but the student knows how to apply it and to identify strengths and improvements. 1.0) The student defines the solving the problem process, and can describe its steps, strengths and the improvements needed.
PR 6 - Complexity of the problem or task.
0.0) The problems or tasks require little training in the subject matter. 0.5) The complexity of the problem or task doesn´t require much effort with regard to looking for information or alternative solutions that will resolve them. 1.0) The complexity of the problem or task stimulates thinking and sets challenges on how to develop ideas for solving the proposed problem.
PR 7 - Evaluation and analysis of how the problem was resolved
0.0) How to resolve the problem is proposed by one of the team members, from their knowledge and/ or individual experience. 0.5) Solutions are proposed by one or more apprentices, towards the best solution. 1.0) The solutions are built from an investigative process and questioning of ideas among all members of the team, towards the best solution.
PR 8 - Reflexion on the content learned and the learning process.
0.0) The students have no opportunity to reflect on their learning. 0.5) The students have the opportunity to reflect on their learning, but it is not oriented towards their self-awareness during the learning process. 1.0) The student is encouraged to think, and thus to demonstratie skills of self-awareness on the content learned and the learning process.

PR 9 - Collaborative and multidirectional learning.
0.0) Learning is unidirectional (teacher/tutor -to-student). 0.5) Learning occurs in groups, but there is little collaboration and interactivity among peers, teachers and tutors. 1.0) Learning is collaborative and multidirectional, involving discussions and greater interaction among peers, teachers and tutors.
PR 10 - Continuous Assessment.
0.0) The assessments are not aligned with the educational objectives in the teaching plan. 0.5) The educational objectives were not clearly defined and evaluations are applied to award a grade that classifies the learner as pass or fail. 1.0) Assessments are continuous and aligned with educational objectives planned. They are applied in order to monitor the learning progress and provide feedback to the learner.

The answers to each question are related to how one PBL principle was applied. Each question is associated with three statements that correspond to the following scale of values: 0 (Does not meet the principle), 0.5 (Partially meets it); 1 (Fully meets it). On this scale, the score for each question is related to one these values.

The score of each participant is defined as the sum of points obtained in each question. After collecting the responses of all the participants, the score for the course/ training program evaluated is determined. For simplicity, we chose to calculate this score by using the arithmetic average of the final scores of all participants, equally. The scale range was from 0 to 10 points, given that each of the 10 questions can obtain the maximum value of 1 point (Meets the principle completely). The points calculated are associated with classes of quality indicators, which determine the maturity levels of the model.

According to [13], a level of maturity can be defined as a "plateau" of improvement achieved by a given organization. Therefore, the levels of maturity in the PBL Test model set levels of evolution for processes, by characterizing stages of improving the implementation of the PBL teaching and learning processes in the teaching organization/ institution.

As can be seen in Table 2, the PBL Test model is structured into five maturity levels.

TABLE III. LEVELS OF MATURITY IN PBL

Category	Overall Average	% of Principles Evidenced
Level 0: Insufficient	Overall average < 7	< 70%
Level 1: Initial	<= 7 overall average < 8	< 80%
Level 2: Satisfactory	<= 8 overall average > 9	< 90%
Level 3: Good	<= 9 overall average > 10	< 100%
Level 4: Excellent	Overall average = 10	= 100%

The PBL Test is used to obtain a certain level of maturity which is achieved when the score set for the level in question is reached: *Level 0 - Insufficient*: indicates that the teaching process evaluated does not adhere to PBL principles; *Level 1 - Initial*: indicates that the teaching process evaluated adheres weakly to PBL principles; *Level 2 - Satisfactory*: indicates that the teaching process adheres to a significant extent to PBL principles; *Level 3 - Good*: indicates that the teaching process evaluated adheres strongly to PBL principles; *Level 4 - Excellent*: indicates that the teaching process evaluated is fully adhering to PBL principles, which may be deemed "authentic" or "pure" PBL.

The classification of the level of maturity is directly related to the final score obtained by the arithmetic mean of the final score given by those who take part in the training program evaluated. On a scale of 0 to 10, we chose the value 7 as the average, given that at least the first three principles must be met in full (tasks anchored on a problem, the learner feels he/she owns the problem and the problem is real) and none of the other principles was zero.

This division into levels enables the current state of the teaching process to be visualized with regard to implementing and adhering to PBL principles. But we note that it is important not only to define at what level the teaching process is, but rather also what must be done to ensure that it evolves over time.

B. *Application of the PBL-Test Model*

The conditions for applying the model can be summarized in the following questions: *Who applies the model?* The coordinator or manager of the training program; *What is assessed?* The process of PBL teaching and learning; *Who does the evaluation?* The coordinator or manager is the person who should evaluate and consolidate the results obtained from applying the questionnaire; *Who takes part in the evaluation?* Students, teachers and/ or tutors; *When should the model be applied?* During each cycle of assessing the training program, i.e. during the steps of the PDCA cycle (Plan, Do, Check and Act); *How should the model be applied?* As a survey that uses the evaluation questionnaire given in the model. This may be applied via online Web-format, or face-to-face.

Ideally, we recommend that the PBL-Test be applied over four steps, as shown in Fig. 1.

Figure 1. Steps of applying the PBL-Test model.

Initially, the participants of the evaluation (Teachers, Students, and Tutors) should be introduced to the model, informed what the objective of applying it and given guidance on how to answer the questions in the evaluation questionnaire.

The next step is to apply the evaluation questionnaire. This should be completed by the students, teachers and/or tutors of the training program being evaluated. To reduce the influence responses that are repeated, we recommend that the order of the questions be altered each time that data is accessed/ collected. The ideal is that all the actors of the teaching process evaluated take part in the survey. However, it is known that this is not always possible. In these cases, we recommend that the minimum number of respondents should be at least 1 student, 1 teacher 1, and 1 tutor. Where there is no tutor, or the teacher takes on both roles, the teacher can substitute for the tutor. With the results at hand, the responses obtained are scored and the overall average of the training program is calculated. Finally, the maturity profile of the PBL teaching process of the training program evaluated is checked, taking the levels of maturity for the proposed model into account. It is recommended that the coordinator or manager of the training program be responsible for the activities of applying the model.

Given that one of the objectives of applying the model is the continuous improvement of the processes of PBL teaching and learning, we also recommend that this be inserted as an activity of the Check phase of the PDCA cycle of Deming or that it be applied to each evaluation cycle of the training program. In other words, the teaching process as a whole should be planned, executed, verified (controlled) and improved in every cycle. In this context, the model is inserted as a tool to support managing the PBL teaching process, thus making a contribution towards defining and monitoring continuous improvement actions (Act).

IV. APPLYING THE PBL-TEST IN SOFTWARE ENGINEERING EDUCATION

With the aim of validating the PBL-Test model initially, an empirical study of an applied nature and quantitative approach was conducted, which used the data collected from responses to the questionnaire described in Section 3 and consecutively an analysis was made of these data based on the criteria described in Table III (PBL maturity levels). The Ex-Post-Facto method or "method applied after the occurrence of the facts" was used as a technical research procedure [14].

To undertake the study, we selected three training programs, referenced in this article as Course A, Course B and Course C. All programs selected are higher education ones in Computing: Course A is at the Masters level, lasts 1 year and the class has 16 students, 10 teachers and two tutors; Course B at the undergraduate level, lasts 6 months, has a class of 11 students, 1 teacher and 1 tutor; Course C at the undergraduate level, lasts 5 months, and there are 10 students, 5 teachers and 1 tutor. These formal training programs were selected because they use PBL as a teaching approach. Specifically in the case of Course B, the coordinator was not sure that it should be included in this context, but the fact of there being strong signs of using PBL in the teaching-learning process prompted us to apply the PBL-Test in this program.

For data collection, we made the evaluation questionnaire proposed in the PBL-Test model available on SurveyMonkey in September-October 2012, given that this made both the collection of data and the analysis of results easier. We invited the students, teachers and tutors of three courses to be participants, and thereby a sample was obtained comprising 23 volunteer collaborators, distributed as follows: 6 participants were from Course A (2 students, 1 tutor and 3 teachers); 8 from Course B (7 students, 1 tutor and 0 teachers), 9 from Course C (5 students, 2 tutors and 2 teachers).

From the point of view of the principles, Table IV presents the arithmetic averages of the participants' evaluations of each PBL principle, in each of the three training programs.

On analyzing the results, we found that all the courses evaluated used the PBL approach, since they received scores of above the average of 7.0. Taking the maturity levels of Table 2 into account, Courses B and C were classified within the level of adherence to PBL principles in the category of "Initial", while Course A stood out by being classified in the category of "Satisfactory".

TABLE IV. AVERAGE OF EVALUATIONS PER PBL PRINCIPLE.

Principle	Course A	Course B	Course C
1	0.9	0.8	0.9
2	0.8	1.0	0.7
3	0.9	0.3	0.6
4	0.8	0.3	0.7
5	0.8	1.0	0.6
6	0.8	1.0	0.7
7	0.7	0.6	0.6
8	1.0	0.9	0.8
9	1.0	0.9	0.9
10	1.0	0.9	0.9
Overall average:	**8.6**	**7.7**	**7.3**

On evaluating the principles most perceived as having been met, the result gives evidence of the PBL approach by showing adherence to two of the principles that characterize this approach: the problem is the core of the pedagogical purpose and the student takes ownership of the problem. Moreover, we found that the programs had a very positive concern with the educational methodology, namely, they sought to maintain: adherence to the principles that targeted reflection on the learning and the learning process (Principle 8); collaborative learning based on multidirectional interactions between students, teachers and tutors (Principle 9); and the process of continuous assessment (Principle 10).

On the other hand, the reality and authenticity of the problem (Principle 3) and of the learning environment (Principle 4) were the aspects that showed the greatest need to improve in the evaluations of courses B and C. Course A reinforces its greater maturity by remaining adherent to these principles. It is worth noting another deficiency in perception regarding the analysis of alternative solutions (Principle 7), pointed up by all three training programs, which probably arises from the effort and length of time this approach requires. All of these deficiencies represent improvements in PBL teaching processes that clearly affect the effectiveness of the approach.

From the point of view of the participants, Figs. 2, 3 and 4 represent the distribution of the sample, by case study, and list the subjects taking part in the experiment and their respective responses to each PBL principle. The "PR" index refers to the principles of Table I, "P" to the participants and their parameters (P - Professor, T - Tutor or S - Student).

As per Fig. 2, the absence can be observed of non-adherent responses (0-zero) related to any principles questioned on Course A, which is thus a behavior that is statistically divergent from the other training programs. This behavior can be understood as there was a larger number of mature participants involved in the assessment, a higher educational level (Masters) and the predominance of active subjects within the educational process, such as tutors and teachers (1 tutor and 3 teachers). Another factor that deserves consideration is the total adherence to all the principles, scored by participant P06. This reinforces the students´ positive perception of this course, although in smaller number.

Question/Principle	Participants						
	P01 (T)	P02 (P)	P03 (P)	P04 (S)	P05 (P)	P06 (S)	Total
Q5 - PR 1	1	0,5	1	1	1	1	5,5
Q6 - PR 2	1	0,5	1	1	0,5	1	5
Q7 - PR 3	1	0,5	1	1	1	1	5,5
Q8 - PR 4	0,5	0,5	1	0,5	1	1	4,5
Q9 - PR 5	1	1	0,5	0,5	0,5	1	4,5
Q10 - PR 6	1	0,5	1	0,5	0,5	1	4,5
Q11 - PR 7	1	0,5	0,5	0,5	0,5	1	4
Q12 - PR 8	1	1	1	1	1	1	6
Q13 - PR 9	1	1	1	1	1	1	6
Q14 - PR 10	1	1	1	1	1	1	6
Total	9,5	7	9	8	8	10	51,5
General Average of the Course A:	8,6						

Figure 2. Distribution of Course A.

As per the data reported in Fig. 3, what can be seen is a statistically consistent and better behaved distribution in relation to other training courses. Thus, we regarded the behavior of the participants' responses as tending to be in harmony on this training course. Given that that this course had the largest number of students (7 seven) and only one tutor, it is worthy of note that the effective presence of students in the assessment may represent a positive aspect, since the PBL methodology is based on student-centered processes.

Question/Principle	Participants								
	P01 (S)	P02 (S)	P03 (S)	P04 (S)	P05 (S)	P06 (S)	P07 (T)	P08 (S)	Total
Q5 - PR 1	1	1	1	1	0,5	0	1	1	6,5
Q6 - PR 2	1	1	1	1	1	1	1	1	8
Q7 - PR 3	0,5	0,5	0	0	0,5	0,5	0,5	0	2,5
Q8 - PR 4	1	0,5	0	0	0	0,5	0,5	0	2,5
Q9 - PR 5	1	1	1	1	1	1	1	1	8
Q10 - PR 6	1	1	1	1	1	1	1	1	8
Q11 - PR 7	1	0,5	1	0,5	0,5	0	0,5	1	5
Q12 - PR 8	1	1	1	1	1	0	1	1	7
Q13 - PR 9	1	1	1	1	1	0	1	1	7
Q14 - PR 10	1	0	1	1	1	1	1	1	7
Total	9,5	7,5	8	7,5	7,5	5	8,5	8	61,5
General Average of the Course B:	7,7								

Figure 3. Distribution of Course B.

The data presented in Fig. 4 show the greatest variation in scores between the other training courses analyzed, thus demonstrating a behavior that is not as statistically balanced. This class has a well distributed sample on account of the presence of all the roles involved in a PBL process, in acceptable proportions - 5 students, 2 teachers and 2 tutors. Attention is drawn to participant P09 because of the non-adherent score (0 - zero) in more than one PBL principle and this may therefore reduce the maturity average of the group. At this point, it may make sense to exclude points of dispersion from the analysis, so as to have a more precise statistical approach from the results of the questionnaire.

Question/Principle	Participants									
	P01 (T)	P02 (P)	P03 (S)	P04 (P)	P05 (S)	P06 (P)	P07 (S)	P08 (S)	P09 (S)	Total
Q5 - PR 1	1	1	1	0,5	1	1	0,5	1	1	8
Q6 - PR 2	0,5	0,5	1	0,5	0,5	0,5	1	1	0,5	6
Q7 - PR 3	0,5	0,5	0,5	0,5	0,5	0,5	1	1	0,5	5,5
Q8 - PR 4	0,5	0,5	0,5	0,5	0,5	0,5	1	1	1	6
Q9 - PR 5	0,5	0,5	1	0,5	1	0,5	0,5	0,5	0,5	5,5
Q10 - PR 6	0,5	0,5	1	1	1	0,5	1	0,5	0,5	6,5
Q11 - PR 7	1	0,5	1	0,5	1	0,5	0,5	0,5	0	5,5
Q12 - PR 8	1	1	1	0	1	1	1	1	0	7
Q13 - PR 9	1	1	1	1	1	1	1	1	0	8
Q14 - PR 10	1	1	1	1	1	1	1	1	0	8
Total	7,5	7	9	6	8,5	7	8,5	8,5	4	66
General Average of the Course C:	7,3									

Figure 4. Distribution of Course C.

In general, we note that in the sample collected from the selected training courses there was a significant variation between the behavior of the subjects analyzed as to the composition of the training subjects. In this context, it is understood that a more rigorous assessment of the influence of each role of a participant as well as identifying atypical behaviors in the evaluation may result in an analysis that is able to verify and validate the maturity of PBL processes more precisely. This supplies greater consistency to the PBL-Test model. This is work in progress, which will give rise to future articles.

V. CONCLUSIONS

This article put forward a model for assessing the maturity of teaching processes under the PBL (PBL-Test) approach. This model basically consists of an evaluation questionnaire, which uses a points scale (1, 0.5 and 0) to calculate the result. This reflects the PBL maturity (Level 0 to Level 4) of the course evaluated and is supported by a process of applying a questionnaire and analyzing the results. To validate the proposed model, an initial experiment was conducted in three formal IT skills programs. Although this sample is a starting point for further analysis, the results demonstrate the applicability and potential contribution of the model for improving the quality and the PBL teaching management process, to the extent that it points out the principles that are or are not met in the teaching process. It also indicates the state of adherence of the teaching process as a whole. In general, some shortcomings were found in the PBL processes on the courses evaluated and in the influence of their participants and we acknowledge that the PBL-test model needs to be evolved.

Finally, it is important to emphasize that the proposed PBL-Test aims to be an evaluation instrument the maturity of PBL according to their principles, but does not evaluate the effectiveness of PBL approach with regard to the development of learning and skills in the students involved, a central theme work on authentic assessment, discussed by the authors of this article in [15].

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An Online Training Course for Instructors Wishing to Implement Team-Based Learning (TBL)

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***Abstract*— Due to success at adapting and implementing team-based learning (TBL) for use in sophomore-level electric circuit theory courses, an initiative is underway to encourage other faculty to use TBL in their courses, and instruct them in how to do so. The purpose of this work-in-progress paper is to describe an online training course that is being developed to assist engineering instructors in learning to use TBL as well as other forms of group-based student-centered active learning in the classroom. Currently, the course consists of five units, each of which culminates in a quiz that must be taken successfully before moving on to the next section. The content sections consist of Powerpoint slides plus detailed instructor commentary for further explanation. Also included are selected illustrative video clips taken during an exemplary classroom session.**

Keywords—team-based learning; online faculty training; student-centered active learning.

I. INTRODUCTION

Research has shown that traditional lecturing is an inefficient way to facilitate conceptual learning [1], and that student-centered active learning can result in a deeper understanding of the concepts in question [2]. Furthermore, when active learning is conducted in an extensively group-based learning environment, students also develop various professional skills, such as problem-solving, written and oral communication, independent learning, teamwork, etc. [1]. Team-Based Learning [3] (TBL) is a form of group-based learning that has been used successfully in many academic settings both outside [3] and within engineering [4-8].

Author R. O. has been successfully implementing and adapting TBL for use in sophomore-level electric circuit theory courses [7, 8] for three years. Because of this success, an initiative is now underway to encourage other engineering faculty to use TBL in their courses also. Experience has shown, however, that TBL as described in the literature [3] needs to be modified somewhat in order to be used most effectively in engineering courses. Thus, engineering faculty unfamiliar with TBL must surmount a significant learning curve in order to successfully implement the strategy. To streamline this process we have developed an online training course that shares our knowledge of and experience teaching with TBL [9]. An online delivery format was chosen over a live, face-to-face format to provide prospective trainees greater scheduling flexibility and to permit inclusion of illustrative video clips and detailed instructional explanatory text. This work-in-progress paper describes the course delivery format, course content, unit mastery quizzes, and the results of an evaluative survey taken of volunteers who agreed to pilot the course. Information from that survey is being used to make improvements to the course.

II. DELIVERY FORMAT

The course is accessed through the Blackboard^{TM} course management system, and it is designed to be self-paced and self-explanatory. The home page contains introductory information and explains how to proceed through the course. It states that the course is self-paced, and that it consists of five learning units, each of which includes a textual content section based on Powerpoint slides with detailed instructor commentary, and culminates in a mastery quiz which must be passed with a score of at least 80% before the trainee may move on to the next unit. There is no limit to the number of times a quiz may be taken. The home page also directs the trainee to the learning units.

Currently, the mastery quiz for each learning unit is generated from a pool of multiple-choice questions. The software uses an instructor-defined algorithm to select a subset of those questions to generate a quiz. Thus, a trainee will see a slightly different quiz each time he repeats it. For example, the quiz for the first learning unit currently consists of twelve questions from a pool of fifteen. To satisfy the 80% requirement, the trainee must answer ten of those questions correctly. To provide prompt feedback and remedy incorrectly answered questions, the software refers the trainee to corresponding slides in the textual content section.

III. COURSE CONTENT

In order to facilitate learning of the principles of TBL, it has been helpful to first place TBL in the context of other group-based learning methods, such as problem-based and project-based learning [10], and to place group-based learning methods in the context of student-centered active learning generally [11]. Thus, the course consists of five learning units, which are described briefly in this section.

Unit 1: Introduction and limitations of lecture-based learning

The introductory portion of the unit states and discusses the four course aims and seven learning outcomes. The aims of the course are to provide trainees with: a) an awareness of and appreciation for student-centered active learning; b) knowledge of some lecture-based active learning activities; c) knowledge of the differences among different group-based learning strategies; and d) practical ideas for adapting TBL to engineering courses. The learning outcomes are that at the end of the course, trainees should be able to:

- Discuss the limitations or shortcomings associated with the traditional lecture style of teaching.
- Define and describe student-centered active learning.
- Describe some teaching and learning activities for the lecture-based learning environment.
- State and discuss the principal shortcoming of lecture-based active learning.
- Compare some of the features of problem-based learning (PBL) and project-based learning (PjBL).
- Describe textbook-defined TBL and compare it to PBL and PjBL.
- Describe some recommended practices concerning the use of TBL in basic engineering courses.

The second part of the unit addresses some of the reasons why traditional lecturing is a poor teaching and learning strategy. These include a) the natural decline in attentiveness that occurs during a passive lecture session; b) the use of relatively inefficient learning styles, e.g., listening; c) the lack of constructive alignment between learning outcomes and traditional lecturing; and d) the inability to develop professional skills.

Unit 2: Student-centered active learning for the lecture

Short of converting to a group-based learning environment, the instructor can insert pauses in the traditional lecture to interrupt the inevitable decline in attentiveness and engage students in various learning activities. This unit discusses some of those activities, which include using short quizzes to check readiness for class, using guiding questions throughout the lecture, consolidation pauses for students to compare notes and prepare questions, short reflective essays, and "think-pair-share" exercises.

Unit 3: Group-based student-centered active learning

Extensive use of learning groups enables students to maximize use of highly efficient learning styles, such as doing things, discussing them, and teaching each other. It also enables students to develop certain professional skills, such as problem-solving, teamwork, oral communication, and interpersonal skills. While we consider TBL to be the group-based method of choice for basic engineering courses, in order to fully appreciate its virtues as well as its limitations, it is important to know how it compares with the other popular group-based methods, i.e., PBL and PjBL, which are the subject of this unit.

Unit 4: Textbook Team-Based Learning (TBL)

This unit essentially describes TBL as is done in the textbook by the original developers of the method [3]. Discussed in depth are the three phases of TBL (preparation, application, and unit assessment); the four essential principles of TBL, which relate to group formation and management, student accountability, group assignments, and feedback; and a comparison of TBL to PBL and PjBL. The unit also includes six video clips, taken during an exemplary TBL classroom session, that illustrate various aspects of the TBL strategy.

Unit 5: Practical recommendations for using TBL in engineering courses

TBL as described in [3] was originally developed and optimized for senior and graduate level courses in psychology and business. When it was first used by author R.O. in the sophomore-level electric circuit sequence, it was observed that some of the textbook aspects of the strategy did not work well in those classes; subsequently, four beneficial changes have evolved, which have improved its use in the electric circuit sequence. Those changes are discussed in this unit as practical recommendations. Briefly, they relate to the use of learning outcomes, including one related to learning the principles of TBL; to the use of shorter preparation assignments and more frequent readiness testing in the preparation phase; to the use of a specific problem-solving scheme during the application phase; and to the use of formative assessments in the unit assessment phases.

IV. Evaluation

The online training course is currently being piloted by several faculty volunteers. In addition to completing all course requirements as described above, pilot volunteers also complete an evaluative questionnaire that is helping to improve the course. The questionnaire contains multiple-choice and open-ended questions related to the following: a) length of time needed to complete each learning unit; b) ease of navigation within the course site; c) clarity of writing and ease of comprehension of the textual course content; d) quality and usefulness of the illustrative video clips; e) usefulness and difficulty of the mastery quizzes.

To date two volunteers have piloted the course and completed the evaluative questionnaire, the results of which suggest that Unit 4 is disproportionately long, that parts of Unit 4 in particular are unclear and/or difficult to comprehend, and that several mastery quiz questions, particularly some of those in the quiz for Unit 4, are ambiguous. Limited though the evaluative data is at this point, it is clear that Unit 4 needs work. Thus, for the next version of the course, Unit 4 is being divided into two units, the material therein is being rewritten, and the associated mastery quiz questions are being examined and rewritten as needed.

V. CONCLUSION

The purpose of this project has been to provide engineering faculty with an on-line training course that will help them obtain the knowledge and skills needed to incorporate various forms of student-centered learning, especially TBL, in their own practice. A “first edition” of the course is being piloted and evaluated by several faculty volunteers. Using feedback from them, the course is being revised and a “second edition” is now being developed. Eventually, the course will be made available to other engineering faculty wishing to improve student engagement and learning in their courses.

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The Practical Applications of Understanding Graduate Teaching Assistant Motivation and Identity Development

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***Abstract* - As the field of Engineering Education continues to grow so does the number of research studies. In this ever developing field, it is important to understand the practical applications and implications of this growing body of work. This paper discusses the initial practical applications of one study designed to examine the motivation and identity development of Graduate Teaching Assistants (GTAs). Our hope is that by sharing the initial practical applications of our work in the work-in-progress format, we can better define the appropriate applications of this particular study but also contribute to the conversation of research to practice in Engineering Education.**

Keywords - teaching assistants, motivation, identity, application

I. Introduction

Engineering Education is a growing and developing discipline and research field; as Jamieson and Lohmann [1] have discussed, to continue to move Engineering Education forward with meaningful progress, we need to continue to connect research and practice. This work-in-progress addresses that key issue by presenting the initial practical applications from a large research study about GTAs who are the future of Engineering Education both in terms of research and practice. At this time, this research is in the analysis phase, and we hope that by presenting our findings in this format, we can gain further insight into our research and applications. We also hope to further contribute to the ever developing conversation of research to practice by focusing our research on future faculty who will be instrumental in connecting the two areas in the years to come.

GTAs serve a variety of functions in engineering classrooms. Many times they are the primary instructor for a lecture or lab or they may be an assistant in the classroom, helping to mentor students and support faculty [2]. Regardless of their specific role, GTAs are often in direct contact with undergraduate engineering students, creating the potential for GTAs to have a significant impact on a student's educational experience. To create GTA development programs to best prepare GTAs for their roles and optimize student experiences, it is important to understand the experiences and needs of GTAs from their own perspective. This work-in-progress paper addresses the possible applications of a research study currently examining GTA teaching experiences in first-year engineering programs. The ultimate goal of that work is to identify the key factors affecting GTA motivation to teach and identity development as teachers. This paper focuses on the specific applications of the findings.

II. Theoretical Framework

This research is based in a theoretical approach that combines motivation and identity. As previously described [2], the theoretical approach uses Self-Determination Theory (SDT) [3] as the motivational perspective and Possible-Selves Theory (PST) [4] as the identity component. In the proposed model, PST serves as the foundation for understanding an experience where views of one's future possible self influence how we experience something. The SDT constructs of competence, relatedness, and autonomy can then be examined keeping in mind the individual's view of their future self. In our work, as defined by Ryan and Deci [3], autonomy includes an individual's feelings of decision making power and control, competence addresses having appropriate knowledge, and relatedness encompasses feelings of belonging to a community. By using a combined theoretical perspective such as the one described above, a holistic understanding of GTAs' experiences can be developed taking into account both identity and motivation which are both fundamental to who we are and how we act in certain situations.

III. Methods

Overall, this research employed a multi-phased mixed methods design incorporating qualitative interviews and a quantitative national survey with GTAs teaching in a variety of first-year engineering programs. For the qualitative portion, 12 interviews, representing five different first-year engineering programs, were coded using an *a priori* approach where the major constructs of the theory served as the codes [5]. The quantitative portion, which had 33 participants representing seven different first-year engineering programs, was analyzed using basic descriptive techniques due to the size of the sample.

The main outcome from the project so far is a set of teaching profiles that represent different clusters of GTA participants based on SDT and PST constructs: specifically identity, competence, autonomy, and relatedness. The clusters were developed by statistically clustering the quantitative data and subsequently examining the qualitative data in a mixed methods approach. The profiles combine both the qualitative and quantitative findings from the study through connecting and mixing. Essentially, the profiles represent possible types of graduate students that are working as GTAs in first-year engineering programs. It is not our intention to suggest that all GTAs only fit into specific groupings. Rather our intention is to show that there are similarities and differences in students that choose to be GTAs and thinking of them by profile could help researchers and supervisors alike to develop strategies to help prepare GTAs for their teaching roles. Additional information about the methods (i.e., details on the analysis, reliability, and validity concerns, etc.) will be provided in future publications.

Below we discuss the first teaching profile developed as an example of the initial findings from this work. We also provide detailed examples of how that profile can be applied towards reconsidering structures for GTA teaching appointments and towards revising traditional GTA training programs.

IV. Strong Identity Profile

Based on the analysis, we discovered that the most salient construct for determining the profiles was identity. With this in mind, here we discuss the strong teacher identity profile that emerged from our work.

Based on the interviews, individuals who make up the strong teacher identity profile believe that teaching is integral to who they are. They also believe that teaching is something you do beyond the confines of a classroom taking place in many aspects of life. For this group of GTAs, teaching is a natural fit and is something they feel they were meant to do. As Wesley, a first time GTA, said:

> *"Just being conservative, but um, it's all, it goes along with the fact that [being a teacher is] part of who I am. [...] I always knew I had to you know, teach in order to be happy…"*

From this quote, we see that Wesley has a strong connection to teaching, believing it is something he has to do in life. Additionally, in keeping with PST, these GTAs more often than not want future careers to involve teaching in some direct capacity. Many cite being future faculty members as part of their ideal job after graduation.

V. Applications of the Profile

Based on the profile described above, these individuals want to teach in the future and see it as a strong part of who they are. For these types of GTAs, programs should be developed that help foster advanced teaching experiences for these individuals so they can continue to develop their skills as teachers. The current development programs that are reported most commonly in the Engineering Education literature are universal in the sense that they do not consider individual identity or motivation needs. To supplement the current training, we suggest that strong teacher identity GTAs take part in programs such as the Preparing the Future Faculty [6] or get involved in Engineering Education PhD programs or certificate programs to further supplement their teaching in the classroom. In these types of programs, students get to hone their teaching practices, but they are also exposed to educational theory and literature further supporting their interest and knowledge about teaching. Looking towards early career faculty development literature also provides examples of how GTAs could continue to develop and progress in their teaching abilities. A recent example would be the work by Felder, Brent, and Prince [7] who explore instructional development programs, best practices, and recommendations with regard to adult learner motivation.

We also suggest that GTAs meeting the strong identity profile be given increased responsibilities in their programs and be considered for advanced roles where they can serve as role models and mentors to other GTAs providing support and encouragement as needed. By serving in advanced roles, GTAs would not only impact the learning of their students, they would also impact the learning and development of their fellow GTAs. This impact could ultimately help to contribute to improving the quality of Engineering Education as a whole. In K-12 teacher education, similar approaches have been taken where K-12 teachers are involved in leadership roles to help with overall education reform at the school and district level (e.g., [8-9]).

We would like to clarify that the recommendations above are targeted at the strong identity profile, but they may also be suitable for GTAs in other profiles as well. These recommendations serve as a starting point for understanding GTA experiences but are by no means the only recommendations for supporting their experiences. To fully understand a GTA's experience, we suggest they take the survey we have created related to motivation and identity to better understand themselves and their own beliefs. These initial results should be used as a starting off point as we believe the profiles are fluid and GTAs can easily move between them given teaching appointments.

VI. Conclusions and Future Work

The overall purpose of the study is to better understand the teaching experiences of GTAs involved in first-year engineering programs examining their motivation and identity. However, this paper serves to set the stage for applications and implications from that work. By presenting this research in a work-in-progress format, we are able to open this topic of research to practice for formal discussion. We plan to use the results of presenting this paper to influence the applications and implications of this research beyond the first profile and beyond first-year engineering programs. In the future, we plan to expand this research beyond engineering examining the motivation and identity of GTAs in a variety of disciplines. Additionally we hope to develop this research providing information about the connection between GTA motivation and identity and student motivation, identity, and achievement. Finally, we believe that the audience for this work includes anyone who is a TA, uses TAs, or is new teacher in general.

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Institutional Benefits Policies and Family Formation among Engineering Faculty

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***Abstract* - This work in progress examines family-related benefits policies across doctoral institutions and the family formation patterns of engineering faculty. The nationally representative data come from the 2004 National Study of Postsecondary Faculty surveys of institutions and faculty. Data show that a little over half of engineering faculty members provide financial support to one or more dependents. Yet, many doctoral institutions do not provide childcare benefits or parental leave for full-time faculty and instructional staff, highlighting the need to examine the role of institutional structures and benefits policies in the career progression of engineering faculty with dependents.**

Keywords- faculty, engineering, child care, benefits policies

I. INTRODUCTION

The complexity of the issues surrounding the underrepresentation of women in science and engineering has inspired a sizable body of research encompassing every stage of the life course from preschool through post-doctoral employment. The importance of family formation cannot be overstated in the career progression of women faculty. Women with dependents experience unique barriers to career formation when they assume primary responsibility for childcare and household labor [1]. Many academic institutions were developed based on traditional gender norms (men as breadwinners and women as caregivers), and therefore, female faculty with dependents may face disproportionate challenges in the workplace compared to their counterparts [2,3]. This study is a comparative examination of institutional benefits policies as a potential source of variation in the career progression of faculty with dependents using a nationally representative dataset. How do the career patterns of male and female engineering faculty with dependents differ based on the availability of institutional family-related benefits?

Previous research investigating the influence of family formation on academic career progression find that female doctorates with children are less likely than male doctorates with children to enter tenure-track positions and are more likely to obtain part-time academic or non-tenure track positions [4,5]. Among those who are on the tenure-track, women with children are less likely than men with children to earn tenure. Both men and women, however, do not consider tenure-track faculty positions at research institutions to be "family-friendly" [6]. While engineers are often included in these analyses, engineering has unique characteristics that warrant a closer inspection. Chief among these is the relatively lower representation of women in engineering relative to other science disciplines. Attracting and retaining women as engineering professionals and as tenure-track faculty members in engineering are of critical importance. The nation's scientific, technological, and economic progress is partially dependent on the size and diversity of the engineering labor force [7]. Further, the representation of women faculty in science and engineering is positively associated with increases in the persistence of women undergraduates [8-10]. Research results will therefore aid key stakeholders in postsecondary institutions shape benefits and institutional policies to support work-life integration among employees. These policies also have the potential to be adapted to address caring for aging parents.

II. DATA

The nationally representative data come from the 2004 National Study of Postsecondary Faculty (NSOPF) institutional-level and individual-level surveys, which were conducted in 2003 via web-based questionnaire or telephone interview. Institution-level data include information regarding types of benefits available to full-time staff, such as childcare, paid maternity leave, and paid paternity leave. The institution-level data are comprised of 920 Title IV-participating degree-granting institutions across the 50 states and District of Columbia. The stratified sampling generated 1,070 eligible institutions and 920 institutions completed the survey, resulting in a weighted response rate of 84 percent. The weight also adjusts for changes or merges between institutions. The 920 institutions therefore represent a population size of 3,134 institutions across the United States.

The individual-level data include 26,100 survey responses from faculty and instructional staff sampled from the institutions resulting in a 76% weighted response rate. Faculty and instructional staff include permanent, temporary, adjunct, visiting, acting, and postdoctoral appointees employed full or part-time in tenure or non-tenure track positions. Individual-level data include demographic characteristics, such as gender,

This research is funded by the American Educational Research Association Grants Program.

race, marital status, and number of dependents. Information regarding employment status at the time of survey such as faculty rank, length of service, and field are also available.

The sample for this study is limited to full-time engineering faculty at doctoral institutions. Approximately 78% of engineering faculty members are full-time [11]. When data were collected in fall 2003, women comprised 9.5% of engineering faculty [11]. The institution sample is limited to doctoral institutions. Weighted proportions of faculty with dependents and of institutions offering family-related benefits to all, some, or none of full-time faculty and instructional staff are estimated. Weights are applied to adjust for the differential probability of selection of institutions and individual faculty, such that the results are generalizable to the population.

Fig. 1 indicates the proportion of male and female tenure-track engineering faculty in doctoral institutions with dependents. A dependent is defined as an individual 24 years old or younger for whom the faculty member provides financial support. Among male tenure-track engineering faculty in 2003, 41% indicated no dependents. Meanwhile, 59% reported one or more dependents. In comparison, 47% of female tenure-track faculty members indicated no dependents while 53% reported one or more dependents.

Although over half of the engineering faculty reported supporting at least one dependent, benefits associated with childcare, paid maternity leave, and paid paternity leave were not commensurately available. Among doctoral institutions, 31% provide childcare benefits to all full-time faculty and instructional staff (Fig. 2). Meanwhile, 59% of institutions do not provide any type of childcare. In regard to parental leave, nearly half of institutions offered paid maternity leave while only 32% offered paid paternity leave. In contrast, tuition remission is available to all faculty and instructional staff at 54% of the institutions.

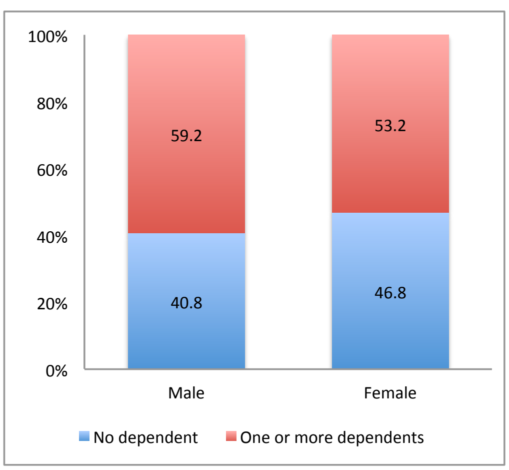

Fig. 1. Proportion of male and female tenure-track engineering faculty with dependents

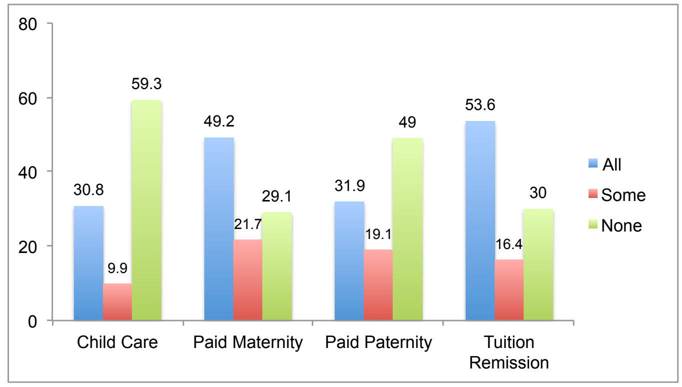

Fig. 2. Proportion of doctoral institutions offering family-related benefits to all, some, or no full-time faculty and instructional staff

III. FUTURE WORK

The disparity between the proportion of engineering faculty with dependents and the availability of benefits associated with dependent care highlight the need to examine how policies influence academic career progression. Further, the relatively smaller proportion of doctoral institutions providing paid paternity leave suggest that work/life issues for men should also be investigated [12]. While the data provide a comprehensive national perspective, the data are limited in that they were collected in fall 2003. Future work entails analyses of the career progression of female and male engineering faculty as a function of the availability of family-related benefits policies. Data from more recent faculty cohorts will also be analyzed from the National Science Foundation Survey of Doctorate Recipients.

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Innovative Practices for Engineering Professional Development Courses

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***Abstract*—Many universities require engineering majors to take some form of a professional development course. Generally, the goal of these courses is to prepare students for the engineering profession. Another important aspect of these courses is to provide a mechanism to satisfy accreditation criteria on student outcomes that are difficult to implement in other technical courses. At the University of Oklahoma, most engineering disciplines take the course titled: ENGR 2002 – Professional Development. Historically, this course was effective in satisfying accreditation requirements on student outcomes, but was not well received by the students. Details of the reasons for this dissatisfaction and changes made in the re-design of this course are discussed in this paper. The new version of ENGR 2002 includes many innovative practices in team-based learning and peer learning that are shared in this paper. All of the vital elements of the four projects included in the course are provided to support others who would like to implement similar projects. Course surveys, completed by 148 students, were used as the primary assessment method. Additionally, standard course evaluations were used to compare this course to other engineering courses and show improvement from the previous version of ENGR 2002. Many student comments are included in the paper to show their reaction to different aspects of the course. One student made a comment that echoed our sentiments regarding the teaching of this course for the first time in the fall 2012 semester: "from being in this class it is noticeable that people need to take it to work on public speaking skills or working with groups." From our experience, many students grow a great deal in terms of communication effectiveness and ability to function on a multi-disciplinary team as a result of this course, and we believe these skills are essential to become a great engineer.**

Keywords—professional development; team-based learning; ethics; entrepreneurship; peer learning; rubric; ABET

I. Introduction

Many universities require engineering majors to take some form of a professional development course. Generally, the goal of a professional development course is to prepare students for their engineering career. Many universities require their engineering students to take non-engineering courses, such as technical writing, communications, and leadership to help satisfy this need. Some universities have even developed specific courses in engineering ethics [2] and engineering entrepreneurship [3, 4] to better serve their students. This paper discusses a unique professional development course, titled ENGR 2002, developed by the University of Oklahoma (OU) that includes all of these topics.

In addition to providing engineering students the type of well-rounded education needed for them to be successful in their careers, a professional development course can provide a mechanism to satisfy accreditation criteria on student outcomes that are difficult to implement in other technical courses. At OU, most engineering disciplines take the two credit-hour ENGR 2002 course. Historically, this course did an excellent job of satisfying difficult accreditation requirements, but was not well received by the students. To address this issue, the College of Engineering at OU formed a task force of leaders in different engineering disciplines to formulate a solution. The task force researched the problem and discussed with industry partners the areas of competency that should be emphasized in ENGR 2002. They arrived at similar conclusions that are presented in a recent study [1]; The EAC of ABET competency that is most important for engineers in industry is the ability to work in teams (EAC of ABET outcome d) [5]. The second and third most important competencies were shown to be data analysis (b2) and problem solving (e) in this study. Outcomes b2 and e are thoroughly taught in technical engineering courses so they are typically not difficult for engineering departments to assess. The study stated that the next three most important competencies were: communication (g), life-long learning (i), and ethics (f). With this information, the task force set out to modify ENGR 2002 to emphasize these four competencies (d, g, i, and f). The following additional outcomes are also assessed in ENGR 2002: (a, b, h, j, and k). Later in the paper, each project is described and the EAC of ABET outcomes that are emphasized are listed.

The next step for the task force was to analyze student feedback to see how the structure of the course could be modified to increase their interest level and overall satisfaction. There were four findings that became the foundation of the new ENGR 2002 course structure. First, the course relied too heavily on in-class lectures and a top-down learning model. In response to this finding, the course was switched to a team-based learning model with lecture time minimized and the time allotted to work in teams maximized. In a similar finding, the second thing that the students liked most about the old version of the course was the final group project. In response, this project was modified to overcome some of the issues the students had with various details. In addition to enhancing the final project, three more group projects were added to the course. The third finding was that the students disliked the multitude of quizzes and assignments in the old version of the course. The new team-based model we implemented for the course put the vast majority of the work required in the course to be performed in group projects. The last finding is that students had a difficult time aligning schedules to work on the final group project. To address this issue a lab/discussion session was added to the course. The students now have two 105 minute blocks in their schedule for the two credit-hour course. Attendance for the second class period of the week is usually optional, but it provides the students a time block in their schedules to work on the course projects. The new course was implemented in the fall 2012 semester. After the semester, a thorough assessment process was conducted that led to numerous changes to the spring 2013 version of the course.

II. Course Structure

The primary goal of this paper is to provide as much detail as possible to allow others to implement this course. From the experience gained and insights learned in teaching nine sections of this course over the fall 2012, spring 2013, and summer 2013 semesters, it is our belief that this course could be easily implemented in any engineering curriculum at any university. In order for this paper to be better used to implement the course, a week by week schedule will be used as a means to describe the course. Before discussing the projects and weekly schedule, the structure and some of the unique practices are discussed. Each section is composed of nine teams of four to five members that are programmatically selected to have diverse engineering disciplines and leadership styles. Each team selects a leader, who ideally only serves as a leader for one project to allow everyone the opportunity to gain leadership experience. In order to encourage participation in the team-based learning model of the course, a peer evaluation process is utilized that accounts for 10% of the overall grade. A peer evaluation template is filled out after each project that rates the team leader and members.

Each project includes a presentation that the students in the class grade with a provided rubric. The rubrics are kept simple so that students and faculty can easily judge the presentations while they are observing them. Details of the rubric are provided for each of the four projects in their corresponding sections of this paper. The average rubric scores from the students in the class equates to one judge. Three to five additional judges (including the instructor and the teaching assistant) also grade each presentation. The rubric scores from all of the 4 to 6 judges are averaged and normalized so that the team with the highest presentation score gets a 100% grade. The rubric scores from the four projects in the course results in 48% of the overall grade. Over the first two offerings of the new version of ENGR 2002, there has been strong correlation amongst the judges rubric scores. The correlation is shown to the students to provide them with a sense that the grading process is fair. In the assessment section of this paper, data shows the students strongly support this grading process. Furthermore, in reviewing survey data and student comments, we found that one of the greatest strengths of the course is the peer learning that occurs during the grading process.

The remaining 42% of the grade is broken down as: 10% for attendance and participation, 5% for a FE style ethics quiz, 10% for a final quiz, and the remaining 17% for various writing assignments. For the first two offerings of ENGR 2002 only 5% was assigned to the final quiz and the other 5% grade was given for participation in the course assessment process.

III. Project 1 Overview (Outcomes: d, g, h, i, j, k)

Project 1 is titled "Greatest Achievements of the 21st Century". The student's objective for this project is to study different engineering achievements of recent history and make a case for which one is the greatest of the 21st century. The students are allowed to select their own criteria to measure "greatness". Details of the schedule during this 3-week long project are described below. Week 1 is the most complicated and critical week in ENGR 2002 because it sets the stage for the entire semester. For the students to embrace the course, they need to be given clear justifications for the course and detailed explanations of expectations.

A. *Project 1 Weekly Schedule – Spring 2013*

Week 1 – The students are given a questionnaire to determine their major and there leadership style. The questionnaires are then turned in and the teaching assistant enters them into a spreadsheet while the instructor goes over the syllabus. Once the data is entered a LabVIEW program is executed to produce teams with high levels of different leadership styles and majors. While the program is running and the students see their names shuffling around into different teams on the screen, the instructor explains that the reason for assigning teams in this way is to give the students experience working with different types of engineering majors and personalities. The nine teams of four to five students assemble and select a team leader. The instructor then introduces project 1. The teams work the rest of the class period to finalize the three engineering achievements they will study. During this process the instructor and teaching assistant engage with the teams individually to help them get started. The students also turn in a timeline and task list by the end of the class period.

Week 2 – First, project management information is presented by an engineering professional with considerable experience in managing projects. The students are given a tutorial of how to make Gantt charts and information about project timelines and roles. The teams finalize their selection of the greatest engineering achievement of the 21st century from their list of three and create a Gantt chart and assign roles that they must adhere to in the completion of the project.

Week 3 – Each team presents their work; while all other teams score the presentation with the rubric they are provided.

B. *Project 1 Presentation Rubric – Spring 2013*

The following are the items judged with the presentation rubric. To keep the grading simple, each item in the rubric is worth 10 points for all of the projects.

- **Timeline and Roles** - A project timeline was prepared and team member roles were identified and adhered to. If timeline and roles were not kept, explain why.

- **Achievement Comparison** - The team made adequate comparison with 3 achievements and justified their rankings in a logical way.
- **Technical Details** - Describe how the product/technology was envisioned and brought to market. Which company and/or visionary team led the development of the project from start to completion?
- **Technical Details** - How will it (or does it) benefit or inspire society? What other positive or negative unintended consequences did the achievement generate?
- **Conclusion** - The team made a succinct and convincing conclusion statement highlighting all of the main points.
- **Overall Delivery** – It was presented clearly in a logical, organized, and easy to follow sequence. Topics were presented by all team members.

C. Project 1 Writing Assignment – Spring 2013

Each team is also required to write an abstract over their project. The abstract is graded by engineering faculty members skilled in writing. Each team receives detailed feedback from the graders.

D. Project 1 Lessons Learned

After each project description, a section will be dedicated to reviewing the lessons that were learned and changes made between the fall 2012 and spring 2013 courses. Many of these changes resulted from student feedback during the fall 2012 assessment process, which is discussed later in the paper.

- We found that project 1 was extremely effective in the fall 2012 semester at laying a foundation for the rest of the course. The great achievement theme was interesting to the students and the required items were not very difficult to complete. This allowed them to ease into the course and become comfortable in working in a team structure.
- Since we were limited to 105 minutes for 9 presentations, allotting the correct amount of time for each presentation was critical. In the fall 2012 semester, we used 8 to 10 minutes for the presentation length and had problems with going over the allotted time in some sections of the course. We found that having a presentation length of 7 to 9 minutes was the optimal length. We also instituted more severe penalties on the rubric score sheet for not staying in this time window in the spring 2013.
- Writing was emphasized in the fall 2012 course, but the feedback needed for them to learn to become better writers was lacking. In the spring 2013 we received support from an expert in technical writing to help provide feedback on writing assignments and redesign our writing exercises.
- In the fall 2012 semester, the writing assignment over the greatest achievement they selected was a short essay. To add a writing component to the course that is important to many engineers, we changed this to an abstract (or executive summary) writing assignment. This allowed us to be able to explain the importance of writing a good abstract and give them resources to assist them. We also turned this assignment into an Abstract competition, where the best abstract would receive bonus points. To provide better writing feedback and fair grading we found qualified faculty members to serve as the judges for this competition.

IV. PROJECT 2 OVERVIEW (OUTCOMES: A, B, D, G, H, I, J, K)

One important aspect of project 2 is that it is the only project that is highly technical. It is important to add a technical element into engineering courses to keep students interested. This project also allowed us to assess ABET outcomes A and B, which are not included in the other projects. Another important element of project 2 is that it is a video project. By forcing the students to experience a different form of communication that is growing in popularity, we were able to keep the course from being too repetitive. In the fall 2012 semester we titled project 2 "As the Pendulum Swings – The Movie". The objective was to experimentally validate the equation of the period for a pendulum. This was the one portion of the course in the fall 2012 semester that required a significant change.

From studying the student responses, we determined that the primary reasons that changes were needed were due to two factors. First, they didn't like watching a video of the same scientific principle numerous times during the peer grading process. To address the first item, we redesigned project 2 so that the students could choose any scientific principle to validate experimentally. The students were encouraged to build something to facilitate their experiments. Some examples of things that students built were a trebuchet, an aluminum foil-based capacitor, and a tennis ball launcher. The students also were required to select a unique application of the principle (discussed later). The second reason that changes to project 2 were needed was that students needed more guidance on how to make a video and what was expected of them. We added a lecture module describing how to make a video and used the example videos from the fall 2012 semester to give them guidance on what was expected. We showed them pendulum videos from the fall 2012 semester and told them that a good example of a unique application would be the Burj Kahlifa, which uses a massive pendulum as a tuned mass damper to stabilize the tall building. It is interesting to note, that we came up with the example of the Burj Kahlifa because it was selected by a team as their greatest achievement of the 21st century in the fall 2012 semester. From informal feedback, project 2 appeared to be very successful with these changes implemented and survey data (shown in Table I) supported this observation.

A. Project 2 Weekly Schedule – Spring 2013

Week 4 – The teams are reshuffled and no students are allowed to work with the same people as project 1. Next, research fundamentals are presented by an expert in performing research and navigating the OU library. This presentation prepares them for the more detailed research that is required in the remaining projects of the course. We also introduced the IEEE citation style guide at this point and required the students to properly cite all references in their work. Project 2 is introduced and the previously described fall 2012 video examples are shown and the Burj Kahlifa is highlighted as a possible application. A tutorial is then provided to give the students a basic understanding of how to make a video. For the remainder of the class the teams selected a team leader and chose a scientific principle to validate. Students who were team leaders in project 1 could not be team leader again. With the peer grading experience in mind, we didn't allow more than two teams to select a scientific principle in the same area.

Week 5 – Leadership fundamentals are presented. Then the teams work on their projects. The instructor should try to provide as much support as possible for the students during this project. We purchased a set of tools, materials, and measuring devices that the students could check out. Making arrangements with labs that might be needed to perform the experiments is also beneficial to the students.

Week 6 – Each team shows their video; while all other teams score the rubric they are provided.

B. Project 2 Video Rubric – Spring 2013

The following are the items in the video rubric.

- **Scientific Principle Validation Explanation –** The video explained the scientific principle in an easy to understand and thorough fashion.
- **Scientific Principle Validation Experiments –** The experiments performed were done in a clear fashion and were sufficient to adequately validate the scientific principle.
- **Applied Scientific Principle to a Product** - The video showed how this scientific principle is cleverly applied in an existing product to solve some type of problem.
- **Overall Video Content** – Video is logical, organized, and easy to follow sequence. The video is exciting and interesting.

C. Project 1 Writing Assignment – Spring 2013

For the team writing assignment for project 2, the students were given a scenario where they were the engineering team who first proposed the idea of applying this scientific principle to the unique application that was described in their video. With this in mind, the students were told to write a white paper to convince an audience of potential clients that the scientific principle is valid and persuade them to use this solution for the problem or activity being addressed. This required the group to learn about the technical details of the application.

D. Project 2 Lessons Learned

Changing the structure of project 2 to allow the students to be creative and come up with their own ideas was a big success. The students were much more excited and engaged in the project as a result. The videos were also much better than in the previous semester. The most important lesson we learned in this project is that the peer learning element of the students grading the presentations must be a central focus in the creation of projects. In the new version of project 2, the students learned about several different scientific principles and many unique applications that they were not aware of prior to the class. For future semesters, we are not going to allow any group to select the same scientific principle so the students of each section will learn about 9 different topics. We also purchased additional measurement devices that they can use.

V. PROJECT 3 OVERVIEW (OUTCOMES: D, F, G, I, J, K)

Project 3 was titled "Ethical Disasters". This project was similar in style to project 1, except the focus was on engineering ethics and professional licensure. Each team selected two ethical disasters that have a strong engineering focus. They performed a thorough literature review, obtaining reliable articles. During their presentation, they discussed the ethical and criminal issues related to the disaster and the societal, economical, and political impacts of the disaster. They also commented on key reasons for unethical conduct. The students then picked which of the ethical disasters they felt that "every engineer should know about" and justified their selection.

A. Project 3 Weekly Schedule – Spring 2013

Week 7 – The teams are reshuffled again with the students working with a new group of people. Ethics and professional licensure information is presented, which includes the steps involved to become a professional engineer. To tie professional licensure to ethics, the NSPE code of ethics is used. The students are told that they would be given a quiz similar to the ethics questions that are on the FE exam. For the remainder of the class, the teams select a team leader and chose two ethical disasters to study. Students who were team leaders in projects 1 or 2 could not be team leader again. Again, for the peer grading experience, we didn't allow more than two teams to select the same ethical disaster.

Week 8 – A guest speaker from industry with a strong ethics background and practical examples is brought in for a presentation on engineering ethics. For the remainder of the class the teams work on their projects.

Week 9 – The students take the ethics quiz at the beginning of class. Then, each team presents their work; while all other teams scored the presentation with the rubric they were provided.

B. Project 3 Presentation Rubric – Spring 2013

The following are the items in the presentation rubric.

- **Ethical Disaster # 1 - Overview:** Clearly Describe the Disaster and show the references that were used. Did the ethical disaster have a strong engineering focus?
- **Ethical Disaster # 1 - Details:** Discuss the ethical and criminal issues, and the societal, economical, and political impacts. Describe the reasons for the unethical conduct
- **Ethical Disaster # 2 - Overview:** Same as previous
- **Ethical Disaster # 2 - Details:** Same as previous
- **Most Important Ethical Disaster** – Select the ethical disaster that is the most important ethical disaster that every engineer should know about. (Justify the selection).

C. Project 3 Writing Assignment – Spring 2013

In the fall 2012 semester, an individual writing component was included where students compared different engineering disciplines code of ethics, such as NSPE, IEEE, and ASME. In the spring 2013 semester, the writing assignment was replaced with the ethics quiz. Since additional writing assignments were added in the spring 2013 semester it was decided that the ethics code comparison assignment should be removed to avoid increasing the student's workload.

D. Project 3 Lessons Learned

We received many comments from the students in the surveys that made it clear that studying the ethical disasters was a good way to emphasize the importance of ethics in the engineering profession. One student stated: "I think it's important to know about the mistakes that other engineers made and make sure they don't get repeated. Our mistakes cost lives so we should be reminded of that every day."

VI. Project 4 Overview (Outcomes: D, G, H, I, J, K)

Projects 1 through 3 focused on researching and presenting information about things that other engineers and scientists have done. Project 4, titled "Great Idea" leveraged the knowledge gained in the previous projects and allowed the students to come up with a unique engineering solution to a market problem. The project 4 presentation is the student's opportunity to pitch their great idea to "potential investors" (The class and the judges). The presentations start with the showing of the elevator pitch video (discussed later). For the rest of the presentation the students had the freedom to do any communication style they preferred.

A. Project 4 Weekly Schedule – Spring 2013

Week 11 (*Week 10 was spring break*) – The teams are reshuffled, trying to keep a minimal number of students working with the same people as project 1, 2, or 3. Also, students who have not served as leaders are put in different teams so they have the opportunity to be the leader for this project. Next, a guest speaker discusses the importance of engineers being involved in entrepreneurship. Project 4 is then introduced and an explanation of the "elevator pitch" is provided. For the remainder of the class, the teams select a leader and watch kickstrater.com videos. They must write a summary over one of the videos they liked and explain why they think it will be successful or not. Having the students watch kickstarter.com videos together was a method to get them thinking like entrepreneurs.

Week 12 – A presentation is given over idea protection. This is ideally presented by a lawyer who has experience in patent, copyright, and trademark law. Next, a technical ideation presentation is performed over the paper "The Innovator's DNA" [6]. The students are then assigned an individual writing assignment, which is due in week 13. The assignment requires the students to read the paper discussed in the technical ideation presentation and reflect on their discovery skills. The teams are also required to finalize their great idea by the end of this week.

Week 13 – A presentation from an entrepreneurship professor is provided to help the students with their business plans.

Week 14 – Half of the teams present their great idea during the first class of the week and the other half do their presentations during the second class. The presentations are increased to a maximum of 15 minutes and there is time at the end for questions form the judges. Business professors and graduate students are brought in as guest judges for this project.

B. Project 4 Presentation Rubric – Spring 2013

The following are the items in the presentation rubric. Additional details are provided in the project 4 assignment for each of these items.

- **Elevator Pitch** – Did the elevator pitch convince you to have a second meeting? The students were required to write an elevator pitch that clearly identified four major sections: Who, Why, What, and the Goal. An online template (http://www.alumni.hbs.edu/careers/pitch/) was used and the teams were required to meet the following specifications: 200 to 500 words and 56 to 120 seconds. The students made a video of one of their team members delivering the elevator pitch and it is shown at the beginning of the presentation.
- **Research** and study the "Market Problem" with regards to your "great idea". Assess how much this problem costs the market. The "cost" can be financial or other negative impacts of this problem.
- **Ideate** a technical engineering solution to the market problem. How will you reduce the 'pain' in the market (i.e. reduce the negative effects of the problem)?
- Describe your **technical solution** in detail?
- Address any **ethical**, **safety**, **regulatory**, or **intellectual property protection** issues that might arise in the implementation of this solution.
- **Conclusion** - Communicate why clients' would want to pay for your solution.
- **Overall Presentation Quality and Responses to Questions** – All members presented clearly in a logical, organized, easy to follow sequence.

C. Project 4 Writing Assignment – Spring 2013

The writing assignment for project 4 was a project proposal document, which is an abbreviated version of a business plan. The same elements that were required in the presentation are also in the business plan specifications. In the spring 2013 semester the students are given until the end of week 15 to complete the business plan. It was due at the end of week 14 in the fall 2012 semester, but we realized an extra week was needed for this assignment.

D. Project 4 Lessons Learned

In the spring 2013 we made several changes to project 4 after receiving valuable student feedback.

- First, in the fall 2012 the students were given 6 market problems that they could pick from if they couldn't think of one on their own and they had to choose something in the first week of the assignment. We observed that the students that seemed the most engaged in the project were those that selected their own idea instead of using one of the provided market problems. For this reason, we didn't provide any options and allowed an extra week to come up with an idea.
- The guest speaker in the fall 2012 mentioned kickstarter.com and it spurred a lot of interest amongst the

students. This is the reason we added in this element in week 11.

- The elevator pitch was also added in the spring 2013 semester because it is such a key entrepreneurial concept.
- The last thing that was changed was the length of the presentation and the style restrictions were removed. In the fall 2012 semester the project 4 presentations were of the same format as project 1 and 3. We realized that there was not enough time to cover everything, so we decided to split the presentations into two class periods to give more time. We also decided to allow the judges to ask questions at the end of the presentation.

VII. ASSESSMENT

To help determine the effectiveness of the modified ENGR 2002 course, an assessment was performed during the last class period (week 16) in the fall 2012 semester. The first assessment tool was a survey, where 148 students ranked different aspects of the course on a scale of 0 to 10, where 10 was the most positive answer. Following the survey, we had a team discussion about different aspects of the course. Many valuable ideas were obtained from this discussion time. In the last assessment exercise we asked for comments about different aspects of the course.

A. ENGR 2002 Survey

The following instructions are listed on the survey:

"DO NOT answer 5 on any of the questions. We want to avoid neutral responses. Answer every question for participation credit. You are free to answer the way you really feel (good or bad). The responses will have no impact on your grade."

For the first question of the survey the students were told to: *"rate each of the projects from 0 to 10. 10 would mean you really liked the project and 0 would mean you really didn't like the project."*

Table I shows the results of this survey question for the fall 2012 and spring 2013 semesters. For this question, additional survey data were obtained in the spring 2013 from two sections of the course that were taught by an instructor from fall 2012 (77 students) to assess the change in project 2. The average scores are shown along with the percentage of positive responses (6 to 10). The shaded cells in Table I show the dramatic improvement in project 2 that resulted due to the changes that were made between the two semesters.

TABLE I. FALL 2012 AND SPRING 2013 STUDENT PROJECT RATINGS

Project Number	*Fall 2012 Rating (0-10)*	*Fall 2012 % Positive*	*SP 2013 Rating*	*SP 2013 % Positive*
1	7.4	89.2%	8.2	95.4%
2	5.6	55.4%	7.5	89.2%
3	7.1	81.0%	7.7	90.8%
4	7.5	87.8%	7.5	83.1%

The next section of the survey asked various questions about the course. *"For each of the items below the students were told in the survey to "rate from 0 to 10. 10 is the most positive response and 0 is the moset negative"*

The **bolded underlined** data are the results from all sections in the fall 2012 semester (148 students). The original quiz had a blank where this data is located for the student to write their response.

- **7.6 avg. (+91%)** The CoE task force designed the content (Project themes) and group-structure of the new version of ENGR 2002 that was taught this semester. Do you like what they did?
- **8.4 avg. (+97%)** The Instructors (Landers, Sluss, and Davis) worked together to implement the task force recommendations. Do you like what they did?
- **8.1 avg. (+89%)** The rubrics used for the presentations were a good way to assign a grade.
- **7.9 avg. (+88%)** The class collectively serving as one of the judges was a good idea.
- **7.6 avg. (+88%)** You learned new things by watching/scoring other group's presentations.
- **8.1 avg. (+89%)** The attendance/participation grade served as good motivation to stay engaged in the class.
- **7.5 avg. (+86%)** The peer evaluation grade served as good motivation to stay engaged in the group.
- **8.9 avg. (+97%)** The attendance/participation grade should be continued next semester.
- **8.0 avg. (+84%)** The class collectively serving as one of the judges should be continued next semester.
- **8.2 avg. (+89%)** The peer evaluation grade should be continued next semester.

B. ENGR 2002 Comments

Following the survey we asked the students to comment on different aspects of the course. Some of the comments about what they liked about the projects are shown below:

- **Project 1** – "I had to do a lot of research … and in the process I learned … new things that were not only limited to science and engineering."
- **Project 1** – "I was introduced to several engineering innovations that I was not aware of previously. Also, it sparked my interest in keeping up with new fields of research and invention."
- **Project 2** – "It involved math and testing rather than just plain research."
- **Project 2** – "… the movie aspect forced you to be more creative and made the process much more fun.
- **Project 3** – "I found it very interesting to learn about several, historical engineering disasters where these codes

of ethics could be applied. This project tied everything together and made me realize just how important it is to approach ethics with a very high level of respect."

- **Project 3** – "I liked the learning about history aspect, and it gives someone the ability to realize the consequences of actions before they put themselves in a position where they do it to themselves."
- **Project 4** – "It required an understanding of everything we have done in this class. We had to apply the research skills, ethical skills, business plan skills, and ideation that we learned in this class. Also, this project required the teams to be more original and actually come up with new ideas."
- **Project 4** – "… introduced the creative and business aspects that are associated with becoming an engineering entrepreneur. The process of developing a unique solution to a current or foreseeable market problem is no simple task and is somewhat time-consuming. This creative exercise helped to teach the students just how much it takes both for ideation and research to develop a product or service that is truly unique and that solves a problem. By including a business plan in the project deliverables the business aspect was introduced, allowing students to further research their target markets, methods for marketing, product development and integration of consumer feedback and how they would integrate these aspects into their overall product development plan."

Student evaluations were also used to assess the course. The only question in OU's evaluation that provides evidence of an improvement in course effectiveness is the following question: "In general, the instructor taught this course effectively". The students respond on a 1 to 5 scale, where 5 is the most positive response. The average score for the 99 students in the four sections in the fall 2012 semester, which were taught by three different instructors, was 4.46. This was 27% higher than the average score of all courses in the College of Engineering in the fall 2012 semester for this evaluation question. It is also 60% higher than the average scores received for all ENGR 2002 sections in its previous version in spring 2012.

VIII. CONCLUSIONS

The ENGR 2002: Professional Development course at OU, in its new redesigned format, shows signs of success according to the assessment that has been performed. The numerous comments from the students that support the structure and material of the course gives us confidence that we are on the right track. To fully assess the effectiveness of ENGR 2002 we would need to survey the students (and possibly their supervisors) after they are practicing engineering at their job to see if the things they learned have been useful. In conclusion, student comments that speak to what we are trying to accomplish will be shared:

- "It forced me out of my comfort zone. What I mean is that it forced me to do a lot of public speaking and work with a variety of people with differing opinions/ideas, which are two things that I sometimes struggle with."
- "It teaches you valuable skills that you would actually use in your future career such as working in teams, writing technical papers, and presenting your research."
- "Getting comfortable with presenting project findings to a large group of people was highly beneficial personally as I have never been comfortable presenting in front of a group particularly over something that I have researched or developed. Now I am much more confident and comfortable with presenting and can better prepare for future presentations either for a potential thesis defense or for future jobs."
- "There was a lot of information and skills gained in this class that aren't developed in technical classes. This is a great way to get our minds thinking in not just a strictly technical viewpoint. It helps open our minds to other aspects of what an engineering career is really like."
- "It was good experience to work in multi-disciplinary groups and be able to lead and follow. It helped people that are introverted be more outspoken and extraverted take a lesser role."
- "The course is unlike any other required for engineers and from being in this class it is noticeable that people need to take it to work on public speaking skills or working with groups."

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Professional Development for Mid-Career Women in Computer Science and Engineering

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Abstract—This paper reports on self-rated career management knowledge, use, and confidence for women in computer science and engineering before and after participating in a CRA-W Cohort of Associate Professors Project (CAPP) professional development workshop. We find that months after their workshop, three years worth of participating women gave higher ratings for their knowledge and use of skills such as time management, networking, and productive mentoring relationships, as well as confidence in their promotability. These findings suggest that professional development interventions can have long lasting positive effects on mid-career women in computing, and that the type of group mentoring, role models, and community offered by CAPP can help compensate for women's reduced access to career mentoring.

Keywords—women; computer science; computer engineering; professional priorities; professional development; networking; leadership; soft skills; productivity; visibility

I. Introduction

Mentoring is the gold standard for advancing professionals. Its positive effects are well documented (for example, see [13]). Even among the studies of mentoring women faculty in academic settings [10, 14, 15], there is evidence for the importance of mentoring in faculty professional development [3, 4, 6, 7, 11, 12]. Positive impact is not a given, however. The most effective mentoring methods might vary by circumstances, including stage of faculty development [7, 11, 14], although the evidence is clear that high quality mentoring has a positive impact on professional development of diverse people.

Unfortunately, members of underrepresented groups, such as women in computing, have less access than majority men to informal mentoring [1, 2, 5, 8]. Likewise, senior women's scarcity means that even in formal mentoring programs, junior women face challenges finding someone demographically similar with whom to form a close personal bond. Demographic similarity is not required for successful mentoring, but it can offer understanding of the particular challenges associated with underrepresentation, such as low professional self-confidence, limited professional networks, and lack of insider information, which can hinder academic women's career achievement.

To level the playing field and help more women succeed in computing research careers, the Computing Research Association Women (CRA-Women) offer professional development workshops that help mid-career women advance their careers in computing. These Cohort of Associate Professors Project (CAPP) workshops develop women's careers by building community, offering intentional role modeling, and providing group and brief individual "mentoring"[1]. The group mentoring focuses on knowledge of strategies for professional visibility, time management, working productively with a mentor, effective communication. Armed with this information and with enhanced professional networks, our model for change predicts that these women will gain confidence in their promotability and become leaders in their fields.

This paper describes evaluation findings from three years of these CAPP workshops. Analyzing data from surveys of 127 participants, we find that after CAPP, participants reported more knowledge and use of career skills, and more confidence that they will be promoted in a timely fashion. This evidence suggests that professional development in the form of role modeling, group mentoring, and networking can build women's confidence that their careers in computing will advance. CAPP appears to achieve its goal of developing women leaders in computing research.

These findings suggest that employers of women researchers in computing can benefit from either sponsoring participation in CAPP programs, or organizing similar workshops for in-house professional development.

II. Description of the Project

CAPP aims to increase the percentage of Computer Science and Engineering (CS&E) women researchers at the rank of full

[1] More information about the program is available at http://cra-w.org/ArticleDetails/tabid/77/ArticleID/45/Advanced-Career-Mentoring-Workshop-CAPP.aspx

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professor, or the top of their organization's technical ladder. It provides professional development, a supportive community, and mentoring to cohorts of women researchers. As the project website describes, senior CRA-W Distinguished Professors or Researchers actively participate as role models, mentors, and advisers to the CAPP participants.

The CAPP project began in 2004 and repeats at two-year intervals. Each cohort participates in an initial professional development workshop, a series of smaller meetings in conjunction with technical conferences/seminars, and ongoing electronic support activities. Pre- and follow-up evaluation surveys are administered for each iteration of the workshop. The follow-up surveys are generally fielded a year or more after the workshop.

In total, 127 participants responded to either the pre-survey or the follow-up survey, 88 responded to both, with some missing data in both surveys. We include only first-time responses from the very few repeating CAPP participants in our analyses, and our analyses focus on the matched pre and follow-up surveys for the 88 respondents to both. We conducted qualitative analyses on open-ended questions regarding participants' professional activities and concerns, and quantitative analyses on questions regarding knowledge and use of career management skills as well as their relationship to confidence in promotion.

The extent of CAPP's reach into college and university computing female faculty may be estimated by comparing the number of CAPP participants during the three study years with the number of mid-career women in research universities. This approach approximates CAPP participants as accounting for approximately 21% of all female associate faculty from research CS&E departments in the U.S. and Canada[2].

For statistical analyses, we merged answers from 3 iterations of the surveys into one data set with matched pre and follow-up responses. In addition to descriptive statistics, we tested pre- and follow-up responses for significant changes in three categories of self-rating questions using paired samples t tests. Each survey item has an individual sample size due to missing data. Sample sizes for descriptive statistics range from 55 to 107 responses. Sample sizes for paired samples t tests range from 60 to 86 responses.

III. PROFESSIONAL ACTIVITIES & CONCERNS

CAPP participants are at mid-career and already have engaged in many well-known activities for advancing careers. For example, pre-surveys show that more than 70% of them collaborated on research or writing with someone inside and someone outside their institution or lab. More than 70% also served on a conference committee. All of these activities were within the year prior to CAPP. Unfortunately, only 37% had been mentored within that year.

Perhaps because so few had been mentored, participants came to the workshop wanting to learn a variety of things. More than 85% wanted to learn about networking and the promotion process, but more than 90% expressed interest in learning the less specific "skills that will help make me more promotable," "common mid-career issues," and "career management strategies for my stage". Without guidance from a mentor, these women may have worried that they did not know what they did not know. Certainly, our findings show that they initially were less than confident in their own promotability, despite believing that their accomplishments were appropriate for their career stage.

Overall, it appears that CAPP participants got what theuy wanted from the workshops. Their positive evaluations included free comments that they had learned about other computing subfields and other people, and felt more comfortable seeking advice, more energized, and more connected. Specific significant changes from before and long after the CAPP workshop are described in the following sections.

IV. PRE AND FOLLOW-UP SELF RATINGS

Prior to their first CAPP workshop, the average participant indicated that she knew something about time management strategies, ways of making herself professionally visible, how to work productively with a mentor, effective communication strategies, her organization's expectations for promotability, and its typical schedule for promotions. The average participant reported that she used that knowledge somewhat effectively, except in the case of working with a mentor, where she used this knowledge "not very effectively". Participants were also moderately confident that they met their organization's expectations for their current career stage. They were only slightly confident, however, that they met the criteria for timely promotability or that they had a professional network that would support their career growth.

A year or more after the workshop, the same respondents rated their knowledge, use, and confidence better than they rated it before the workshop, as shown in Figures 1, 2, and 3. To identify the statistical significance associated with the increases in ratings from Pre-CAPP to Follow-Up, we use t-test, paired sample t-test, and regressions to compare ratings from different time periods. Data sets used for comparisons in this chapter are of both equal and unequal sizes, due to missing data problems. Hence, using all three types of analysis render the most robust results [9]. Statistically significant results from these tests provide empirical evidence for the effectiveness of CAPP project.

In particular, knowledge of time management and being professionally visible rose from "some" to "quite a bit," on average. Effective use of knowledge about working productively with a mentor rose from "not very effectively" to "somewhat effectively." Confidence in being promotable and promoted in a timely way, as well as having a network supporting career growth, all increased to "moderately

[2] Based upon the survey responses, there were approximately 127 CAPP participants during our study years, with about 83 holding associate professor positions. We compared this number with the 2011-2012 Computing Research Association (CRA)'s Taulbee Survey, which reported a total of 291 female associate faculty members in CS&E [15]. We assumed similar numbers in the non-responding Taulbee population of departments. The result was 83/(291*.72)= 21%.

confident." All test results shown in Figures 1 – 3 are statistically significant at .01 level.

The t-tests confirm that the observed changes in pre and follow-up means are very likely to be real changes. Participants rated themselves higher on knowledge and effective use of information that contributes to career advancement. They also felt more confident that their careers would advance than they felt prior to the CAPP workshops.

A. *Self-Ratings of Knowledge*

There are five items in this category. Participants provided self-ratings of their knowledge of these areas on a 1-4 scale (1: none; 2: almost none; 3: some; 4: quite a bit). As Figure 1 shows, there was a significant increase in the four evaluated strategies – time management, professional visibility, working productively with a mentor, and effective communication. They did not however, show any significant improvement in the fifth item - their knowledge of their own organization's expectations for promotability. Of course, this last content was not covered during CAPP, but learning about it was encouraged.

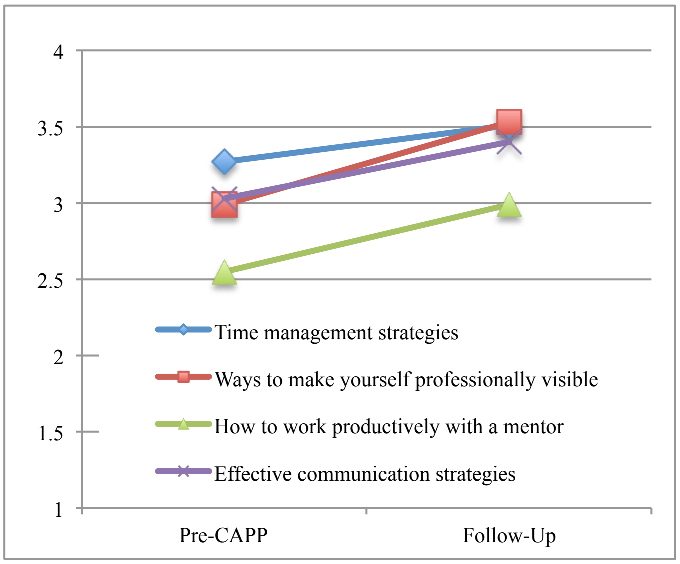

Fig. 1. HOW WOULD YOU RATE YOUR **KNOWLEDGE** OF THE FOLLOWING AREAS?

B. *Self-Ratings for Effective Use of Knowledge*

Participants provided self-ratings for how effectively they use their knowledge in certain areas on a 1-4 scale (1: don't use what I know, 2: not very effectively, 3: somewhat effectively, 4: very effectively). The pre and follow-up mean ratings shown in Figure 2 illustrate the improvements in use of knowledge reported by CAPP participants.

Paired Sample t test results confirmed that self-ratings of effective use of knowledge increased significantly in time management, professional visibility, working productively with a mentor, effective communication, and the respondent's own organization's expectations for promotability.

The means ratings for effective use of knowledge are across-the-board lower than ratings of knowledge in the same areas. All differences are statistically significant at .01 level, with means of use of knowledge lower than means of knowledge in each of these four areas: time management, professional visibility, working productively with a mentor, and effective communication. This indicates that our participants believe they know about these areas better than they use their knowledge.

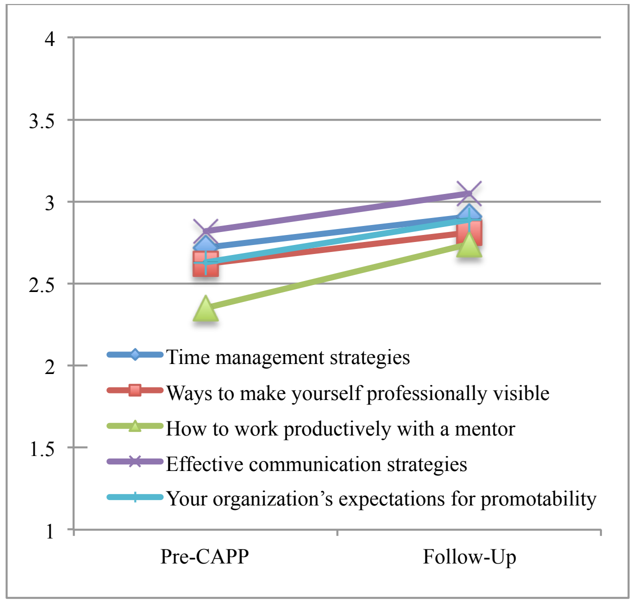

Fig. 2. HOW EFFECTIVELY WOULD YOU SAY YOU **USE YOUR KNOWLEDGE** OF THE FOLLOWING AREAS?

C. *Self-Ratings of Confidence*

Participants provided self-ratings on how confident they are in following areas on a 1-4 scale (1: not at all confident, 2: only slightly confident, 3: moderately confident, 4: very confident). Figure 3 below shows clearly that participants significantly increased self-confidence from before to after CAPP. The most dramatic increase is in their confidence related to professional networking. As with the other self-ratings, t-tests confirmed that these changes are statistically significant.

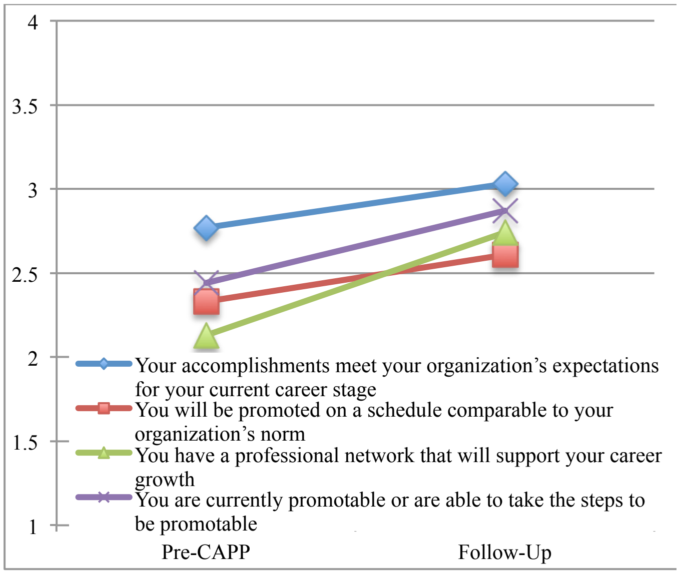

Fig. 3. HOW **CONFIDENT** ARE YOU THAT…

D. *Relationships among Knowledge, Use, and Confidence*

In this section we measure relationships between changes in knowledge of subjects addressed at the CAPP workshop and changes in effective use of that knowledge. We also investigate their contribution to changes in confidence regarding promotability. Finally, we consider whether the amounts of knowledge, use, and confidence are more important than the degree of change.

To create the Change in Knowledge index, we combined the difference in ratings for time management, professional visibility, productively working with a mentor, and effective communication strategies, and then calculated an average Change in Knowledge. We did likewise for Change in Use of that knowledge. The correlation between these two variables is moderate and statistically significant (r=.31, sig. at .01 level), meaning that an increase in knowledge is somewhat associated with an increase in effective use of that knowledge.

Much stronger correlations were evident between the follow-up Knowledge and Use indices (actual average ratings for these categories, not average changes) (r=.52, sig. at the .01 level). Evidently, level at follow-up is more important than changes in level.

E. *Explaining Confidence in Career Advancement*

The CAPP model for change is that improved confidence in professional advancement results when mid-career women researchers in computing gain knowledge from group mentoring by role models, and formation of a supportive community. To test that model, we regressed Change in Confidence on Change in Knowledge and Change in Use.

Our regression results for the change indices, shown in Table 1, find that this model is weak, but statistically significant. Together, Change in Knowledge and Change in Use predict five percent of the variance in Change in Confidence (sig. at .05 level). Change in Use is the stronger predictor of Change in Confidence (beta=.19), but neither variable has a statistically significant effect.

Level of Knowledge and Use, rather than Change in Knowledge and Use, is a better predictor of post-CAPP confidence. We regressed indices constructed similarly to those above on an index of follow-up Confidence level.

The regression results for measures of levels, also shown in Table 1, find that this model explains 26% of the variance in Confidence level (R^2 significant at the .01 level). Clearly other factors play a role in Confidence level, but Knowledge and Use each also contribute significantly. As with the Change analysis, level of Use is a better predictor of Confidence than is Knowledge. In this case, a one unit increase in Use is associated with .38 units increase in Confidence, and a one unit increase in Knowledge is associated with a .21 unit increase in Confidence (both are significant at the .05 level).

V. DISCUSSION

Many studies support the effectiveness of career mentoring, role models, and community membership as contributors to career success. Unfortunately, women in computing have less access to these beneficial conditions than do their male colleagues. To compensate for this inequality, CRA-W CAPP workshops seek to develop women's careers by building community, offering intentional role modeling, and providing both group and brief individual "mentoring". This paper investigates whether this approach succeeds.

CAPP's group mentoring conveys information about strategies for professional visibility, time management, working productively with a mentor, and effective communication. Armed with this knowledge and with professional networks enhanced by the workshop, participants are expected to take more effective action toward advancing their careers. The expectation is that this type of mentoring compensates for women's relatively lower access to career mentoring and increases their confidence in their promotability, which should help advance women to leadership positions in their computing research field.

Our analyses of pre- and long term post-CAPP survey data lends support for this model. Perceived knowledge, effective use, and confidence were greater for the average participant long after CAPP workshops. This improvement was especially evident with respect to working effectively with a mentor and feeling confident in having a supportive professional network.

The evidence also supports the model of career development knowledge contributing to effective use of that information, and together contributing to mid-career women computing researchers' confidence they are promotable. The change associated with the workshop, however, is less influential than the participants' actual levels of knowledge and use of career advancement strategies. In other words, women with access to career information, who also use it effectively, have less need for the CAPP experience. As long as this access remains low for many women in computing, however, professional development workshops like CAPP meet an important need.

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Planning Teamwork Teaching Based on Students' Feedback in Engineering Education of China

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***Abstract*— Teamwork has been considered as one of the important learning outcomes for engineering graduates. Industry sees higher education as being where graduates should be prepared with these professional skills. Every year, a lot of engineering students graduate in China and how best to train these students to be good team players is an urgent and important need. This paper describes a planned, improved mechanism for teamwork teaching on a joint degree programme between a top Chinese university and a key British university. A previous experiment about teamwork teaching to Chinese engineering students was conducted in a Personal Development Plan (PDP) module that takes professional skills as its main objectives. This work describes an improved approach to teamwork teaching based on the experience derived from the previous practice and a summary of students' feedback about PDP that was collected from several questionnaire-based semi-structured interviews. The improved approach will be conducted in both the PDP module and a technical module – Software Engineering.**

Keywords—teamwork; students' feedback; engineering education; China; technical module; improved mechanism

I. Introduction

Current levels of complexity in technology make it impossible to complete an engineering project on one's own; it should be designed and implemented by a group drawn from different disciplines or from different countries. Chinese engineers must welcome this challenge and learn how to work well with others on a common technical goal. Industry sees higher education as the place where graduates should be prepared with these professional skills.

This paper describes a planned, improved mechanism for teamwork teaching on the joint degree programme (JP) between Beijing University of Posts and Telecommunications (BUPT) and Queen Mary, University of London (QMUL). This programme aims to mix the best of teaching approaches from China and the UK; it recruits the best students who have achieved well above the top line in the Chinese national university entrance examinations. This programme puts more emphasis on professional skills training than other Chinese degree programmes.

The background of Chinese engineering students is very different from that in most Western countries: emphasis is traditionally on individual and competitive learning of complex mathematics and physics rather than working together. The large population in China results in high levels of competition. Students' learning is motivated by factors such as high marks, degrees or certificates, rather than by intellectual inquiry, interest, gaining competence or self-improvement. Therefore they put more effort into the learning of "hard" technical skills, essential for degree application and job hunting – and importantly to them, which are always given marks. This means they often sacrifice the "soft" professional skills, which are difficult to assess and demonstrate in a short period of time. Cultural influence, like face saving, compliance, harmony and group thinking, also makes it complex and difficult to teach technical teamwork to Chinese engineering students.

A previous experiment about teamwork teaching to Chinese engineering students was conducted in the Personal Development Plan (PDP) module that takes professional skills as its main objectives in 2011. The experiment results have been analysed in an earlier paper [1].

This work describes an improved approach to teamwork teaching in the PDP module based on the experience derived from the previous experiment and a summary of students' feedback about PDP that was collected from several questionnaire-based semi-structured interviews [2]. For the first time it attempted to put some tests and checks in the group project of a technical module: Software Engineering (SE).

II. Related Study

Many studies report successful practices in classroom-based teaching of teamwork [3-5], the most popular practice being to assign group projects in technical modules. Many approaches to design and manage group projects can be found from the literature, for example [6, 7]. Researchers often comment on the teacher-controlled factors that influence students' team experience [8, 9], and many computer systems have been developed to help the process of group formation, administration and teamwork assessment [10-12].

However, other researchers and educators argue that teamwork skills cannot be learned through *ad hoc* project experience without teaching; it is a learned skill, and should be taught, practised and assessed as other academic skills in a project module with teamwork as its main objective [13], a specific programme that teaches interaction skills [14], or a minor in Engineering Communication and Performance [15].

III. MECHANISM PLANNED

A. PDP Experiment

The experiment will be conducted in the Year 1 PDP module. Students will be asked to produce and deliver a presentation in English for a foreign audience in groups. The topic can be a famous Chinese engineer or scientist, introduction to the JP for a visiting student, 'Inside Beijing' - tips for travellers, 'Hidden China', or a day in the life of a JP student.

1) Four group formation methods:

It was found in the previous experiment that self-selected groups did not perform better than groups formed by other methods; in fact they were worse [1]. This was contrary to the finding of Phuong-Mai and colleagues: it was better for Asian students to form groups based on existing friendship to enhance cooperation [16]. However due to the small sample it did not show any statistically significant difference between the four team forming methods in academic results and team performance in the previous experiment.

This work will select a bigger sample to find the statistical difference of the four different team-forming methods. The Year 1 JP students (20-22 classes) will be grouped by four different methods, with each method grouping 5-6 classes (30-36 groups): i) self-selection; ii) random assignment; iii) academic merit (grouping students with the same ability range); iv) fair system (mixing the academic rank with good, middle and bad together). The hypothesis that will be tested is: *self-selected groups do not perform better than groups formed by other methods for Chinese students; they are even worse*.

2) Introduction of teamwork skills

In the previous experiment, it was found that the introduction of teamwork skills was helpful and welcomed by students. But the students also expressed demands for more skill training and instructor interaction. In this experiment, a brief introduction of teamwork skills will be given at the beginning of the task, and then several workshops will be organized to discuss and practise specific team skills. The instructor will attend some group meetings to give advice and guidance.

3) Team policies

In the PDP interview[2], students reported that in groups already-confident students were more likely to take the role of leader and presenter to further develop their confidence, while the shy students had no opportunity or space to come forward. The definition of confidence varies: it can be the confidence to speak in public, it can also be the confidence to assert one's right (say NO to others politely), to deal with unexpected problems, difficulties and conflicts in relating with others, and to search and learn new knowledge and skills to solve a problem. These attributes are required in team work, but are often lacking in Chinese people.

In order to overcome this weakness, an explicit policy should be made. Firing members of the team after two formal warning letters beforehand is allowed. The sacked members are allowed to form their own groups or join other groups if accepted, otherwise they will work on their own to finish the work. Students are, therefore, encouraged to deal with problem members instead of tolerating their misconduct.

Random checks and mine/ours strategies will be used: the instructor nominates one or two students to represent the group to present their work, and asks questions about the work strategy, individual contribution, and individual suggestions on choosing topics. In this way, the dominant students will share work and knowledge with others to reach the team goals.

It was found that the Chinese students preferred single leadership, and did not know how to set up or accept shared leadership in the previous experiment. In this experiment, students are asked to select one leader who coordinates the whole group's work and keeps team work on track. Other members take separate shared responsibilities in specific tasks.

4) Agreement of expectations & Teamwork evaluation

Students will be asked to work out an agreement of expectations for their group at the beginning, and evaluate their team performance in the middle. These two mechanisms were adopted from Barbara and Richard's work [6], and were found effective and culturally appropriate in the previous experiment.

5) Peer rating

Many educators continually invent and improve peer evaluation approaches [17, 18]. In this experiment, students will still be asked to rate team members including themselves upon team citizenship instead of academic contribution. Because the peer rating system suggested by Barbara and Richard [6] did not have detailed grading criteria and the grading consistency is a concern in the previous experiment, in this experiment the Comprehensive Assessment of Team Member Effectiveness (CATME) [12] will be used. At the end of the task, each student fills the CATME peer rating form online. An individual mark will be calculated by the weighting factor of the peer rating results (Individual Mark = team mark * (individual peer rating mark / average group peer rating mark)).

6) Give sufficient detailed feedback quickly

Immediate feedback will be given in class to comment on the overall work of all groups: good examples and common problems. The anonymous peer rating results and a short comment on each group's final work will be given together with the mark later.

B. Technical Module Experiment

The previous experiment of teamwork teaching to Chinese engineering students was done in the PDP module, which takes professional skills as its main objective. This research initiated a pilot study on the supplementary strategies on teamwork teaching in the group project in a Year3 (Y3) technical module – Software Engineering (SE), in which teamwork skills are also one of the course objectives. Many educators have done a lot of research on teamwork teaching in SE [19, 20].

In this Software Engineering module, students were grouped into 9-10 to do a group project – developing a Technical Conference Management System. In the middle of the project, students were asked to do two tests: Team

Knowledge Test (TKT) [21] and Self Assessment of Communication Skills [22]. These tests will help students to enhance their awareness, knowledge, understanding and self-reflection of teamwork and communications skills. In the TKT test, students were asked to mark what they think is correct and what they would choose to do. The difference between knowledge and behaviour will be examined. These students are the same cohort of students as in the previous experiment two years ago. A similar TKT test was conducted with the current Year1 (Y1) students. This allows a comparison of the team knowledge level between Y1 and Y3 students to investigate any progress in the process of group work practice. After the project, students will be asked to complete the Team Process Check (TPC) [21] online to evaluate their team performance. The correlation between TKT result and TPC result will be tested. The coursework mark is marked out of 100 – 90% are group marks and 10% are given for individual participation and achievement presented by weekly reports. Since the peer rating mechanism had not been shown to be effective, valid, reliable and culturally appropriate in the PDP module, it was not introduced in SE. Because this is a senior core course that takes a reasonably high percentage in the degree Honours calculation, more caution should be given in changing the evaluation criteria. In senior years, the course content becomes more difficult and students are all busy preparing postgraduate applications and job hunting. If the overhead for students in teamwork learning is too high, the efficacy of the study suffers as student responses become hurried and superficial. A questionnaire was circulated to students to complete, and students' perspectives of the teamwork teaching and learning in this senior technical module will be collected.

IV. CONCLUSION

This study aims to improve teamwork teaching in Chinese engineering education. An improved approach to teamwork teaching has been designed with increased introduction and instructor interaction, single leadership and a more precise peer evaluation method. The four team formation methods will be compared statistically in promoting team performance and productivity. A pilot survey and tests were performed in a technical module (SE). Students' teamwork knowledge, communication skills and team performance were examined. The gap between declarative knowledge and skill based behaviour will be identified. Maybe because these teamwork tests were not graded in the final course mark, the response rate was very low. However it at least reflected a more realistic situation in teamwork teaching in technical modules. The questions will be studied using data collected from questionnaires: how do the senior students rank the importance of teamwork learning? How would they like to incorporate it in the technical modules?

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Improving Student Writing Through Multiple Peer Feedback

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Abstract - **This paper describes the design of a study to examine the effects of various types of feedback and revision on student writing quality improvement in a first-year engineering course. We apply the previous work of Cho and MacArthur that showed that multiple peer feedback is superior to single peer and single expert feedback in improving student writing quality. We extend their work to examine the effects of in-class instruction on giving peer feedback, and also examine the effect of giving (rather than receiving) feedback on student revisions. Preliminary findings from this study will be presented at the conference.**

Index Terms – communication, peer feedback, revision, writing

INTRODUCTION

It is widely recognized that effective written communication skills are essential for engineers. [1] This is reflected in the ABET accreditation criterion 3g, that students should develop "an ability to communicate effectively." [2] In addition, International organizations like The Chartered Institute for IT consider communication to be an essential transferrable skill for any student of information technology. [3] However, many engineering instructors are reluctant to integrate writing assignments into their curricula and writing instruction is often relegated to a technical writing service course rather than in the context of engineering courses [4]-[5].

Best practices of writing instruction include a recursive understanding of writing as a process and review of an earlier draft to allow for revisions before the paper is submitted for evaluation. [6]-[7] Revision is considered a fundamental component of improving written work, yet writing assignments in engineering courses are often submitted unrevised. Many engineering instructors feel that they do not have the requisite skills to effectively provide feedback or that within a content-packed course, revision is not possible given the limits of instructors' time, the large class sizes, and the lack of pedagogical training for teaching assistants.

One way to address these concerns is to use peer feedback. Recent research by Cho & MacArthur [8] showed that feedback from multiple peers (MP) in a psychology research methods class was more effective in improving students' writing than feedback from a single expert (SE)—typically the instructor—or a single peer (SP) reviewer. When compared with single-expert and single-peer feedback contexts, multiple-peer (MP) feedback revealed improved student understanding of comments and included non-directive recommendations for revisions, which resulted in more complex repair decisions (global issues like organization and thesis focus vs. local issues like sentence structure and grammatical structure) and new content revisions as well as improved paper quality overall.

The purpose of this study is to examine the various ways that peer review affects student writing quality in a first-year engineering course. We will attempt to reproduce the results from Cho & MacArthur's study in this context, as well as extend it to explore the impacts of different types of peer review instruction. We also compare the effects of the act of peer reviewing vs. the act of receiving feedback.

Research questions include:
1. How do different forms of feedback (SE – single expert, SP – single peer, MP – multiple peer) affect improvement in students' writing quality in an engineering course?
2. How does the form of peer review instruction affect student perceptions of the helpfulness of feedback received?
3. How does training on feedback best practices for writing peer review affect the quality of peer review comments?
4. How does acting as a peer reviewer impact writing improvement?

SETTING

This study will take place in a second-semester course of a first-year engineering program at a large research university located in the southeastern United States. This course includes mainly first-year students intending to major in electrical and computer engineering and computer science, although a small portion of the students are more advanced or intend to major in other disciplines. Approximately 400 students are enrolled in the course.

The Contemporary Issue Report (CIR) is a major assignment in the course. The CIR asks students to select and report on a contemporary issue in electrical and computer engineering or computer science. Students are given a template based on IEEE formatting and citation styles and an example of a report that was written by the instructors. This assignment has been given for three semesters, but past semesters did not include any peer review or opportunity to revise the submission.

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ANALYTICAL FRAMEWORK

To define improvement in writing quality, researchers utilized a rubric with categories in writing mechanics, writing quality, and technical quality. Student work was evaluated against these categories and was assessed as unacceptable, marginal, proficient, or excellent. Writing mechanics were evaluated based upon students' use of assignment template and grammar, mechanics, and spelling. Writing quality was evaluated based upon the paper's structure, conceptual engagement, support, and references. Technical quality was evaluated upon students' ability to engage the problem, link the problem to their field, and discuss solutions, tradeoffs, ethics, and societal impacts of the contemporary issue.

METHODS

In order to confirm and extend the previous findings of Cho and MacArthur, students in this study will be divided into a total of six feedback group conditions. In the prior work, there were three feedback group conditions:

1. Single Expert Feedback (SE),
2. Single Peer Feedback (SP),
3. Multiple Peer Feedback (MP).

Students in all conditions still reviewed others' work based on a general writing rubric.

To extend this framework we further divided the students in this study. Half of the peer feedback condition students received in-class training from a writing instructor on how to give effective feedback, and the other half received their feedback training via a handout developed by the writing instructor. This extends Cho & MacArthur's work to determine the efficacy of two types of instruction on feedback best practices. Within the SE group, students will be divided such that some give no feedback to their peers and some give feedback based on the handout. In this study, our experts consist of both workshop instructors and graders who are advanced engineering students. The peer feedback will not be exchanged in this group so that we can examine the effects of giving peer feedback independently from receiving it. These new parameters mean that this study has a total of six feedback conditions rather than three. The division of students into groups is summarized in Table 1.

TABLE I
DESCRIPTION OF TREATMENT GROUPS

Feedback Condition Group	Received Feedback Parameter	Peer Feedback Instruction Parameter
A	Single Expert	No Instruction
B		Handout
C	Single Peer	Handout
D		In-class + Handout
E	Multiple Peer	Handout
F		In-class + Handout

Student work products in this course are collected for research purposes under IRB approval. Only work products of students who actively consented to this collection are analyzed in this study. In order to ensure equity, we will identify any significant difference between treatment groups in students' mean assignment grades and normalize them.

ANALYSIS

A random sample of student drafts and final papers will be taken from each feedback condition to be evaluated by the researchers. This evaluation will consist of three steps:

1. Assess initial draft according to rubric
2. Code peer or expert feedback on initial draft
3. Assess final submission according to rubric

Feedback will be coded according to the parameters of quality peer feedback included in the handout and in-class instruction. Quality peer feedback guidelines instructed students to write comments that were specific, encouraging, and that offered suggestions for improvement. The evaluation rubric was included in the handout and students were encouraged to use the rubric's values to guide their feedback (e.g. peer feedback should focus more weight on issues of argumentation and source synthesis—worth a combined 20% of the grade—than grammatical errors or typos that are worth only 5% of the grade).

By comparing the level of writing quality improvement between the six feedback conditions, we will be able to verify that multiple peer feedback results in the highest level of improvement. We will also be able to examine the effects of peer feedback instruction on both feedback comment quality and overall paper improvement. Finally, by comparing group A to group B, we can determine the extent to which writing improvement from draft to revision is affected by giving others feedback rather than just receiving feedback, a result that could allow students to become better readers of their own writing during draft stages.

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An Empirical Study: Team Charters and Viability in Freshmen Engineering Design

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Abstract—*While the concept of teams has been diffused into engineering education as an instructional activity for nearly two decades, questions remain about how best to provide instruction so that it supports student teams' effectiveness without compromising technical content. Additionally, employers in industry, government, and higher education have an insatiable need for engineers proficient in work that requires multi-disciplinary teams. The issue is further compounded by the sky-rocketing cost of education—students and families want an acceptable rate of return on their tuition. Administrators must determine how to increase value-adding coursework. Engineering education and team literature is replete with theoretical and descriptive studies focused on adding separate team-building courses to the already full and expensive mandatory class lists. Students and their families do not want to pay for more credits; they want more for their investment. To this end the current study looks at one facet of planning, team charter enactment, in relation to team effectiveness—operationalized as team viability within an existing freshmen design engineering course at a large Mid-Atlantic university.*

Keywords—*team effectiveness; teamwork mental model similarity; team charter; team viability*

I. Introduction

This study seeks to understand and measure the relationship among team charter enactment, teamwork mental model similarity, and team viability. Team charters are codified agreements on how team members will work together to accomplish team goals. Teams that share a "common view" or "lens" are said to have a similar team mental model. Current research highlights team mental models as predictors of increased teamwork and team performance. Team viability, the desire to take on future work as a team, is critical to engineering freshmen because they are likely work with the same students on future team projects. The extant engineering education literature offers little on empirical team effectiveness studies—that is, no engineering studies have looked at the use of team charters in the classroom, yet data indicate the use of team charters in engineering classes [1], [2], [3]. Articles mention team charters or codes of cooperation as parts of larger team-based assignments; however, they give no details or explanations on their use. This investigation addresses gaps in the extant engineering student team effectiveness literature.

II. Contribution

A. Situation Being Addressed

Teams have become commonplace in engineering education over the last 20 years. Yet questions remain: Are students effectively working in teams? Are educators and administrators consistently offering empirically tested instructional activities? What instructional activities can educators use in the classroom to ensure students not only deliver the team-based project assignment, but work effectively in the team context? Where is the demonstration of such learning?

B. Goals of Proposed Practice

This study aims to determine whether team charter enactment is a direct antecedent of team viability. Additionally, the study reviews the mediational effect of teamwork mental model similarity on team viability. Team viability is a predictor of team effectiveness [4]. Hence, successful use of team charters should improve team effectiveness. This work in progress seeks to understand and measure the reciprocal relationship among team charters, teamwork mental models, and team viability.

A secondary goal is to provide educators with an empirically tested team effectiveness instructional activity that may be easily executed within their current team-based classes. Results will help instructors provide students with a foundational team skill that is applicable in their work as they matriculate from freshmen to world-class engineers.

C. Research Foundations

Three areas of team-based research provide the foundation for this proposed practice: team charter, teamwork mental model, and team viability.

Team charters have been shown to increase the quality of work [5], develop cognitive and practical skills [6], clarify goals and operating principles [7], and improve team effectiveness and performance [5], [8], [9], [10], [11]. Additionally, team charter enactment has minimized many of the common pain points for student teams: poor communication, lack of decision-making processes, social loafing, and unresolved conflict [8], [10]. Once students acquire team chartering skills they will be poised for success in future similar team interactions [6], [10].

Teamwork mental models are "organized mental representations of the key elements within a team's relevant environment that are shared across team members" [12: 877], including: objectives, "team roles, behavioral expectations, and interaction patterns" [13: 65]. Members who have similar teamwork mental models have been shown to demonstrate better team performance [14]. More concretely related studies include findings that team-shared mental models had a positive effect on team coordination in geographically dispersed software engineering teams [15]; and shared team mental models (degree and structure) were shown to improve performance between measured time periods [16]. Additionally, a recent study of shared knowledge among engineering design teams revealed that the level of shared knowledge changes most during the early phases of team development. This is represented more by teams with more complex and longer team project life-cycles [17]. Hence, designating time toward planning is vital.

Team viability, the desire to want to work as a team in the future, has been consistently linked to team effectiveness and performance [1]. Team viability is of critical importance to team-based learning, which is an integral part of engineering education. Negative team experiences can distort a student's attitude towards future team experiences [21]. Today's freshmen will be required to work together in a team environment in future engineering courses as sophomores, juniors, and seniors. Therefore, helping them proactively plan for "how" to work as a team, team charter creation, should reduce counterproductive intrateam interactions such that members desire to work together again in the future as a team.

III. Description

The study is being designed for implementation in team-based freshmen engineering design and/or problem-solving courses. Motivating factors for this study are threefold: a) provide much needed empirical team-based research in the engineering education discipline; b) offer useful and actionable research for faculty and instructors to apply in the classroom with minimal interruption to the delivery of technical content; and c) provide students with a team skill that can be used throughout their academic and professional career.

IV. Research that has Supported the practice

Team effectiveness instruction was delivered, via in-class facilitation, to a class of Engineering Leadership minors at a large Mid-Atlantic university during spring 2012. Teams took part in an industry-sponsored semester-long design project. The deliverable was a business plan and team presentation. Each team had members in the United States and at least one European country. Due to distance and resources members relied on email, Skype©, and other virtual communications to complete their work. The course is a major component of the Leadership minor in the engineering college. Feedback from the students, teaching assistant, instructor, and faculty were overwhelmingly positive. The session was requested by the instructor and faculty member for future classes. During the spring 2013 session two students from the spring 2012 class served as guest presenters. Their topic was lessons learned in 2012 and how to be successful in the project phase of the class. When asked where they developed their presentation content, they replied, "the team effectiveness session you did from last year." Two of the most helpful strategies learned, per the two students, were: "just being given time to sit down and plan out how we would get the work done"; and "the team calendar was really helpful".

Additional pre-pilot study work has been accomplished at a small public southern university during summer/fall 2012. A team charter lesson and assignment were used in a U.S. Department of Education-funded STEM retention program. The project was put in place to increase STEM student retention between the freshmen and sophomore years. Seventy-two STEM freshmen received team charter instruction, subsequent homework assignments, and feedback from peers, instructors, and the team charter lesson facilitator. Feedback was collected via class discussion and an anonymous survey. The survey included open-ended and Likert-type questions. The feedback was overwhelmingly positive. Ninety-three percent of participants reported, "Developing the team contract assignment was helpful to me as a team member". Eighty-nine percent stated, "I plan use the team contract idea from the discussions in future team projects." Similar responses were given in response to questions regarding participants' belief that the lesson increased their competency to be successful, and was helpful in strengthening their knowledge and interest, in STEM (96.5% and 89.5%, respectively).

V. Work Remaining to be Done

Future work includes executing a quasi-experimental study in multiple sections of a freshmen engineering design course. The study will be the first test of team charter quality, shared teamwork mental model, and team viability. This work in progress builds on recommendations in the existing literature [16] by offering "better team-based instruction" that seeks to improve team mental model similarity.

In summary, the proposed work aims to provide engineering educators with an empirically tested, low-cost (time and resources) instructional activity that can positively impact student team effectiveness.

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Drafting Program Educational Objectives for Undergraduate Engineering Degree Programs

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Abstract - **This paper outlines the process to draft Program Educational Objectives (PEOs) appropriate for undergraduate engineering degree programs at ABET-accredited institutions of higher education. In the ECE department at our University, the existing PEOs were deemed to have language that was very similar to that used in the ABET student outcomes. Therefore, it was imperative to distinguish the PEOs from the ABET student outcomes since the PEOs must quantify the expected attainments of graduates a few years after graduation. First, PEOs must reflect the Mission Statement of the institution and serve as a yardstick of student achievement three to five years following graduation. The objectives represent the expectations of the department from its graduates. Active participation by the faculty in defining the PEOs yield clear and concise objectives and promotes ownership of the goals of the Department and ABET process. However, not all faculty members are necessarily familiar with the assessment language and the process to evaluate the PEOs. In order to ensure a meaningful contribution from all faculty members involved in defining the PEOs, this paper presents a framework to define the PEOs that (1) adhere to the Mission of the University (2) achieve consistent and measurable expectations.**

Index Terms – Program Educational Objectives, Accreditation, Assessment, Bloom taxonomy

INTRODUCTION

Program Educational Objectives (PEOs) for undergraduate engineering degree programs must clearly define the vision of the program for its graduates three to five years after graduation. These objectives represent the expectations of the department from its graduates and must be crafted such that measurable objective evidence can be obtained through alumni surveys. In addition, there must be in place internal and external review procedures to periodically review and revise the language, assessment, and evaluation of the PEOs. The focus of this paper is on defining the process to draft the PEOs. The framework that we propose is first to provide an assessment language that is similar to the cognitive learning pattern of *Bloom's Taxonomy for Knowledge, Comprehension, Application, Analysis, Evaluation and Synthesis* during the different stages completed by our graduates in their career path. Faculty members should recognize that the students in the undergraduate degree program are viewed as *learners* who must acquire the intended skills over the duration of the baccalaureate program. These students are then expected to *demonstrate* the application of these skills three years following graduation. They are expected to assume more responsibilities in management or to *lead* in their profession and/or society six years after graduation. Ten or more years after graduation, these students should become *contributors* with significant influence on policy and decision making in their chosen profession and/or society. The assessment language at these different stages of our graduates' career path is different. Hence, it is important to use the proper set of assessment language intended for the PEOs that focuses only on the immediate or first three years to measure the direct impact of our program on young careers, not the six-year or the ten-year longer term objectives which would measure learning experiences and contributions beyond the direct impact of our program. Second, the framework requires faculty to extract key words from the Mission Statement of the institution which emphasize the broad and specific intent of undergraduate education along with a set of key words that the faculty see as attributes to gauge graduates in becoming the individuals the PEOs intended. Third, capture the distinction between educational objectives and student outcomes, and formulate each objective recognizing the need for measurability.

The faculty of the Electrical and Computer Engineering (ECE) department at our institution met on different occasions for discussion and a final work session for almost six hours to complete the steps of the process in order to revise the existing set of PEOs. The PEOs of our fully accredited undergraduate ECE program (accreditation period from 2005 to 2011) were deemed to have language that was very similar to that used in the ABET student outcomes. Therefore, it was imperative to distinguish the PEOs from the ABET student outcomes since the PEOs must quantify the expected attainments of graduates a few years after graduation. For instance, the ECE program at one pre-eminent institution [2] develops the PEOs according to three expected outcomes from graduates five years after graduation – *professional expertise, innovativeness, and leadership*. At another institution [3], continuous education program assessment is addressed by bringing together a working team of departments and education specialists using a Web-based assessment process to gather and evaluate the data. There are also institutions that stipulate

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the PEOs of the program without empowering the faculty to develop, own, and adopt a consistent set of measurable PEOs.

Section 2 provides a broad overview of the PEO assessment cycle at our institution with internal and external review processes. Section 3 describes the framework to formulate the PEOs. Section 4 discusses the PEO assessment and evaluation process, summarizes the mapping of these PEOs to the ABET student outcomes, and the preparation of the alumni survey. The conclusions and future issues appear in Section 5.

SECTION 2: PEO ASSESSMENT CYCLE

The following requirements are stipulated by ABET in its Self-Study Questionnaire [1] as part of Criterion 2. Program Educational Objectives.

A. Mission Statement of the Institution
B. Program Educational Objectives (PEOs)
C. Consistency of the PEOs with the Mission Statement
D. Program constituencies
E. Process for revision of the PEOs

In order to fulfill the requirement of consistency between the PEOs and the Mission Statement of the institution, key words and phrases are identified in the Mission statement that would directly relate to the language used to formulate the PEOs. For example, the following Mission Statement of our institution has words and phrases underlined to indicate their significance in the drafting of PEOs.

This Institution is a Catholic, Diocesan, student-centered University which provides for the <u>*holistic development*</u> *of undergraduate and graduate students in the Judeo-Christian tradition. As such, it offers each student outstanding teaching and a* <u>*value-centered education in both liberal arts and professional specializations*</u> *in order to* <u>*prepare students for leadership roles*</u> *in their careers, society, and church. The University faculty and staff are committed to excellence and continuous improvement in teaching, learning, scholarship, research, and service. The University's* <u>*environment is to be one of inclusiveness and cultural diversity*</u>.

Figure 1 displays the overall Quality Assessment cycle with Level 1 representing the PEO Assessment highlighted. as the focus of this paper. The assessment cycle for Level 1 is once every three to five years to gauge the relevancy of the PEOs to the requirements of the program constituents because the PEOs are measured three to five years after graduation. Student outcomes assessment, identified as Level 2, is in a different cycle but provides the major input to address the attainment of the PEOs. The Level 1 PEO Assessment cycle is shown in Figure 2.

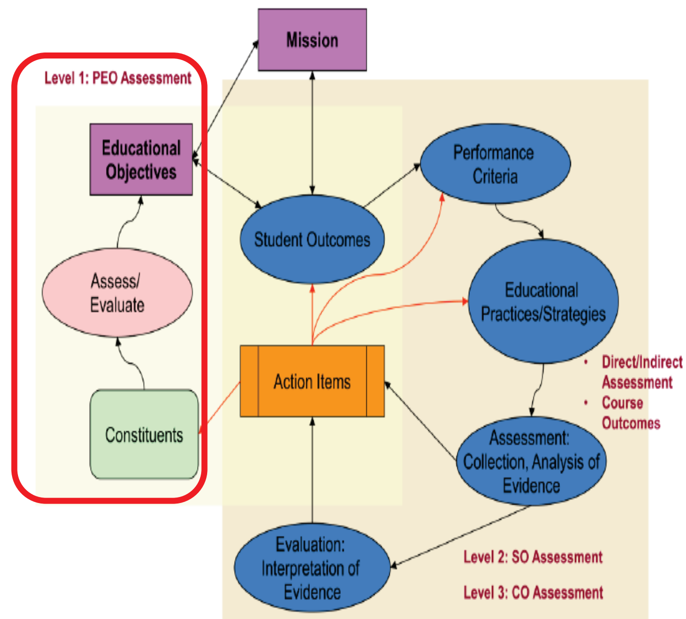

FIGURE 1
QUALITY ASSESSMENT CYCLE

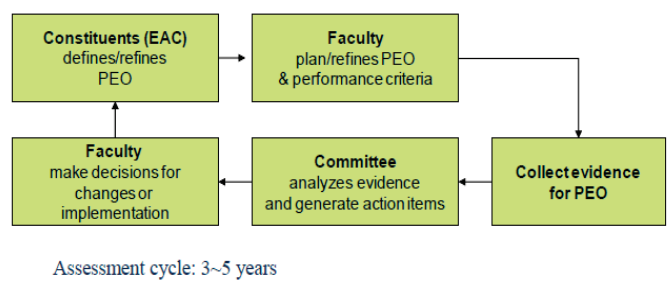

FIGURE 2
LEVEL 1 PEO ASSESSMENT CYCLE

The program constituents for the PEO assessment process comprise the faculty, staff, students, and the local industry represented by its members on the Engineering Advisory Council (EAC). The toolsets used in the PEO assessment process are as follows:

- Alumni survey (*external*)
- EAC review (*external*)
- Executive summary report for student outcomes (*internal*)

SECTION 3: FRAMEWORK TO FORMULATE PEOs

The first step was that faculty members as *individuals* had independent PEO ideas, leveraging our multi-cultural and multi-discipline resources. Then, the faculty members, objectively as a team, had long workout sessions to revise and commit to these new PEOs, thus promoting PEO ownership as a Department. At the beginning of the workout session, the faculty identified and agreed to the following keywords of the Mission Statement of our institution –

professional development, value-centered, leadership roles, cultural diversity, and *lifelong learning*. In addition, the faculty identified the categories in which objective evidence shall be obtained to measure each key word keeping in mind the proper set of assessment language. Faculty members then formed break-out groups of two to draft the PEO suitable for each key word. Finally, the faculty reconvened as one group to review and revise each objective as well as to arrange the objectives in the order of chronological impact and accomplishment before reaching agreement for adoption.

The framework for the review and revision of the PEOs at the departmental level involving all the faculty members comprises the following broad stages.

1. Provide the assessment language
2. Use the key words and phrases extracted from the Mission Statement of the institution to identify attributes to gauge graduates
3. Capture the distinction between the educational objective and the student outcomes
4. Formulate each objective to be measurable

The assessment language is patterned along the lines of the *Cognitive domain* of *Bloom's taxonomy* [4]. The Cognitive domain (or *What should I know*?) corresponds to the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills.

There are six major categories from simple to complex - *Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation* - to be mastered. Although these categories are covered within every course at all levels (first year to senior year), the focus of the pattern of learning at each level is as follows:

TABLE I
FOCUS OF LEARNING

Level of Course	Focus of learning
First year	*Knowledge*
Second year	*Comprehension*
Third year	*Application & Analysis*
Fourth year	*Evaluation & Synthesis*

SECTION 4: PEO ASSESSMENT & EVALUATION

Figure 3 illustrates the components and the flow of the process of PEO assessment and evaluation. The two primary approaches to PEO assessment are (1) internal review, and (2) external review.

The internal review consists of assessing the attainment of student outcomes, through senior exit surveys and embedded course assessment processes, to determine if the skill sets necessary for attainment of PEOs are being provided within each course and across the curriculum. The external review comprises the assessment of data gathered through the alumni survey to determine how well our graduates are performing in the workforce three to five years following their graduation. This measures the level of attainment of each PEO.

The PEO evaluation process determines the relevancy of each PEO to address and successfully meet the needs of the program constituents. The program constituents are faculty, students, alumni, and industry. The evaluation of the PEOs by both the EAC and the faculty members helps address the needs of program constituents. Action items generated at faculty and EAC review meetings are expected to lead to changes in the PEOs and have significant impact on the shaping of our educational practices.

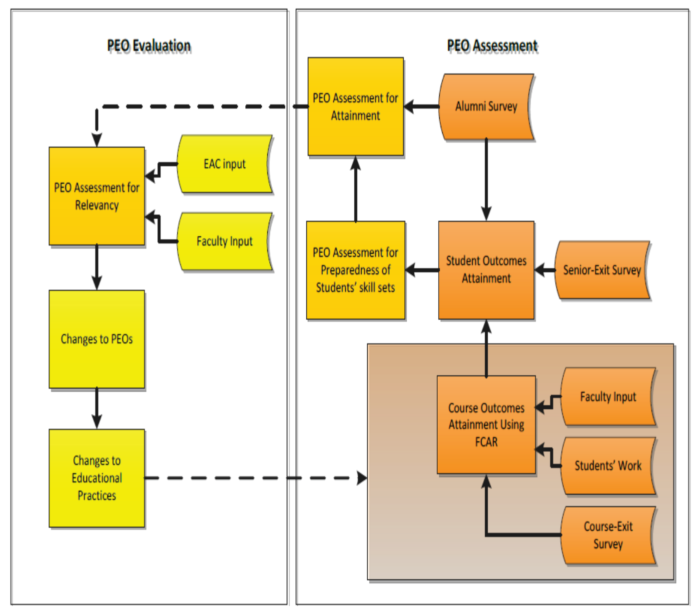

FIGURE 3
PEO ASSESSMENT AND EVALUATION PROCESS

The mapping of the student outcomes to the PEOs is intended to help us determine if our educational practices within each course and across the curriculum prepare our graduates to meet the intended PEOs. Table II illustrates the mapping.

The PEOs used to complete this mapping are as follows:

PEO 1. Sound preparation for adaptation in the exciting, rapidly-changing areas of technology and a passion for lifelong learning

PEO 2. Ability to understand how engineering solutions affect our society and respond to ethical and public issues, including safety, social, and environmental concerns.

PEO 3. Ability to apply personal values to daily and professional life, develop the skills necessary for exercising informed literary and aesthetic judgments, and appreciate diverse cultures and societies

PEO 4. Ability to communicate effectively in both oral and written forms and work efficiently with multi-disciplinary/multi-cultural teams which foster leadership qualities

PEO 5. Foundation in problem formulation and problem solving skills to include the following:

- Sound preparation in general science and applied mathematics
- Strong preparation in electrical engineering and applications
- Strong preparation in computer and software systems development
- Effective use of computer-aided design and analysis tools
- Quality experience in engineering design

TABLE II
RELATIONSHIP OF STUDENT OUTCOMES TO PEOs

Student Outcomes	PEO 1	PEO 2	PEO 3	PEO 4	PEO 5
ABET Criteria:					
SO1: Ability to apply knowledge of mathematics, science, and engineering	X				X
SO2: Ability to design and conduct experiment, as well as to analyze and interpret data					X
SO3: Ability to design a system, component, or process to meet desired needs	X				X
SO4: Ability to function on multi-disciplinary teams			X	X	
SO5: Ability to identify, formulate, and solve engineering problems	X				X
SO6: Understanding of professional and ethical responsibility		X	X		
SO7: Ability to communicate effectively				X	
SO8: Board education necessary to understand the impact of engineering solutions in a global and societal context	X	X	X	X	
SO9: Recognition of the need for, and an ability to engage in life-long learning	X		X		
SO10: knowledge of contemporary issues	X		X	X	
SO11: Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	X				X
ECE Program-Specific Competencies:					
SO12: Knowledge and ability to apply mathematics including probability, statistics, and discrete mathematics	X				X
SO13: Develop systems containing hardware and software components	X				X
SO14: Analyze and Design of complex electrical and electronic devices	X				X

The language of the PEOs listed above does not make the clear distinction between PEOs and ABET outcomes. The implementation of the process described in this paper resulted in the following set of PEOs.

PEO 1. Demonstrate *professional ethics* and *personal values* in daily and professional life that exercise informed literary and aesthetic judgments by leveraging diverse cultures and societies

PEO 2. Demonstrate *teamwork and leadership qualities* and/or the attainment of *leadership roles* in a global work environment

PEO 3. Demonstrate *technical competency* in applying comprehensive engineering knowledge throughout their chosen profession

PEO 4. Demonstrate *passion for life-long learning* through engaging in the rapidly changing and emerging areas of technology, and/or continued professional development

This set of PEOs is also mapped to the ABET outcomes as in Table II. Table III summarizes this mapping.

TABLE III
SUMMARY OF REVISED MAPPING

PEO #	Student Outcomes
1	SO6, SO8, SO10
2	SO4, SO7
3	SO1-3, SO5, SO8, SO11-14
4	SO1-3, SO5, SO7, SO8-14

The alumni survey provides the data for assessment of the PEOs as part of the external review. The survey addresses the following question:

How well are our graduates really doing in the workforce?

The survey is administered through secure access on the Web [5] and has quantitative and qualitative sections in the following categories.

- *General information*
- *Employment History*
- *Preparedness of Gannon Education*
- *Soft Skills and Broad Education*
- *Liberal Studies*
- *Intern Experience and Professional Societies*
- *Rate education based on the PEOs*

Table IV lists the questions asked in the quantitative section of the alumni survey for the category titled *Preparedness of Gannon Education*.

TABLE IV
QUANTITATIVE SECTION - I

Preparedness of Gannon Education

	Questions
1	How well do you feel your undergraduate training helped you to develop the ability to apply technical knowledge in the solution of specific work-related problems?
2	How well did your undergraduate training prepare you to design and conduct experiments?
3	How well did your undergraduate training prepare you to analyze and interpret research data?
4	How well did your undergraduate training prepare you to design a system, component or process to meet task needs?
5	After graduation, how prepared were you to function effectively on a multi-disciplinary team?
6	How well did your undergraduate training prepare you to develop your leadership skills?
7	How well did your undergraduate training prepare you to identify, formulate and solve engineering problems?
8	Compared to engineering friends and colleagues from other colleges and universities, how well do you feel the Gannon Engineering program prepared you to handle the technical aspects of your job?

The qualitative section for this category asks the graduate to comment on any special strengths or weaknesses they saw in the technical preparation they received at Gannon.

Table V lists the questions asked in the quantitative section of the alumni survey for the category titled *Soft Skills and Broad Education*.

TABLE V
QUANTITATIVE SECTION – II

Soft Skills and Broad Education

	Questions
1	Do you feel your Gannon education helped you to understand the ethical responsibilities of your profession?
2	How well did your Gannon education prepare you to give oral presentations?
3	How well did your Gannon education prepare you to write technical reports and other written communications?
4	Do you feel you have the ability to use the most modern engineering tools and techniques effectively?
5	Do you feel your education at Gannon was broad enough to give you a perspective on how a particular engineering solution might impact society?

SECTION 5: CONCLUSIONS & FUTURE PLANS

This paper describes how the process to draft PEOs is and implemented in our ABET accredited ECE degree program. The key requirements to guarantee success of this process are as follows:

- Engagement and commitment of the entire engineering department to the discussion, ratification, and eventual adoption of the PEOs
- Active participation by the faculty in defining the PEOs to promote ownership of the goals of the Department and ABET process
- Adherence to the Mission of the University
- Distinguish PEOs from student outcomes
- Draft PEOs with measurable outcomes

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From Global to Local: Investigation of Necessary Engineering Skills for KBE Transformation in Qatar in the Context of Global Engineering Attributes

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***Abstract*— this paper provides the findings of a study on investigating the required contextual engineering skills in Qatar in light of the global engineering skills. A set of 20 attributes were identified in the literature, and surveys were implemented to measure the importance of these skills in Qatar. The targeted groups spanned from students, practicing engineers, senior industrial engineers, and academicians. The basic logic behind surveying various engineering groups was mainly to evaluate the capabilities of the current engineering labor force as well as evaluating the potential of the future engineering supply (current students). The main findings indicated the consensus of participating groups on the importance of enhancing communication skills. High perceptual gaps were identified in communication skills, business and entrepreneurship and practical skills. Remedy actions that were proposed so that the future supply of engineers is featured by required and desired level of selected skills.**

Keywords— Global Engineering Skills; Engineering Education; Transformation; Knowledge -based Economy (KBE); and Statistical Analysis.

I. INTRODUCTION

Engineering in particular and other relevant STEM (Science, Technology, Engineering & Mathematics) fields in general are the most critical areas for a nation to focus on while seeking for- or maintaining a knowledge based economy status [1] [2] [3], [4], [5], "unpublished"[6]. For that reason, Engineering and Technology are at the core of realizing the Qatari government strategic vision that aims to transform its economy from being hydrocarbon based into a knowledge based one by 2030. To respond to the requirements of the KBE age, a clear necessity in producing and managing the right engineering technical and non-technical skills is recognized. Given the increasing complexity and interdisciplinary nature of the engineering profession, equipping engineering graduates with a set of non-technical skills such as communication, decision making, management, leadership, emotional intelligence, cultural awareness, and social ethics is required. A global literature review on skills outcomes of engineering degrees in the US, Europe, and Asia Pacific showed that students lack enough competencies in these soft skills [7]. Similarly, certain core engineering competencies such as problem solving, design, and analytical thinking became essential in the 21st century work force even for those who would study and work in non-engineering disciplines [8].

A number of key thematic areas for an engineering education that is fitting with a KBE requirements are identified: 1- Engineering Entrepreneurship, 2- Engineering Leadership (technical and societal), 3- Engineering Design, 4- Engineering Creativity and Innovation. Focusing specifically on futuristic characteristics of next generation of engineering graduates, a list of 20 attributes of future engineers has been identified in the literature in support of the four engineering KBE themes identified earlier; where ten attributes belong to the technical aspects, and the other ten belong to the non-technical aspects. These skills are communication skills [9][10][11][12], teamwork [10] [13] [14], leadership [1][2] [9] [13], business and entrepreneurship [1][2] [15], "unpublished" [16], creativity and innovation [12] [13] [14], adaptability [1][2][17], strategic thinking [1][2][17], lifelong learning [1][2] [17], cultural and diversity [1][2] [18], ethical awareness [1][2], "unpublished" [19][20], practical skills [1][2][10], technical breadth [21][22], theoretical understanding [1][2], science principles' knowledge [1][2], critical thinking [1][2][23][12] [17], problem solving [2][3] [12], analytical thinking [9][10] [17], engineering design skills [24][25], wide variety of IT skills [22][26] and research skills.

Generally, these attributes were derived from global studies on future engineers in USA, UK, Europe, and Australia, such as the UK study: "Educating Engineers for the 21st Century: The Industry View" and the US study: "The Engineer of 2020: Visions of Engineering in the New Century". Yet, no similar efforts were done in the Middle East. For assessing the current status of Qatari engineering graduates attributes, an instrument in a form of Questionnaire has been implemented. The core part of the instrument was utilized to collect data from four different samples: 1- Senior engineers in the local industry, 2- Engineering academics from Qatar, 3- Undergraduate engineering students in Qatar, and 4- Postgraduate engineering students in Qatar (mainly professional working engineers). The following section provides further details on the conceptual framework of the study, the methodology, data analysis, and main findings of the investigation.

II. CONCEPTUAL FRAMWORK OF ENGINEERING EDUCATION FOR A KNOWLEDGE BASED ECONOMY (KBE)

To have a productive engineering education system in place, the efficiency of inputs should be developed and controlled in such a way that leads to the effectiveness of outputs. This will be only possible if it is supported by the use

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of innovative, quality and value added processes. Fig. 1 below illustrates the proposed conceptual framework of engineering education and its role in supporting and building up a KBE as discussed in what follows.

Fig. 1. Illustration of a closed loop of engineering education and its role in supporting building up KBE.

According to the Organization for Economic Cooperation and Development (OECD), a science system can support KBE development by contributing to three key functions which are knowledge production, knowledge transmission, and knowledge transfer [27]. Knowledge production means developing and creating new knowledge mostly in a form of research. Knowledge transmission means educating, developing and upgrading human capital. This is a key enabler in raising the awareness of today's students while building in the desired capabilities of tomorrow's engineers. Furthermore, knowledge transfer means publicizing knowledge and providing solutions to real life problem. This element addresses the practical implication of engineering in all real life aspects. To reflect a comprehensive role of education system in KBE, another key function is added which is the knowledge acquisition. To have an innovative and effective processes, education system should reflect the two way communication between academicians and other key entities in the system such as students. To complement the knowledge transmission function, a well-grounded knowledge acquisition process should be endorsed. In this process, students are the recipients of current available technical, social, environmental, economic and technological information while academicians are the providers.

In parallel to these functions that are based on knowledge, a focus should be given to developing and enhancing certain set of soft and core engineering skills. A literature review on required modern and future engineering skills was done indicating that engineers need to be equipped with both soft and core skills "unpublished" [28]. These skills are very important as they eventually capitalize the produced engineering workforce who directly supports the KBE development. In this aspect, academicians and elite students are considered to play a vital role. To support the main objective of this paper, research efforts can be steered further towards modernizing engineering education, revising and restructuring engineering curricula in such a way that support the development of these skills. Such modernization may include shifting from classical teaching towards more constructivist learning approaches, such as technology enabled learning [29][30][31][32], research based learning [33], meaningful mathematics [34], experiential and project based learning approaches [35], continuous assessment and effective feedback provision [36]; "unpublished" [37], etc. These modern teaching and learning approaches may equip students with better skills than traditional approaches. Before shifting into curricular and pedagogical major changes, an assessment of the current inventory of these skills would be recommended. Initial assessment is provided in this paper.

Finally, all inventories of knowledge and skills formed through these processes are acquired and employed in engineering workforces, who are eventually utilized to serve in building up systems, products, Research and Development (R&D) activities, patents and services. These outputs are required to back the development of all KBE pillars. These pillars are defined by the World Bank as Economic Incentive and Institutional Regime (EIR), innovation and technological adoption, education and training, and Information and Communications Technologies (ICT) infrastructure [38]. All these pillars if enabled, support a smooth transition to knowledge based economy and society driven by innovation and knowledge. It is worth noting that defined framework is a closed loop system. It means that continuous feedback from all downstream are fed again as inputs to the system so that all processes are adjusted to cope with the new requirements.

III. METHODOLOGY

This section looks at the framework and methodologies used in this study. Mainly, surveys and pilot interviews are the two techniques aimed to collect the relevant data. Data which are needed to identify needed skills were collected through four different surveys. It may seem reasonable that these surveys were designed to target different engineering groups, classified as engineering practitioners; engineering academics; undergraduate engineering students; and postgraduate engineering students (mainly professional working engineers pursuing their graduate degrees). As the general objective is to identify the level of awareness and satisfaction in regards to major attributes needed to support Qatar vision 2030, all surveys were administrated locally in Qatar. Basic content analysis was utilized to analyze the pilot interviews, and different statistical techniques (descriptive statistics, hypothesis tests and inferential statistics, etc.) were utilized for analyzing the surveys. Having the surveys anonymously administrated, a total of 190 valid responses were received by which 121 were submitted electronically and the remaining 69 were paper based. Following this, data were organized in one database and then, statistically analyzed using SPSS. Rating of skills was based on a likert scale from 1 to 5, where "1 = Strongly Disagree", and " 5= Strongly Agree".

TABLE I. MEAN VALUES OF GROUPS' PERCEPTION IN EACH OF THE ENGINEERING SKILLS. "I" REFERS TO "IMPORTANCE", AND "S" REFERS TO "SATISFACTION"

Attributes	Groups							
	Bachelor Student		*Master Student / Junior Engineer*		*Professional Engineer*		*Academic Engineering Staff*	
	I	S	I	S	I	S	I	S
Communication	7	3	6	5	4	3	6	5
Teamwork	7	6	6	6	6	5	5	5
Leadership	6	5	6	5	6	4	5	5
Business and Entrepreneurship	6	4	5	4	6	4	5	4
Creativity and Innovation	6	5	6	5	6	4	6	4
Adaptability	6	5	5	5	6	4	5	4
Strategic Thinking	6	5	6	5	6	4	5	4
Lifelong Learning	6	5	6	5	6	4	5	4
Cultural&Diversity	6	5	6	5	6	5	5	5
Ethical Awareness	6	5	6	5	6	5	6	5
Practical Skills	4	3	6	5	4	3	6	5
Technical Breadth	6	5	5	5	6	4	5	5
Theoretical Understanding	6	6	6	5	6	5	5	5
Science Principles' Knowledge	6	6	6	5	6	5	5	5
Critical Thinking	6	5	6	5	6	5	5	4
Problem Solving	6	5	6	5	6	4	6	4
Analytical Thinking	7	6	6	5	6	5	6	4
Engineering Design Skills	7	5	6	5	6	5	5	5
Wide Variety of IT Skills	6	5	6	5	6	5	6	5
Research Skills	6	5	6	6	5	4	5	4

IV. DATA ANALYSIS

Surveys were designed to: 1- identify the level of awareness of various engineering population with regards to skills needed for transforming Qatar's economy to a KBE; and 2- help in measuring the degree of difference between their perception of how much these skills are important and to what extent they think they are equipped with. The following subsections provide further details on the data analysis.

A. Descriptive Statistical Analysis

Three descriptive measures were used to support the analysis of obtained data related to engineering skills; namely, the mean, the mode and the Pearson Correlation. Firstly, the average perception of each attribute was computed for every respondent group (for both level of importance and satisfaction). Results obtained are presented in table I below. It was noticed that there was a common perception between all groups in viewing majority of the attributes. Yet, to some extent this entire commonality was slightly disturbed when addressing few of them. Major irregularities are highlighted below.

Unlike the strongly agreement in view of Bachelor Engineering Students on the importance of Communication Skills, Expert Engineers expressed a neutral perception in this regards. Irrespective to this inconsistent view, both groups believe that they were not equipped enough with this type of Skills. Additionally, a noticeable difference was observed with regards to Practical skills. While both Junior Engineers and Academician agreed that these skills are very important to be presented in the future engineering supply, both Bachelor level Students and Expert Engineers disagreed with this. Alongside with this differed perception, both latter groups expressed that they are not satisfied with the students/engineers' capabilities in these skills while former groups are somehow satisfied. Moreover, the shared view on Cultural Diversity Awareness was not totally alike. Even though all groups agreed that they are skilled and equipped with this attribute, Academic Engineering Staff did not view it as an important skill as the other groups did.

The targeted groups were also asked to rank the most important six engineering skills according to their own perception. As these data are classified to nominal and non-parametric, Mode Analysis would be the suitable measure to reflect the overall conclusion of this question. Table II summarizes the main findings from Mode Analysis. It can be noticed that a mutual agreement was given to communication skills being the most important skill for engineers of 2030. Only 50% of the identified engineering skills appeared in the top 6 ranking given by all engineering group. Commonly, communication, teamwork and problem solving appeared in the ranking of all groups.

TABLE II. SKILLS RANKING GIVEN BY EACH ENGINEERING GROUP PRESENTED BY THE MODE

Group	Ranks					
	Rank 1	*Rank 2*	*Rank 3*	*Rank 4*	*Rank 5*	*Rank 6*
Bachelor Students	Commu-nication	Team-work	Creativity and Innovation	Problem Solving	Engineer-ing Design Skills	Lifelong Learning
Junior Engineer	Commu-nication	Leader-ship	Teamwork	Problem Solving	Teamwork	Problem Solving
Expert Engineer	Commu-nication	Team-work	Teamwork	Problem Solving	Problem Solving	Wide Variety of IT Skills
Academician	Commu-nication	Critical Thinking	Teamwork	Critical Thinking	Technical Breadth	Problem Solving

B. Inferntial Statistical Analysis

The second part of the analysis aims to identify if there is a statistically significant difference between the ranking of all groups with regards to awareness and satisfaction levels.

Mann-Whitney U test was used and repeated six times as it is designed to test only two independent samples (all possible combinations of two groups chosen from the set of 4 groups is 4!/(2!(4-2)!) = 6 combinations).

TABLE III. STATISTICAL SIGNIFICANCE DIFFERENCE IN SKILLS IMPORTANCE BETWEEN EVERY TWO GROUPS

Attributes	Combination of every 2 groups [(a)]					
	1 & 2	*1 & 3*	*1 & 4*	*2 & 3*	*2 & 4*	*3 & 4*

Communication	×	√	√	√	×	×
Teamwork	×	√	√	×	×	×
Leadership	×	×	√	×	√	×
Business and Entrepreneuship	×	×	√	×	×	×
Creativity and Innovation	×	×	√	×	×	×
Adaptability	√	×	√	×	×	×
Strategic Thinking	×	×	√	×	×	×
Lifelong Learning	×	√	√	×	×	×
Cultural and Diversity	×	×	√	×	√	×
Ethical Awarenss	×	√	√	×	×	×
Practical Skills	√	×	×	√	×	√
Technical Breadth	×	×	√	×	×	×
Theoritical Understanding	×	×	√	×	×	×
Science Preciple Knowledge	×	×	×	×	×	×
Crtitical Thinking	√	×	×	×	×	×
Problem Solving	×	×	×	×	×	×
Analytical Thinking	√	√	√	×	×	×
Engineering Design Skills	×	√	√	×	×	×
Wide Variety of IT Skills	×	×	×	×	×	×
Research Skills	×	√	√	√	√	×

a. Group 1 indicates Bachelor Students, Group 2 indicates Master Students, Group 3 indicates expert engineers and group 4 indicates academicians

TABLE IV. STATISTICAL SIGNIFICANCE DIFFERENCE IN SATISFACTION LEVEL OF SKILLS EQUIPMENT BETWEEN EVERY TWO GROUPS

Attributes	Combination of every 2 groups [(a)]					
	1 & 2	*1 & 3*	*1 & 4*	*2 & 3*	*2 & 4*	*3 & 4*
Communication	√	×	√	√	×	√
Teamwork	×	√	√	√	√	×
Leadership	×	×	×	√	×	×
Business and Entrepreneuship	×	×	×	×	×	×
Creativity and Innovation	×	×	√	×	√	×
Adaptability	×	×	×	√	√	×
Strategic Thinking	×	×	×	×	×	×
Lifelong Learning	×	×	×	√	√	×
Cultural and Diversity	×	×	×	×	×	×
Ethical Awarenss	×	×	×	×	×	×
Practical Skills	√	×	√	√	×	√
Technical Breadth	×	√	×	×	×	×
Theoritical Understanding	×	√	√	×	×	×
Science Preciple Knowledge	×	√	√	×	×	×
Crtitical Thinking	×	×	√	√	√	×
Problem Solving	×	√	√	√	√	×
Analytical Thinking	√	√	√	×	√	×
Engineering Design Skills	×	√	√	√	√	×
Wide Variety of IT Skills	×	×	×	×	×	×
Research Skills	×	√	×	√	√	×

b. Group 1 indicates Bachelor Students, Group 2 indicates Master Students, Group 3 indicates expert engineers and group 4 indicates academicians

Using SPSS, the Mann-Whitney statistics was computed for every combination of groups. Summary of results is summarized in table III and table IV. The main findings of Mann-Whitney hypothesis test are detailed below:

- A statistically significant difference was found between Bachelor level Students and Academicians in regards to all soft skills. It was found that Bachelor level Students felt more strongly than Academician that all soft skills are important to be in Qatari Engineers in light of Qatar 2030 vision. At the same time, a statistically significant difference was found with regards to their level of satisfaction over few of these soft skills. It was noticed that Bachelor Students were more satisfied with the level of capabilities in communication, teamwork, and creativity and innovation.

- Similarly, a statistically significant difference was found between both groups in regards to 50% of core engineering skills which were: technical breadth, theoretical understanding, analytical thinking, engineering design skills and research skills. For research skills, both Bachelor level Students and Master Students perceived it with more importance when comparing it with the perception of Expert Engineers and Academicians. Moreover, a statistically significance difference was found between both groups when ranking the level of satisfaction of their capabilities in 80% of core skills. Noticeably, Bachelor Students were more satisfied when it comes to their capabilities in theoretical understanding, science principle knowledge, critical thinking, problem solving, analytical thinking, engineering design skills and research skills. On the contrary, Academician felt more strongly than Bachelor level Students that the students/engineers' are equipped enough with practical skills.

- With reference to communication skills, a statistically significant difference was found between Expert Engineers and both Bachelor Students and Master Students. More precisely, it was noticed that both groups felt more strongly than Expert Engineers that this attribute is of importance for future engineers.

- Moreover, there was a statistically significant difference between Bachelor Students and Master Students when viewing practical skills, adaptability, critical thinking and analytical thinking. It was shown that Bachelor level Students have a stronger appreciation that adaptability, critical thinking and analytical thinking skills are important for engineers of 2030. On the contrary, Master Students felt more strongly than Bachelor Students that practical skills are important. At the same time, Master Students were more satisfied with both communication and practical skills they have when comparing it to the average level of Bachelor Students satisfaction.

- There was a statistically significant difference when viewing both leadership and cultural diversity awareness attributes by Master Students and Academicians. Noticeably, Academicians viewed these skills with less appreciation when compared with Master Students view.
- There was no statistically significant difference between Expert Engineers and Academicians in terms of soft skills. However, a statistically significant difference was found when viewing the practical skills (one of engineering core skills). It is worth mentioning that academician felt more strongly than expert engineers that they are equipped with practical skills.
- There was a statistically significant difference between Bachelor Students and Expert Engineers in viewing 40% of soft skills; namely in communication, team work, lifelong learning and ethical awareness. In all mentioned skills, Bachelor Students had stronger belief that these skills were important for engineers of 2030. At the same time, for 80% of core engineering skills, a statistical significant difference was observed between both groups when it came to their level of satisfaction. It was noticed that Bachelor level Students felt more strongly than the expert engineers that they were equipped with these skills (theoretical understanding, science principle knowledge, critical thinking, problem solving, analytical thinking, engineering design skills, and research skills).

V. MAIN FINDINGS AND DISCUSSION

In this section, the main findings are highlighted where two main aspects will be of focus. Firstly, major inconsistencies when perceiving both importance level and satisfaction in competency level between groups are highlighted. Secondly, attributes that were perceived with low confidence in competency are identified and methods for bridging these gaps are proposed. This will then be used to adjust the engineering curricula so that the workforce is prepared to support KBE activities as described in Section II.

A. Attributes perceived by groups with unequal level of importance/satisfaction

Two main attributes exhibited some sort of irregularities in regards to groups' perception; namely, communication and practical skills. For communication skills, a mutual understanding on the importance of these skills was demonstrated by all groups. It is worth noting that bachelor students were the group who strongly agreed that communication skills are very important for the future supplies of engineers. Additionally, the same group believed along with expert engineers that they are not equipped enough with these skills. One major note arises here; engineers-in-process who are the potential future engineers are aware that communication skills are necessary to confront professional, technological, social and economic future challenges.

Second attribute that was perceived differently by groups was the practical skills. It was observed that, bachelor students and expert engineers believed that practical skills are not important to be in future engineering supply while junior engineers and academician felt the opposite. Following the same trend, both former groups expressed that they are incompetent in the level of practical skills they have. Underestimating the importance of these skills is an issue of concern and needs to be investigated clearly. Being practitioner in engineering and believing that practical skills are not important may be explained by the fact that the current expert engineers are equipped enough with such skills such that they did not recognize its importance as they do not lack it anymore . Not recognizing the importance of these skills by Bachelor Students may be due to their view of practical skills as purely working experience and that it can only be achieved after graduation and once leaving the education system. However, practical skills cover the ability to use wide range of tools and techniques, as well as laboratory and workshop equipment (including both hardware and software related to their specific disciplines). At this end, both raising the awareness of practical skills' importance and filling in its competency gap are important. Not only statistical results revealed the existence of this gap, but also, evidence from engineering employers had shown that employers struggle while filling vacancies due to the shortage of fresh engineering work force with relevant skills and practical experience. Specifically, Engineering employers find it more difficult to recruit people with technical and practical skills than other skills. To this extent, it remains the educational institutions responsibility to raise the awareness of industries in investing intensively in graduates during their transition phase (from acquiring knowledge to applying it) while working on enhancing students capabilities in engineering practical elements.

B. Attributes perceived by students with low confidence in competency level

The basic logic behind surveying various engineering groups is mainly evaluating the capabilities of the current engineering labor force as well as evaluating the potential of the future engineering supply (current students). For that reason, those skills which were perceived with low or neutral agreement by fresh and in-process engineers are found to be a valuable input for the conducted research. The three highest perceptual gaps between importance and satisfaction were detected in the following skills: "Communication", "Business and Entrepreneurship", and "Practical Skills". Table V summarizes possible reasons behind the perceived gap in competence and provide some possible enhancement solutions that can fit in the framework proposed in Section II. These remedy actions can be used to adjust the existing engineering curricula or by or by introducing extra-curricular activities. Eventually, what is of our interest is to equip the new engineering workforce in such a way that supports the in development of innovation and knowledge driven economy.

TABLE V. INVESTIGATION ON ENGINEERING ATTRIBUTES WHICH WERE PERCEIVED WITH NEUTRAL OR LOW SATISFACTION LEVEL IN COMPETENCE

	Possible Sources of weakness	Possible enhancement solutions
Communication skills	• Students' low confidence towards communication in foreign languages; • Deficient teaching methods; • Lack of opportunity for engineering students to practice communication skills; • Absence of advanced communication specialized courses in engineering curricula.	• Involve active learning as part of engineering courses • Encouraging student exchanges with countries abroad • Encourage extra-curricular activities (such as seminars, presentations, contribution in newsletters with academic articles) by attributing part of the overall grades towards it • Organize specialized seminars, workshops, and tutorial sessions on both basic and advanced communication skills. • Encourage active participation by students in actual communication situations;
Business & Entrepreneurship	• Traditional engineering curricula tend to be focused on how-to-do-it (technical knowledge and skills), with little or no emphasis on entrepreneurship; • Limited view of engineer prevailing career path which is rather oriented towards technical, academic or managerial functions within large companies; • Lack of enterprising spirit among new engineers due to unrealized importance.	• Provide awareness and educational seminars on entrepreneurial attitudes not only to transfer knowledge, but also to develop the building-up of skills and attitudes in favor of entrepreneurship; • Raise the enterprising spirit in engineers from their freshmen year by facilitating the exposure towards successful entrepreneur stories; • Introduce entrepreneurship courses customized to engineering students and integrate it as part of the general engineering core requirement; • Allow engineering students to take relevant courses from school of business as electives.
Practical Skills	• Unappreciated view of courses that contain practical elements due to low or absence of assigned credit hours; that is, it is not attached significantly to grades causing careless attitudes towards its importance and results in ineffective utilization of its benefits; • Lack of activities which contain direct engagement with local/international industries.	• Increase weight of credit hours assigned to courses that address practical skills elements; • Facilitate more opportunities to students for industry exposure outside the study time (during semester breaks); • Integrate experimental sessions that involve use of software and hardware related to specific discipline in theory classes.

C. *Issues of concern*

Surprisingly, when viewing results of analysis and especially when looking at means related to the level of awareness among defined groups, it was observed that the lowest importance rank for around 80% of listed attributes was given by Academic Engineering Staff. This group had the least awareness level with a mean of means equals to approximately 5, which reflects a little agreement on the importance of all the attributes. Being the influential guiders, and facilitators of the educational process, this issue mandates a prompt response due to its significant impact on building up the desired future supply of engineers.

VI. CONCLUSION

This paper provided analysis and investigation of needed skills in engineering workforce in Qatar in light of the country's vision of transformation into a KBE by 2030. Literature was reviewed to identify the futuristic engineering skills that support the KBE development. Then, a framework that illustrated the engineering education and its role in supporting building up KBE was proposed. Both the importance of engineering knowledge and skills were acknowledged in the proposed framework. This study was based on surveying various engineering groups. The main logic behind this was mainly to evaluate the capabilities of the current engineering labor force as well as evaluating the potential of the future engineering supply (current students) with regards to the identified skills. Among these 20 skills, communication skills, teamwork, and problem solving were most frequently ranked important between the main groups of surveyed stakeholders; Communication skills were ranked highest consistently by all groups. This guided us to the conclusion that these skills are of high priority to be promptly included in the engineering curricula when compared to the other skills. Additionally, the highest perceptual gap of importance versus satisfaction was identified in "Communications skills", "Business and Entrepreneurship", and "Practical Skills". The paper provided a set of potential reasons behind these findings as well as a number of recommendations for implementation in the curriculum. As a sum up, the current engineering education system should be adjusted to incorporate the prioritized skills (skills that are commonly ranked as very important). It should also allow the inclusion of proposed remedy actions to overcome identified irregularities. This can be done by either changing the current engineering curricula to address these gaps or by introducing extra-curricular activities.

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Sustainability and the Engineering Worldview

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Abstract— This paper explores what is included in the worldview of the modern engineer and how this compares to the concept of sustainability. Worldviews are important to humanity because they are interwoven throughout civilizations. Societies do not contain but one homogenous worldview, however, they do essentially contain a dominant worldview characterized by the collection of values, beliefs, habits, and norms. This dominant worldview forms the frame of reference for a collectivity of people, such as a nation or culture. In this paper, we attempt to articulate modern worldviews, the contemporary engineering worldview, and the sustainability worldview. We use the concept of worldviews to address the compatibility of sustainability and engineering. Our synthesis suggests that the two ideologies are misaligned and incompatible in many respects. We suggest that for sustainability to gain prominence within an engineering context, engineers and engineering educators must first become conscious of these inconsistencies. Through the philosophical synthesis presented in this paper, it is our goal to begin rethinking how we educate engineering students about engineering and sustainability.

Keywords—*engineering; engineering education; sustainability; values; beliefs; worldviews*

I. Introduction

This paper explores what is included in the worldview of the modern engineer and how this compares to the concept of sustainability. This work complements calls for change in the engineering profession, coming from works such as the National Academy of Engineering's (NAE) The Engineer of 2020 [1]. NAE suggested that the engineering profession must evolve in order to "contribute to success" in context of the way the world "will be, not as it is today". The report continues, "The entire engineering enterprise must be considered [for reinvention] so that the changes made result in an effective system" [1].

The prominent question for engineers and engineering educators is the direction in which engineering must change as a profession. Riley (2008) noted that engineering has been attempting to reconfigure its image for quite some time, noting "leaders in the engineering community in the United States and other countries have been seeking to cast engineering as a profession in service to humanity" [2]. Riley continues, "I personally find it difficult to recruit high school students to engineering by holding out dreams of working on humanitarian or even environmental causes, when I know that most students will be working either on military endeavors focused on the facilitation of war or on corporate endeavors focused on increasing profits, often on the backs of poor communities" [2].

Matutinovic (2007) suggested, "The process of radical institutional change is contingent upon prior change in the dominant worldview, while its dynamics resemble that of a paradigm change in political and scientific arenas" [3]. Using this suggestion as a starting point, in this paper we explore what an operational understanding of "modern worldview" entails. We begin by first examining the literature on the term, "worldview". We next explore literature pertaining to "Western", "modern", and "dominant" worldviews. We proceed to explore the relationship between what we call the dominant Western worldview, the engineering worldview, and sustainability and qualitatively assess their compatibility.

A. Research Questions

This paper is guided by the following research questions: What is the relationship between the Western worldview and engineering? How does the Western worldview influence engineering praxis? What are contemporary understandings of sustainability? Are there any discontinuities between the Western dominant worldview, engineering, and sustainability?

B. Study Overview

To answer this study's research questions we start by conceptualizing several terms essential for our synthesis, followed by a literature review exploring articles where *engineering* and *worldview* or *sustainability* and *worldview* were discussed. We use worldview analysis as a framework for deconstructing the worldviews of sustainability and engineering [4]. This work is *not* empirical in the sense that it collects its own data. It is, however, empirical in the sense that it draws on observations and empirical work produced by others. This paper should be looked at as a starting conversation for engineers and engineering educators to become conscious of how their underlying beliefs influence the sustainability implications of their work.

In the following section titled Conceptual Overview we conceptualize the terms worldview, Western worldview, and worldview analysis. In the subsequent section titled "The Engineering Worldview" we provide an overview of what engineering is according to the literature, providing connections to the "worldview", namely, the Western/modern one. Following this section, we present an overview of "The Sustainability Worldview". Lastly, we

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discuss the relationship between the Western dominant, engineering, and sustainability worldviews.

II. Conceptual Overview

A. Worldview Analysis

Starting in the mid-19th century, "worldview analysis" or the study of religions and ideologies became a serious scholarly endeavor in fields of anthropology and sociology, before establishing itself as the academic field of Religious Studies in the 1960's. Prior to this, people "had little inclination to explore the thoughts and values of other" [4] as studying such ideologies "was only thought appropriate for believers" (p. 2). Worldview analysis, unlike those theological studies prior, strives to take on the perspective strictly as an observer (as opposed to a believer) in order to examine "experience, ethics, beliefs, ritual, and institutions" (p. 4) with no preconceived notions of what is right or wrong.

Despite the novelty of worldview analysis, Devall and Sessions write, "For the last five hundred years, some of the assumptions of the dominant worldview have been questioned and criticized in the west by philosophers, poets, religious spokespeople and others from different philosophical backgrounds" [5]. Therefore, opposition to the dominant modern worldview is not entirely novel. However, the formalized mode of questioning dominant worldviews through "worldview analysis" is.

B. Defining Worldview

Smart (2000) wrote, the importance of worldview to humanity is that "civilizations are importantly interwoven with them" [4]. Society does not contain but one homogenous worldview. Albeit, as Devall and Sessions suggest, civilizations essentially contain a "dominant worldview" characterized by "the collection of values, beliefs, habits, and norms which forms the frame of reference for a collectivity of people, such as a nation" [5]. Devall and Sessions go on to suggest that the overall components of any worldview are as follows:

- "[G]eneral assumptions about reality, including man's [sic.] place in Nature"
- Methods for "approaching problems", the methods being "generally agreed upon"
- A common societal "definition of the assumptions and goals of their society"
- "[C]onfidence among believers in the worldview that solutions to problems exist within the assumption of the worldview"
- And "[p]ractioners within the worldview present arguments based on the validity of data as rationally explained by experts"

As our individualistic worldview that becomes an intricate part of our very being, it may become unwavering. Ray and Anderson (2000) suggest, "Most of us change our worldview only once in our lifetime, if we do it at all, because it changes virtually everything in our consciousness". They continue, "Changing a worldview literally means changing what you think is real" [6].

C. Contemporary Dominant Western Worldview

Western civilization has been constantly evolving. Florman (1987) highlights this when he notes, "The Renaissance, the Protestant Reformation, the Age of Exploration, the Age of Science, the Age of Reason—all these terms are historians' shorthand for vast and complex changes that occurred in Western civilization" [7]. Thus, we title this section "Contemporary Dominant Western Worldview" simply to highlight that the worldview is not stagnant. Further, while associating the dominant worldview explicitly as "Western" allows comparison of a dichotomous Western versus non-Western, this comparison is not the intent of this paper. Many individuals may find that their worldview is more comparable or heavily influenced by non-Western worldviews not emphasized in this paper. To reiterate, our focus in this paper is on the *dominant* intricacies of the contemporary Western worldview.

Devall and Sessions, pulling from Catton Jr. and Dunlap, summarize a few "basic assumptions of the Western worldview" [5]. These are:

- "People are fundamentally different from all other creatures on Earth, over which they have dominion
- People are masters of their own destiny; they can choose their goals and learn to do whatever is necessary to achieve them
- The world is vast, and thus provides unlimited opportunities for humans
- The history of humanity is one of progress; for every problem there is a solution, and thus progress never need cease" (p. 43)

Ehrenfeld describes similarly what he calls humanism as "a part of the lives of nearly everyone in the 'developed' world and of all others who want to participate in similar development" [8]. In this ideology, and as similar to Judeo-Christian religions, Ehrenfeld writes, "the idea of using a Nature created for us, the idea of control, and the idea of human superiority" are all ideas associated with Western civilization since its conception. He goes on to list the primary assumptions of humanism, which are as follows [8]:

- "All problems are soluble by people
- Many problems are soluble by technology.
- Those problems that are not soluble by technology, or by technology alone, have solutions in the social world
- When the chips are down, we will apply ourselves and work together for a solution before it is too late
- Some resources are infinite; all finite or limited resources have substitutes
- Human civilization will survive"

In a critique towards humanism and similar ideologies, Quinn suggests "what is lacking in modernity, in its most succinct formulation, is the principle of wholeness or integrity," which tends to result in "no harmony, no value, no meaning" [9]. Quinn continues, "With the loss of quality, the remaining standard of value for modernity is quantity" [9].

D. Modern Dominant Identity

Note that worldview is not synonymous with identity, although the two, in theory, ought to be highly correlated. Therefore, we find it appropriate to include what is considered the modern dominant group's identity, as this is more often discussed in engineering literature than "worldview". As of 1989 the dominant identity "[w]ithin the United States, the generally accepted norm by which people are evaluated or against which they measure themselves is how close one comes to being anglo, middle class, male, Christian, heterosexual, English speaking, young, and mentally, physically, and emotionally unimpaired" [Highlen, Speight, Myers, and Cox as quoted in 10]. Almost 20 years later, Foor, Walden, and Trytten write, "The cultural rules which govern social spaces reflect and sustain the ideologies and sensibilities of the dominant class. In the U.S., those sensibilities are white, male, Christian, heterosexual, married, and middle-class." [11]

Despite the dynamism we have seen residing in the dominant worldview, the dominant identity within the U.S. seems to be relatively stagnant. But, consider that here we are using the term dominant, and not addressing *how* dominant. That is, not everyone in the population are followers of the dominant ideology, but that there is one particular ideology that is more commonly adopted than all others.

Meyers and others [12] suggested that engineering identity corresponds to a student's sense of belonging in the engineering profession. While the authors do not shed light on how identity relates to what they call "professional persistence", their results suggested a positive relationship between the two.

III. THE ENGINEERING WORLDVIEW

Florman (1987) suggests that changes in the Western worldview have included "a quickening interest in engineering progress" [7]. Quinn writes, "Architecture, products, and transportation are virtually all Western in origin" [9]. Thus, since the conception of Western civilization, engineering has been linked to this/these Western worldview(s).

Today there are many striking similarities between the profession of engineering and the dominant worldview. The latter, in the words of Quinn, include "pursuits and goals" such as "greater reliance on science and **technology**, the refusal to set limits on production and consumption, the fragmentation of human labor into separate and autonomous spheres of operation, the **reductionist** approach to understanding life and the interrelationships between phenomena, and the concept of progress as a process of continually transforming the natural world into more valuable [through exploitation] and more human-made environment" [emphases added, 9] – many ideas that resonate with me as an engineer. For example, compare this to what Simon writes: "[T]he engineering worldview, is quintessentially **reductive** and deterministic… Characteristics of this ideology include the reification of a hierarchical and dualistic relation of mind and body and the insistent imposition of **mechanistic** models on non-mechanistic scenarios" [emphases added, 13].

As most literature does not use the term "engineering worldview", and rather than relying on this singular account, we must enhance our understanding of what engineering as a profession is today. A direct connection between engineering and one dominant worldview has become more complex in recent years, especially due to initiatives calling for specific changes. Note in this essay we discuss what engineering *is* at present rather than what, ideally, the engineering profession *could or should become*, according to existing calls for change.

In 2002, Stonyer wrote that "professional engineering education is located in the intersection of three discourses - the scientific discourse, the managerial discourse and the liberal education discourse" [14]. The first component, scientific discourse, is defined by Stonyer as "thinking based on reason--induction, deduction, logic, analysis, and synthesis" [14]. In terms of the managerial discourse, Stonyer writes, "Engineering practice is, to a large degree, regulated and controlled by corporate/commercial decisions that define and limit, how and where engineers use their engineering skills and knowledge" [14]. And, lastly, in terms of the liberal education discourse, "the confident, well-educated professional engineer… is capable of making informed decisions and acting in ways enhancing and progressing social good" [14].

More recently, a study by Pawley in 2009 assessed faculty responses to the question, "What is engineering?" Three explicitly "universalized narratives" surmounted, with faculty defining engineering as "applied science and math… problem-solving… and making things" [15]. The first characterization presupposed that engineering "helped society more than science", the second that engineers solved "problems that mattered" (leaving the question is, "Mattered to whom?" best answered as, "Society."), and the last "connected engineering to the physical construction of highly technical and mechanized products" [15].

Figueiredo offers a 2-by-2 matrix to help conceptualize engineering, breaking the profession into four disciplines. He explains: (1) "basic sciences views engineering as the application of the natural and exact sciences," (2) the "social dimension… sees engineers not just as technologists, but as social experts… creat[ing] social and economic value, (3) "design… values systems thinking much more than analytical thinking… is founded on holistic, contextual, and integrated visions of the world, and (4) practical realization is the "art of getting things done" [16].

What we see here are a few recurring themes, with one sticking out that seems highly relevant: the engineering profession serves society. Pawley's results suggest engineers perceive engineering help society more than science, Figueiredo thrusts engineers in the realm of the social sciences where they actually create social and economic value, and Stonyer discusses that engineers are limited, even controlled, by corporations. Then, if engineers directly serve society, we must ask what the driving forces of society are. Given that we have already associated the dominant societal forces with the modern dominant worldview, it seems reasonable to assume that there exists an intricate relationship between the modern dominant worldview and engineering.

IV. THE SUSTAINABILITY WORLDVIEW

Eckersley writes, “The dominant worldview of material progress, which gives priority to economic growth and a rising standard of living, is being challenged by a worldview based on sustainable development, with its aim of balancing social, economic and environmental goals to create a high, equitable and lasting quality of life” [17]. Hence, sustainability is deliberately and explicitly decoupled from engineering. But before explaining the division further, we must first look at how the concept of sustainability came to be and what sustainability means today.

The need for sustainability in the modern West has grown alongside technology. Riley writes that transcendentalism, dealing “with humans’ relationships to nature… [and] directly with the ecological problems of our time has emerged since the 1960s, set off by Rachel Carson’s work *Silent Spring* and Aldo Leopold’s call for an evolving land ethic” [2]. Where within an engineering worldview “the facts of ecology in general, do not fit” as ecological issues are too complex [18], we find a new worldview emerge.

As reported by the Brundtland commission following their eighth and final meeting of the World Commission on Environment and Development (WCED) in Tokyo of February 1987 address, “When the century began, neither human numbers nor technology had the power radically to alter planetary systems. As the century closes, not only do vastly increased human numbers and their activities have that power, but major, unintended changes are occurring in the atmosphere, in soils, in waters, among plant and animals, and in the relationships among all of these” [19]. The committee then questions how these difficulties might be addressed in “political agendas” [19] and/or through “concrete and realistic action proposals” [19]. Albeit, the committee suggests these agendas and proposals should be situated in the “institutions we have created”, as the committee self-admits, “we were not called upon to deal with the environment alone, but with development and the environment” [19].

Thus the WCED pioneers introduced the “concept of sustainable development” with the premise that the “will for change must be created” [19]. Inherent in the very core of this concept are “recommendations” based “on the realities of present institutions” [19]. At large, today, sustainable development is reiterated verbatim from the Brundtland report as “an approach to progress which meets the needs of the present without compromising the ability of the future to meet their own needs” [19].

We find ambiguity inherent in the term “sustainability”, as we question how it might ever be possible to quantify “needs”. Milhelcic and others write, building off the Brundtland reports ambiguous definition of sustainability, a “diverse set of constituents have developed different visions of sustainability based on their different needs and aspirations” [20]. This leads to a redefinition of the term, during the 2002 World Summit on Sustainable Development, as “the design of human and industrial systems to ensure that humankind’s use of natural resources and cycles do not lead to diminished quality of life due either to losses in future economic opportunities or to adverse impacts on social conditions, human health and the environment” [20].

Confusion also arises today as we often hear people use the word “green”, and do not realize that this should be distinguished from “sustainability”. Ansari writes, the word green “represents a rather wide and loosely defined spectrum of thought, attitudes, philosophy and practice, centered around the common theme of concern for and protection of the environment” [18]. Then, green engineering is limited to “pollution prevention and industrial ecology alone” [20]. Green engineering is therefore “not sufficient to achieve sustainability because even systems with efficient material and energy use can overwhelm the carrying capacity of a region or lead to other socially unacceptable outcomes” [20]. Despite the wide definition appropriated to sustainability, its goal in creating a “more sustainable world” has had noticeable impact. Eckersley posits that a “shift in worldviews” from “material progress” to “sustainable development… may be taking place.” [17]

V. CLOSING DISCUSSION

Progress in the dominant modern worldview is “measured as the size and rate of increase in Gross Domestic Product” (GDP) [17]. Consequentially, in a dominant worldview where “progress needs never cease” [5] should we optimistically believe that GDP will grow without end? As “engineers are perennially the agents of technological progress” [7], and technological progress is the means through which GDP continues to grow, does it seem feasible to propose that engineers have the ability to accomplish the challenge of continual progress?

Once sustainability became “real”, people attempted to mesh it with the engineering worldview. But sustainability brings with it alternative assumptions about how the world should be approached, views contrary to those of the engineering worldview, and an idea that progress can be environmentally, socially, and economically savvy all at the same time. It should not be surprising that there are some who confuse sustainability with “weak” and “strong types, where in the former acts “that are harmful to the environment damage both society and the economy,” and therefore environmental considerations become the most prominent in an engineer’s decision making process [21]. In the latter case economic considerations come to the fore whereas environmental and social considerations cede to the background. [21]

Ansari suggests that there are different “shades of green” at different ends of the spectrum [18]. One shade he calls the green worldview “assumes ecology to be a basic theoretical and empirical discipline rather than an offshoot of other fundamental branches of science” [18]. This is in contrast with the “engineering worldview” that uses “physics and chemistry as the basic theoretical and practical framework for problem solving" [18]. In turn, each worldview has largely variable solutions, one that considers ecology paramount, the other only minimally. Somewhere in the middle of these two extremes lies the sustainability worldview, which we may be the bridge connecting the green and engineering worldviews. The challenge then is how to construct such a bridge.

The WCED writes, "The radical change in human attitudes foreseen by acceptance of the concept of sustainable development depends upon a vast campaign of public education and re-education, a worldview debate around life-and-death issues. Changing the attitudes of people everywhere is a fundamental prerequisite if the priorities of human society and therefore of human government are to be rewritten." [19] While the Brundtland report suggests that a worldview debate should occur, where our modern society questions what we value, the committee does not provide us context on *how* to spark such a debate. Nor are we provided a metric that shows us if society is progressing towards the "Sustainability Worldview".

Munir Fasheh (1990) seems to be touching on the difficulty of such change when discussing hegemony. Fasheh writes, "Hegemony does not simply provide knowledge; rather, it substitutes one kind of knowledge for another in the context of a power relationship" (p. 24) [22]. Thus, hegemony is itself a "form of domination". From these statements, pertinent questions regarding hegemony of engineering education arise. Who gets to be an engineer? What ideologies must they value? Do engineers get to value solving problems unfamiliar to possessors of the dominant worldview? These are difficult questions, especially given that the hegemony of the dominant Western worldview within the university seems to be beyond scrutiny. The university is the keeper of knowledge. To *officially* become an engineer you must pass through the university first. As a result, ethno-centric forms of engineering tend to be overlooked as something other than engineering [23].

Sustainability has become an ideal simply "bolted-on" to engineering education, rather than the driving ideology for the dominant modes of engineering practice [24]. If our common goal is radical change of the entire engineering enterprise, as reports by NAE such as the Engineer of 2020 suggest [1], the questions contemporary society must concern themselves with first are the direction of change and how to implement it. Our suggestion is that this requires a complete rethinking of the engineering worldview, paired with specific attention to the influence of the broader, societal, dominant worldview driving engineering practice.

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Urban Sustainability – an Engineering Course for General Education

Making the Case for Engineering to be Active in General Education

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Abstract— *This paper will address two closely related topics. The first is the design and successful delivery of an engineering course for General Education at the university level. The focus of the course is how the built environment influences the social, economic, and natural environment. Engineering decisions about the materials used to create the built environment affect structural integrity, energy performance, and the sense of place in cities. These factors, in turn, affect the quality of life for all citizens - so the topic of this course is of interest to students of all disciplines. As such it offers an opportunity to introduce non-engineering students to the way that engineers think and make decisions. The second topic is an exploration of why engineering departments are not typically major players in General Education. We in engineering have often secluded ourselves from the rest of the university. The effect of this is that students outside of engineering view the subject matter as out of reach when many of the main ideas are really central to the shared life of our nation. One way to overcome this barrier is to offer engineering courses meant for students of all academic disciplines.*

Keywords—engineering and liberal arts; general education; urban; sustainability

I. INTRODUCTION

Three distinct personal experiences against a background of nearly 30 years of teaching experience in engineering, and a report published in 1989 converged to lead me to the development of the course described in this paper. The report was issued by the American Association for the Advancement of Science and was titled "Science for all Americans" [1]. On page 13 of that report they simply state "Most Americans are not scientifically literate...and the latest study of National Assessment of Educational Progress has found that despite some small recent gain, the average performance of 17-year-olds in 1986 remained substantially lower than it had been in 1969." There has been considerable effort dedicated to STEM education in the years since that report, however as our national dependence on technology has increased dramatically, the general level of technical literacy has not kept pace.

The three experiences follow:

Experience 1: In 2005 I met Dr. David Billington of Princeton University and was inspired by a series of courses developed by him and by his colleagues. Courses such as "Engineering in the Modern World" and "Structures in the Urban Environment" were intended for students of all academic disciplines and offered an opportunity for students of all disciplines to understand engineering ways of thinking. The courses were well received at Princeton and, it seemed to me, greatly needed at other universities as well.

Experience 2: In the summer of 2006 I joined a group of undergraduate students traveling abroad with an archeology professor from a neighboring university. During our 3 weeks in Greece lectures were delivered on-site and often involved a short introduction, an opportunity to explore, followed by time to report, reflect, and discuss. This was an extraordinary learning experience and I wondered how I could incorporate a similar approach into my engineering teaching.

Experience 3: During the same summer I participated in the building of an energy efficient home for a low income family – a home that my students and I were able to design and that earned a Silver ranking in the LEED-H (U.S. Green Building Council's LEED for homes) pilot program. We were able to obtain energy data for the house with a family living in it. With that data as well as the experience of designing and building the house, I gained an entry into the home-building industry as well as opportunities to make presentations to neighborhood associations, civic clubs such as Kiwanis Clubs, and engineering education conferences such as this one.

II. ESTABLISHING A NEED FOR THIS COURSE

As I presented what we had learned from this house, I was surprised by how little - even well educated people - knew about the topic of energy. I was also surprised by how eager those same people were to learn, and how grateful they were for explanations that they could understand. The need for education about energy for all citizens was clear. When energy education is applied to housing and to creating urban environments that people can care deeply about we have a "vehicle" with which to deliver this education. It is also the mission of universities in this country to prepare citizens for modern life. This is where schools of engineering can and must contribute to the education of students from all discipline areas. Pages 12-13 of "Science for All Americans" [1] provides a list of 6 major points in establishing a need for scientific literacy for everyone. The last point is: "The life-enhancing potential of science and technology cannot be realized unless the public in general comes to understand science, mathematics, and technology and to acquire scientific habits of mind; without a scientifically literate population, the outlook for a better world is not promising." In 2002, 13 years later, The National Academy of Engineering published "Technically Speaking: Why Americans Need to Know More About Technology" [2] in recognition that the critical task of assuring technical literacy for all citizens was far from finished. Numerous articles have been published more recently about the need for STEM education at all levels – even as a necessary part of liberal arts education. In 2008 The Chronicle of Higher Education published an article titled "Engineering and the Liberal Arts: Strangers no Longer"[3], addressing the approach at Smith College, Union College, Olin College, and Duke University to integration of engineering into liberal arts education. Yet in spite of the mandate included in that article, the integration of engineering into the liberal arts is far from universal. When my sabbatical approached in 2007 it was time for me to take action – beginning with the course described in the rest of this paper.

III. COURSE STRUCTURE

Approaching non-engineering students with an engineering class has its own challenges which will be discussed more fully later in this paper. However, the popular saying, "a spoonful of sugar helps the medicine go down" applies in this case. The engineering content is embedded in the urban design and social aspects content of the course. There are two major engineering topics that are addressed. The first engineering topic is structures – more specifically stresses due to gravity loads and wind loads on common structural elements found in buildings. The second engineering topic is energy - beginning with units of energy, purchased forms of energy, and how energy is delivered to buildings. The energy studies then are applied to heating of air and water and end up with heat load analyses for buildings. Engineering topics and the calculation exercises are presented in two small course-packs. In addition to the course-packs there are three text books which are listed in the next section. The approach is to weave the engineering topics into the larger social and economic context of cities. A combination of assigned calculations, journaling, and instructor-led walks through urban areas near our campus enable me to hold the interest of the students and inspire them to look for applications of what they learn. Before every walk a prompt is provided to define what we will be looking for and a walk report is required after the walk. This part of the course was inspired by the experience in Greece and it has been very well received by students who tell me years later that they still return to some of the areas of the city that we explored together. In order to encourage students to explore our city beyond the requirements of the course, up to 3 restaurant reviews can be submitted for extra credit. The restaurants must be unique to our city. That is, no chain restaurants are allowed to qualify and students must order and eat something in the restaurant in order to submit a review. I am careful to point out good and unique places to eat as we walk. The variety of activities keeps students a little off-balance and requires them to stay engaged. This is a 3 credit hour course that meets twice each week for 75 minutes in each session. This allows time for the walks.

Text Books: The texts are: *The Death and Life of Great American Cities* by Jane Jacobs, *The Tower and the Bridge* by Dr. David Billington, and *Suburban Nation – the Rise of Sprawl and the Decline of the American Dream* by Andres Duany, Elizabeth Plater-Zyberk, and Jeff Speck. Billington's book presents a history of building materials progressing from stone and wood to the use of iron and eventually concrete and steel and finally reinforced concrete and post or pre-stressed concrete. In parallel with Billington's book and structures calculations the students are also reading Jane Jacobs book which addresses how cities really work. At the beginning of her book on the page titled "Illustrations", she notes "The scenes that illustrate this book are all about us. For illustrations, please look closely at real cities. While you are looking, you might as well also listen, linger and think about what you see." We take her advice literally. The course is taught on an urban campus and a series of instructor guided walks through selected parts of the city have proven to be the favorite part of the course. As we cover structures, structural elements can be pointed out, but mainly the walks at the beginning of the course are used to tie the ideas of Jane Jacobs' book to the reality of our own city. Later in the semester when we cover energy topics the walks also include the houses that I have personally worked on in the neighborhood next to our campus…and the walks include stories about the people who live in the neighborhood.

IV. THE ORDER OF ENGINEERING TOPICS MAKES A DIFFERENCE

As noted earlier, there are two major engineering topics, structures and energy. It works better to do structures first-mainly because structures are far easier to visualize and so the engineering content is not so formidable. Solutions for stresses in columns and beams are algebra based and college algebra is the math level required for the course. Energy is not as easy to visualize and it is based on thermodynamics – which even engineering students often find difficult. The energy equation is a differential equation and this is beyond the math level of most students. For this reason a series of spreadsheets with the solutions are provided and the emphasis shifts to looking for patterns in the solutions. By the second part of the course students are more comfortable with the engineering content and some discussion of the energy equation (also known as The First Law of Thermodynamics) is possible.

V. WEAVING CONTENT AREAS: EXAMPLE 1

This arrangement of covering structures first and energy second works well with the non-engineering texts that are used. We begin with Jane Jacobs' book and Billington's book. One of the major points of Jane Jacobs' book is that sorting a city by use -putting all of one kind business in one place and destroying fine-grained diversity in a city – is deadly. On our second day of class, with the reading assignment in Jane Jacobs' book completed, we take our first walk to Calder Plaza in Grand Rapids. It is a beautiful example of how sorting by use kills the vitality of a city. All of the government buildings are arranged around an impressive and beautiful plaza – and unless there is a festival, there is no-one on the plaza. The lone restaurant at plaza level struggles to survive and seldom has any customers – even close to noon. Far from being a lively city center it is orderly, quiet, and both economically and socially dead.

On our walk back to school we pass the tallest purely residential tower in West Michigan. It is built on the banks of the Grand River. The exterior is entirely glass and with the exception of the top 2 floors, contains no structural steel. It is entirely re-enforced concrete and post-stressed concrete. It is surrounded by the river on one side, two major limited access highways on two sides, and by the park area around the Ford Presidential Museum on the remaining side. We can clearly see this tower from our classroom and in most semesters I have been able to arrange for a tour of the building, however on this first walk we stand in park and look up 434 feet to the top and note that the Eiffel Tower, completed for the 1889 World Exhibition in Paris stands more than twice as high at 984 feet. The Washington Monument completed in 1884 is also taller at 500 feet. And the John Hancock Tower completed in 1970 is 1100 feet tall. We note this to give everyone a sense of scale since the structures calculations in the course-pack use the Washington Monument as an example of a column, the Eiffel Tower as an example of a wind-loaded cantilever, and the John Hancock Tower as an example of a column-cantilever. We will tour the residential tower after the students have completed many of the structural calculations, after I have added similar calculations for residential tower as part of the lecture material, and after they have read more companion material in the assigned texts. From The Death and Life of Great American Cities they will gain perspective on how such a building with the use that it has will fit into the social, economic, and cultural life of the city. From The Tower and the Bridge they will gain a sense for the history of building materials progressing from wood and stone to iron to steel and both re-enforced and post-stressed concrete. They will also read about the designers of these structures and how they viewed their work within the context of their culture and their time. From Gustave Eiffel who designed the Eiffel Tower to Fazlur Kahn who designed the John Hancock Tower to Swiss bridge designers such as Christian Menn who designed bridges in post-stressed concrete, students gain a perspective on how culture and technical progress are intertwined.

By the time we tour the residential tower they will understand why columns are much larger on the ground floor than on the 30th floor; they will understand how the transfer girders that we see in the lower parts of the building work to transfer load. Beyond simply enjoying the view and the luxurious surroundings in the building they are able to place the building in the full social, historical, economic, and cultural context. The walk report will require that they use the criteria set forth by both Dr. Billington and Jane Jacobs to evaluate this building. They will also be able to do a very simple structural analysis and be able to explain why post-stressed concrete might have been chosen over structural steel as the main material.

VI. WEAVING CONTENT AREAS: EXAMPLE 2

In the second half of the semester we switch texts to Suburban Nation – The Rise of Sprawl and the Decline of the American Dream. We also switch engineering content to the energy studies. The Suburban Nation text is more contemporary and the focus is on a contrast between traditional town development and the urban sprawl that has developed in our country since World War 2. Many of the ideas in Jane Jacobs' book are echoed in this book – particularly the way in which sorting by use destroys social and economic vitality. Many students have grown up in sprawl and by now in the course are able to see the contrast to traditional town development. The isolating effects of sprawl on community, the lack of shared public space, and the effects of increased dependence on automobiles are clearly presented in the book. As we examine social consequences of sprawl and the differences in the style of houses and much of the built environment, the highly energy dependent nature of our lifestyle is apparent and the energy calculations are a natural extension. We begin with units of energy – in particular the units of purchase most commonly encountered for buildings (kWhr of electricity and CCF of natural gas) and we link them to costs so that students can calculate the anticipated electric or gas bill based on rates of energy use. The steady state heat load calculation for buildings can be easily developed and the concept of “R-value” for various types of materials as linked to physical characteristics can be presented. At this point in the class I have many examples of insulation, window sections, and other building materials to pass around. One of the spreadsheet exercises involves the house that I worked on – Green House on Watson. Prints for the house are in the course-pack as well as a detailed case study. In the spreadsheet exercise students can examine the effect of increased temperature difference, infiltration rate, and insulation value of windows, walls, and attics on heat load required to support a given temperature difference between inside and outside. This is related to the cost of heating by various means - natural gas, electric, and fuel oil furnaces - at various levels of efficiency.

Our walks now include the houses that I have personally worked on – most especially the houses featured in the case studies. The neighborhood close to campus is predominately low-income and many of the houses are rental units and, being older houses, many are poorly insulated and highly energy inefficient. The spreadsheets help students to see how poor energy efficiency can result in a \$400-\$500 monthly natural gas bill while the houses are not warm. This is a social justice issue. The most vulnerable in our society, the ones with the fewest options of where to live will bear the greatest energy cost…and with that the greatest social cost. Most students have never encountered the reality of having to choose between paying an energy bill and either eating or medical care, yet that is a reality for all too many of the people who live near our school.

In the walks through these neighborhood areas I am able to point out many of the social and economic consequences of choices made in the past that affect not only energy performance of the houses but the quality of life for the residents today. I have many stories about my experiences with the people who live in the neighborhood and so the class material takes on a human form. While many areas are run-down, there are signs of renewal and the older patterns of traditional town development still underlie what can be seen today. The neighborhood near our school provides a nearly endless supply of illustrations for what we cover in the classroom. All of this has captured the interest of many students and has inspired them to think more deeply about *how* we have chosen to live – and how those choices have affected other people. This is exactly what general education in a university or college should do. The engineering perspective that provides a sense of numbers and potential for improvement is essential in this.

The journals, walk reports, and short papers are essential for reflecting on the learning that is taking place. In the first weeks of the course most students do little more than repeat what they have read or what they have heard in class. When we read a portion from the text, then go out to see how that idea plays out in the city, and then return to write about our observations and discuss them, the students begin to “claim” the material of the course. There are heavy reading assignments in the first few weeks – to bring them up to speed, but after a few weeks of repeated experience with reading, observing, and reflecting, most students are able to recognize and articulate how built environments affect social environments and vice-versa. By mid-term when a short paper requiring a personal observation of this interplay of built and social environments is assigned, most students are able to bring the main ideas from the texts together…and then walks become far more than an opportunity to escape a classroom.

VII. SO WHY ARE SO FEW ENGINEERING SCHOOLS AT THE GENERAL EDUCATION TABLE?

I have been teaching engineering at the university level for more than 30 years. In my own experience and through conversation with many engineering educators at other institutions there has been little enthusiasm for developing courses in general education. The engineering courses starting in 1974 at Princeton University broke new ground and they have offered workshops in an effort to spread this approach to other schools. Approaches such as “Converging Technologies” at Union College and described by J.D. Klein and R. Balmer in a paper titled “Engineering, Liberal Arts, and Technological Literacy in Higher Education” [4] are beginning to gain attention. However we are far from recognizing engineering as a major part of a liberal arts education. Is it because schools of engineering are professional schools and general education is still perceived to be the business of the liberal arts? But then why is it that the schools of business – also professional schools – do participate in general education in many universities?

As I pondered this question I noted the content of my own course. The urban sprawl mindset of sorting by use has penetrated deeply into our view of the world. Sprawl results in isolation on the basis of income because most housing developments are made up of similarly valued homes. The design of many of these homes includes a garage and many people enter and leave their homes by car and through the garage. Once in the car (a private space) they travel to work or to shop or to enjoy recreation – often with other people of similar income. Older people who can no longer drive are forced to move out of the suburbs and into retirement communities and so isolation on the basis of age also occurs. In the communication age we find it harder and harder to communicate or understand people of a differing income level, age, or culture because we seldom encounter them. This is in part a result of how we have chosen to live with great emphasis on private space at the expense of the shared (public) domain.

In universities we are sorted by discipline in a way similar to the sorting by use as seen in sprawl. It takes great effort to cross disciplinary lines. In large universities different disciplines occupy different buildings – often on different campuses. Even within our modern buildings we have fabulous private office space and very little shared space.

We are further specialized by engineering discipline and what we do is often a mystery to even other academics. The paper by Klein and Balmer [4] includes a subheading titled "Engineering, Liberal Arts, and the Two Cultures" in which they further discuss the divide between the separate cultures of engineering/science on the one hand and liberal arts on the other. My own observations echo their discussion.

Within our culture at large there is a prevailing attitude that engineering is far beyond the understanding of most people and certainly our wonderful electronic tools add to this mystique. As a result, students outside of engineering are normally hesitant to sign up for an engineering course. There is a real fear that the level of mathematics required is beyond the student of normal intelligence. Engineers are responsible for the production of the wonderful technology that everyone depends on but few really understand. This is not healthy for a culture so dependent upon technology.

VIII. CONCLUSION

One of the principle ideas presented in Jane Jacobs' book and also in the Suburban Nation book is that sorting by use kills the vitality of a city and that mixed use, mixed income, and fine-grained diversity is essential to the ongoing health of cities. The truth of this is clear if we observe cities. It is as important to academia as it is to cities. One way to promote mixed use and fine-grained diversity is for academic disciplines to work together. This is the challenge to higher education. If we find a way to meet this challenge, not only will students outside of engineering benefit, but we will benefit from the shared perspectives of other academic disciplines and our students will benefit from our enriched perspective. One way to engage the diversity that we seek is to work together with our colleagues in other parts of the university to create general education courses that prepare students to contribute to all of society.

A parting thought:

"Engineering has really been the transforming force in society for the last 200 years. Liberal arts schools that do not deal with engineering are leaving out an important component of liberal education."

Dr. David Billington, New York Times, Nov 4, 1990

He was… and is still correct. We have work to do.

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Recommendations for Engineering Doctoral Education: Design of an Instrument to Evaluate Change

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***Abstract*— In recent years, many studies and reports have highlighted concerns and problems with engineering doctoral degree recipients. Criticisms have come from professionals in both industry and academia, as well as from current and former Ph.D. students. Given the dissatisfaction of a variety of stakeholders, there have been calls from professional societies, disciplinary bodies and federal agencies to improve doctoral granting programs across the U.S. and to educate Ph.Ds. who are equipped with skills and attributes necessary to meet the highly-competitive and rapidly changing 21st century workforce [1, 2]. Within this context, this study focuses on the perspectives of working professionals from both academia and industry. Preliminary findings were obtained from one-on-one interviews with forty engineering Ph.D. holders who are from industry and/or academia. They recommended practical measures for engineering doctoral students to obtain desired characteristics upon graduation. Using the preliminary results, the work in progress precludes the design of an instrument to evaluate on-going changes to different aspects of doctoral education. The instrument will serve as a useful tool to understand the degree and scope of changes in engineering doctoral program. Portions of the instrument informed from these recommendations are provided.**

***Keywords*— engineering doctoral education; recommendations; instrument development**

I. INTRODUCTION

The Doctor of Philosophy is typically the highest degree an individual can earn within a field. It conveys a level of academic accomplishment that only a select group of individuals have chosen to pursue. Admissions criteria for doctorate programs draw a picture of an individual who is intelligent, curious, driven, and dedicated. Students from around the world choose to pursue graduate training in the U.S. because of the high caliber of programs and training and expertise produced by doctoral programs. Such pursuits have resulted in advances in science and engineering that were unimagined only a few decades ago [3]. However, recent years have witnessed a number of changes within the system of U.S. doctoral education. Criticisms of the current system, combined with economic and global changes, have forced universities and academicians to reevaluate the purpose of the PhD.

For example, employers of Ph.D. holders in non-academic sectors (e.g., industry, government, and non-profit organizations) have criticized doctoral recipients for being narrowly trained and educated and for lacking teamwork and management skills [4]. Similarly, many academics criticize recent Ph.Ds. for their limited teaching abilities, grant writing skills, and lack of familiarity performing interdisciplinary work [5, 6]. Even current and past doctoral students have criticized graduate programs for providing limited information about employment opportunities after graduate school [6-8].

A review by Campbell et al. [9] identified a number of the major concerns within graduate education. Of primary concern is the disconnect between the training that graduate students receive and their future professional roles. The assumption that graduate students will pursue academic careers is no longer valid as an increasing number of students are pursuing work in non-research universities, industry, or other arenas [10]. However, while the career goals of doctoral students have changed, the focus of graduate engineering education has remained the same. Graduate programs that focus only on research, to the exclusion of other skills, are not preparing students for the responsibilities of the positions they will fill in the future [9]. It is imperative that engineering graduate educators begin to consider the attributes of a successful engineer at the doctoral level and implement curricula and training that develop these skills in their students.

Considering multiple concerns of engineering graduate education, there have been calls from professional societies, disciplinary bodies and federal agencies to improve doctoral granting programs across the U.S. and to educate Ph.Ds. who are equipped with skills and attributes necessary to meet the highly-competitive and rapidly changing 21st century workforce [4, 5]. Therefore, in recent years, some engineering and science doctoral-granting programs have developed in-house workshops and seminars to equip Ph.D. students for their future roles as professionals [11, 12]. However, there is a need for additional studies to identify improvements and assessments of these improvements within doctoral programs. One way to identify what needs to be improved in engineering doctoral programs is to examine the perspectives of engineering Ph.D. holders who work in industry or academia.

Such employers can reflect accurately the types of work that they do and can provide recommendations for improving engineering doctoral programs. In this study, forty engineering working professionals were interviewed. Their perspectives on ways to improve current engineering doctoral education were explored. Findings identified from these engineers were then translated into measurable outcomes to assess the improvements made in the doctoral programs.

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II. Research Method

A. Data Collection

This study is part of a larger research study which examines topics such as, the desired skills and characteristics of engineering Ph.D. recipients, the ways that current graduate education practices in engineering have or have not prepared the Ph.D. recipients for their current roles and functions at their workplaces in academia or industry, and practical measures that might help students to acquire desired characteristics for engineering Ph.D. holders. Researchers focus on the topic of practical measures to prepare students for desired characteristics. Semi-structured one-on-one interviews with 40 engineering Ph.D. holders working in industry or academia were conducted by the research team.

The original interview protocol included 16 questions. Here, researchers explored the results from the interview question, "What can be done at the graduate level to ensure engineering Ph.D. students are acquiring the desired characteristics to be successful in academic and industrial careers?"

B. Data Analysis

A code book has been developed following a process described by MacQueen, McLellan, Kay, and Milstein [13]. The use of a structured codebook helped to ensure consistency among team coders. Open-coding was used to classify the responses to the interview question. An inter-coder reliability test demonstrated a percent agreement higher than 75% among coders. The code book was used to code all of the forty transcripts.

III. Preliminary Findings

The researchers are in the process of identifying the themes and patterns of the data. In this report, the list of codes obtained through the interview question was summarized. Codes here will be later translated into items that will become part of an instrument to assess changes implemented in current engineering graduate programs. Preliminary results include all codes that emerged from the 40 transcripts. These codes can be grouped into recommendations to students, faculty members, and the doctoral program itself.

These codes emerged from the transcripts cover different aspects of doctoral students' training. For students, the recommendations focused on diverse professional skill sets, experiences, or activities that would prepare students for their future careers. Interviews from the working professionals also stressed on the opportunities to which advisors or faculty members should pay special attention in the process of training and mentoring of doctoral students. Finally, the last set of recommendations indicated some areas that would require formal and informal support from administrators or other stakeholders of doctoral programs.

Sample recommendations to students include:

- Develop business skills.
- Develop good communication skills.
- Develop leadership skills.
- Engage in regular research group activities.
- Engage in interdisciplinary activities.
- Learn how to run a research program.
- Present orally.
- Participate in discussion-based learning.
- Participate in experiential learning activities.
- Teach and/or learn about teaching.
- Understand connections between engineering and society.

Sample recommendations to advisors or faculty members include:

- Allow doctoral students to make mistakes.
- Allow doctoral students to work independently.
- Introduce doctoral students to the realities of the work environment.
- Encourage students to critique their work.
- Encourage students to engage with industry.
- Engage students in publishing.

Sample recommendations to other higher education doctoral program stakeholders include:

- Align programmatic activities with the institutional mission.
- Change the reward system for faculty.
- Encourage faculty to acquire more industry experience.
- Set high expectations for passing Ph.D. milestone exams.
- Teach students about finances.
- Engage with non-academic stakeholders.

The recommendations from the perspectives of professionals who have worked in industry and/or academia provide practical measures to improve current doctoral education. Some of these suggestions were based directly upon their lived experiences through their own doctoral education and their past and current work experiences.

IV. Discussion

Some of ideas proposed by the working professionals directly address the criticisms discussed in current literature. For example, one of the main criticisms is that current doctorate training focus on preparing the doctoral students for academic positions [9]. Some of the recommendations identified in this research seem to respond directly to the concern that many Ph.D. recipients' career choices have shifted to non-academic positions, especially the ones in industrial fields. These recommendations focused on developing students' professional skills, such as, business skills, leadership skills, etc.

It should be noted that many recommendations refer to different skills or experiences that students should possess upon graduation. However, the working professionals also stress the important roles of advisors or faculty members and the doctoral program itself. The successful implementation of the recommended measures for improving doctoral students' training experiences demands the engagement of multiple stakeholders.

These codes will be translated into short statements to be used for developing a survey instrument. The survey will be divided into portions for students, faculty members and other stakeholders, such as administrators of engineering doctoral program (e.g. a department head).

Several sample statements for the part of students' survey are shown in Table 1.

Table 1. Sample statements in a survey for students

In my doctoral training,	Not at all 1	2	3	4	Very Much 5
1. I was exposed to opportunities to understand the connections between engineering and society.					
2. I learnt about how to teach through my own workshops, seminars, or other venues.					

The design of the survey can be used to access the changes that are taking place in current engineering doctoral programs from the perspectives of different stakeholders, including the students, faculty members, administrators, industrial representatives, etc. Researchers envision that the instrument will be used within workshops and seminars and will include specific benchmarks and metrics focused on different areas identified in the interviews.

V. Implications and Future Work

Preliminary results confirm that revisions to graduate education are needed, especially given the likelihood that the vast majority of engineering Ph.D. holders will obtain jobs in industry after graduation. Although many recommendations refer to students, interviewees noted that advisors, faculty members, and higher education administrators need to engage in efforts to reform doctoral education for engineering students.

The survey developed from this work will reflect different components for soliciting perspectives from students, faculty members, etc. By understanding these different perspectives, potential results obtain via this survey can be used to access the degree and scope of on-going changes in preparing students for diverse career options and related professional skills. The tool might serve as foundations for advising, mentoring, and for students' self-reflections of doctoral progress.

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Physics of Computing as an Introduction to Computer Engineering

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Abstract— This paper describes a new required course in the Georgia Tech computer engineering curriculum, ECE 3030, *Physical Foundations of Computer Systems*. Traditional introductory courses take a constructive approach to logic design and computer organization. 3030, in contrast, introduces the major physical concepts underlying computation. It shows how they determine basic properties of computers such as speed and energy consumption. It also explores design trade-offs by showing how changes that improve one type of property inevitably, due to physics, cause another useful property to degrade. The course emphasizes CMOS but many of its principles apply to other logic technologies as well. Students do not directly design logic or learn assembly language---for example, delay and energy consumption are studied for inverter chains. However, they have time in the course to study in detail the basic physical phenomena that underlie design choices in digital systems. Those principles help students absorb material in later classes such as VLSI design. 3030 introduces certain topics to students much earlier in the curriculum than is traditional. We believe that an early introduction to principles is important not just for students who become logic designers but for all computer engineers.

Keywords—logic design, computer architecture, delay, energy, reliability.

I. INTRODUCTION

This paper describes a new required course in the Georgia Tech computer engineering curriculum, ECE 3030, *Physical Foundations of Computer Systems*. This course, which is recommended for the junior year but is early in the prerequisite chain, provides a very non-traditional introduction to computer engineering. Traditional introductory courses take a constructive approach to logic design and computer organization. 3030, in contrast, introduces the major physical concepts underlying computation. It shows how they determine basic properties of computers such as speed and energy consumption. It also explores design trade-offs by showing how changes that improve one type of property inevitably, due to physics, cause another useful property to degrade. The course emphasizes CMOS but many of its principles apply to other logic technologies as well.

The course uses basic device physics to understand the delay and energy consumption of logic gates and logic networks; it demonstrates the inherent trade-offs between performance and leakage current; it studies basic problems in sequential system design including clock distribution and metastability; it describes various forms of memory, the causes of the memory wall and remedies for it; it analyzes heat transfer in server farms; and it considers the technologies behind batteries, semiconductor manufacturing, and other important topics. Students do not directly design logic or learn assembly language---for example, delay and energy consumption are studied for inverter chains. However, they have time in the course to study in detail the basic physical phenomena that underlie design choices in digital systems. Those principles help students absorb material in later classes such as VLSI design.

3030 introduces certain topics to students much earlier in the curriculum than is traditional. We believe that an early introduction to principles is important not just for students who become logic designers but also for all computer engineers. Computer architects need to understand the rationale behind the limitations of memory and leakage current. Embedded software designers need to understand the physical costs in time and energy for programs.

A. Course Goals

ECE 3030 is a first attempt at a re-thinking of the computer engineering curriculum. Mix up device physics and architecture; do it early in the curriculum; concentration on the knobs that control design decisions rather than particular designs.

Engineering is the simultaneous satisfaction of competing design constraints. The key design constraints in logic design are performance, energy, cost (area), and reliability. Logic design without consideration of performance is just the first two weeks of a mathematical logic course in the philosophy department.

Most students won't work on a large-scale chip project, either microprocessor or SoC. However, they will use those chips and need to understand their limitations. Thinking about the design space early gives them a new perspective on

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engineering that they don't get in high school or many early engineering courses.

We have two goals for this course. The primary goal is to related device characteristics to logic design and computer architecture. Transistor and wire characteristics drive some of the most basic design choices in computer systems: caches and memory systems, pipelining, power management. But it is very difficult for a student to pick out those relationships from the coverage given in a traditional device course. We concentrate on a few key characteristics---gate capacitance, leakage, and wire resistance/capacitance---to identify the key advantages and limitations they provide.

A secondary consideration is to relate physics to the mathematics of computing. We want to be sure that students do not assume that all problems can be solved with clever devices and circuits. No amount of circuit trickery will, for example, make P = NP. The Turing model also provides the fundamental framework for the structure of modern computers---memory, discrete values, and discrete time---even though Turing was not concerned with implementation. The story of the early days of computer design is the search for ways to build physical devices that could provide useful memory and perform discrete computations.

Our course was inspired by *Feynman Lectures on Computation* [3]. However, we quickly realized that the book was better as an inspiration than a basis for court development. The book talks about simple VLSI design but it doesn't talk about computer architecture---Feynman is ultimately interested in fundamental limits on computing bits, not designing complex computer systems. One clear example of his view of the subject is that he does not talk about metastability, a critical topic for reliability that is rooted in circuits and physics. We did, however, use *The Feynman lectures on Physics* [2] as a key source for physics concepts.

We have identified some key concepts that underlie much of the course. These topics appear at several points and at different levels of abstraction. Highlighting these concepts provides structure for students and keeps the course from becoming a bewildering list of equations.

- **Boltzmann's constant** surprised us by emerging as a key concept. It appears in all the basic device equations. But it also underlies heat transfer; heat management devices such as heat sinks are important topics. Boltzmann's constant also appears in the Arrhenius equation, a model for the rate of chemical reactions that is used to model on-chip reliability.
- **Impedance matching** also pops up in several contexts. The simplest example is driving pins from on-chip. An exponentially tapered buffer chain is the optimal solution to this problem. But impedance matching also underlies two key topics: driving large clock trees and transistor sizing in any long logic path such as an adder carry chain.
- **Leakage vs. performance** is a key design trade-off in modern CMOS. Device characteristics that provide high performance also increase leakage current. Leakage could at one point be kept to manageable levels using circuit techniques; designers must now deal with the effects of leakage at all levels of abstraction.
- **Reliability** has multiple root causes and therefore crops up in a number of contexts. Heat produced by power consumption is one important cause of failure; heat can be dealt with at the circuit, architecture, and packaging levels. We also explore fundamental trade-offs between performance and reliability.
- **Scaling** is the driving force behind modern semiconductor development. Ideal scaling of the 1970's and 1980's had a few negative consequences but largely led to simultaneous increases in integration and performance. However, limits on devices cause scaling to deliver mixed benefits in modern technology. Those problems can be dealt with at many levels of abstraction.

B. Course Structure

We have developed the course as a series of modules. The first two-thirds of the course are spent on the basic concepts while the last third introduces some more advanced topics. We follow a roughly bottom-up structure, although we do introduce heat transfer early to remind students of the importance of power consumption.

- **Electronics and computation.** We spend the first week on historical background, without any hard-core physics or math. This module illustrates both what we mean by computation and the underlying technologies required to build useful computers. Mechanical computers such as the Babbage Analytical Engine demonstrated important concepts but were fundamentally limited by the performance and size of gears and shafts. Memory is a key technology for computers. The many intermediate steps on the way to dynamic RAM---mercury delay lines, magnetic cores, *etc.*---show that the form of the computer was not at all obvious. We also mention the Turing machine as a mathematical foundation for computing. The Turing machine motivates two critical concepts in computing: memory and discrete-valued computation. We also mention computational complexity to show that some problems cannot be swept under the rug by fancy physics or circuits.
- **Thermodynamics**. This is a short module covers thermodynamics and atomic structure using Boltzmann's constant as a unifying theme. We use some simple examples, including heat transfer and Johnson noise, to motivate the importance of these concepts. However, this module would feel at home in a physics course.
- **Heat transfer**. Heat transfer is the first module in which we talk in detail about computer design. We like heat transfer as an opening topic because it let students know that we will talk about computers at all scales. We introduce the scale of heat generation in a modern server farm. We then describe Newton's Law of Cooling followed by an introduction to thermal resistance and capacitance. We use these concepts to work some simple problems in heat sink selection. We also talk about

power/ground distribution, which for server rooms is itself a massive problem.

- **Scaling**. Dennard's scaling theory [1] gives an extremely useful synopsys of the relationship between device and logic characteristics. That theory casts logic characterisitcs (delay, power, area) as functions of device parameters, then derives relations on how those device parameters scale with feature size. Dennard shows, for example, that gate delay actually decreases as feature sizes decrease. However, the story of the last 20 years is steady erosion in the assumptions underlying Dennard scaling, with leakage being one of the most important drivers of scaling failure. This discussion of ideal scaling therefore sets up the discussion of topics for the remainder of the course.
- **Device physics.** We survey the classical MOSFET theory and the extensions for leakage with an eye toward their use in logic circuits. We concentrate on the classical MOSFET model [4]. We also relate some key device parameters, such as gate capacitance, to Dennard scaling. To motivate leakage, we use a simple model focusing on subthreshold behavior of MOSFET including the concept of the subthreshold slope.
- **Inverter analysis**. We use an inverter as a fundamental logic element and proxy for electrical behavior of other logic gates throughout the course. We first introduce the transfer curve and show how it suggests the boundaries of the logic 0 and 1 ranges. We use the inverter transfer curve to introduce the concept of noise margin and regenerative property. This helps us to explain the difference between a "logical" and a "physical" inverter. We then show how to approximate the transistor as a resistor and develop the RC delay model. We also compute dynamic energy consumption.
- **Interconnect**. We first show how to measure the resistance and capacitance of layers of on-chip material. After introducing the general concept of a transmission line, we concentrate on the RC case. We perform an intuitive definition of Elmore delay and show how RC sections both delay and distort a pulse.
- **Combinational logic**. We reduce the continuous signals we have used so far to an event-based model. We analyze the delay of a chain of inverter using a piecewise linear simplification of the transfer curve and an inertial delay model for the gate. This allows us to not only compute delay but also to show the importance of transistor sizing.
- **Sequential machines**. Turing's model requires us to discretize time. We introduce registers and clocks as the mechanism for turning continuous time into discrete time. We then use our simplified inverter model to analyze the behavior of static registers. This model is sufficient to allow us to model metastability, our first major foray into reliability. We also introduce clock trees and show how they are an example of exponential buffer tapering.
- **Memory**. Turing's model requires bulk memory for the tape. We introduce simplified versions of the DRAM circuit. A simple model is sufficient to explain why DRAMs do not get faster, unlike logic gates, creating a phenomenon known as the memory wall. Because the DRAM cell is read by charge sharing, smaller bit cells results in smaller voltage swings. This motivates the complex bank architectures seen in modern DRAMs. We also discuss flash memory, magnetic disks, and optical CD-ROM storage. For all these technologies, we give simple performance models.
- **Computer architecture**. The students now have all the pieces necessary to understand a complete computer. We consider the effects of technology on modern architectures: the memory wall motivates caches; high clock speeds complicate clock distribution; leakage current causes power problems which in turn cause thermal problems. We also use planet-scale computing to study design trade-offs. Even when signals propagate at the speed of light, an Earth-sized computer has a clock speed slightly slower than an Intel 4004.
- **Batteries.** Mobile devices rely on batteries with limited energy. We survey the design space for batteries: energy, current, recharge characteristics, *etc*.
- **Leakage.** This module spends more time on the device characteristics that cause leakage. We also survey circuit and logic techniques to manage leakage current.
- **Fundamental limits on reliability.** This is a fairly theoretical analysis of reliability based on a barrier model of transistors. We start with a very optimistic assumption: the probability of correct operation can be 0.5. We then go through a series of physical effects that cause us to spend more energy on a computation resulting in a value of energy per computation about 10,000 times larger than our original estimate.
- **Manufacturing.** We survey basic technologies for manufacturing, primarily lithography and testing. We also survey new techniques for 3-D chip manufacturing.
- **Image sensors and displays.** We discuss image sensors for two reasons: a great coincidence of physics allows us to use the same material for sensing light and computing; and multimedia has driven demand for high-performance and low-power mobile computing over the past decade. We also look at several different types of displays, including LCDs, electronic ink, and digital light projection.
- **Emerging technologies.** At the present, this model concentrates on carbon nanotube logic and phase-change memories. We may introduce quantum computing at some point, but an adequate treatment of that topic would require a great deal more quantum mechanics.

C. Grading Criteria

We base students' grades on homework and tests. We have found that questions must be carefully designed to allow students to answer them with the limited amount of information they have. This course emphasizes breadth of material over depth, so we cannot expect students to introspect as much as in some other classes. For example, although we discuss caches and average access time to motivate the limitations of DRAM, some students do not have previous experience with caches.

We had originally hoped to have students read some important papers in the field. However, we have found that virtually all papers require too much background information. At present, we only have students read Dennard's paper on scaling, and do not ask them to read the device modeling material at the start of that paper.

D. Experience and Lessons Learned

We are in the midst of teaching the course for the third time. After being not at all sure how to approach this course, we believe that we have found a reasonable shape for the material. A great deal of work remains to fill in details, however.

A constant challenge is fitting the material to students' background. We have spent a great deal of effort finding simple approximations to complex topics. Students have very little background in either circuits/devices at the low end; they have a little more knowledge of logic design and computer organization, but are still not sophisticated.

We would like to develop material on a few more topics:

- A module on networking that relates the physical phenomenon of latency and throughput to similar concepts in logic/architecture.
- A more thorough treatment of advanced technologies, emphasizing the basic characteristics we need from a technology in order to be able to use it to compute.

E. Acknowledgments

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Automatic Generation of Characterization Circuits – An Application in Academia

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***Abstract*—Circuit characterization is an essential topic in most integrated circuit design courses in an electronic and/or computer engineering curricula. In such courses, a standard set of basic circuits (called *standard cells*) needs to be characterized based on different design criteria, for example, noise margin, power, performance, etc. So the students usually need to go through the manual, iterative process of creation of circuit descriptions (defined by *Spice netlists*) – a process that is not only time-consuming but also prone to errors. For the students to be able to conduct a large number of experiments while focusing on the design issues rather than on the tedious task of creating different circuit variants, an online tool is being proposed. The tool can be used in different courses that cover the topics of nano-sized CMOS (*complementary metal oxide semiconductor*) digital design, VLSI (*very large scale integrated*) circuit design, low-power digital circuit design, circuit reliability, etc.**

Keywords—online circuit generation, digital CMOS circuit, VLSI design, standard cell, cell characterization, Spice simulation, testbench, low-power design, circuit reliability

I. INTRODUCTION

Standard cells include basic building blocks that are used to build larger circuits. Examples of basic digital blocks in a *standard cell library* are inverters, NAND gates with two or more inputs, NOR gates with two or more inputs, etc. Other cells include flip-flops and input-output pads [1].

Circuit characterization is an essential topic in courses[1] on digital design. Various aspects of the topic fall under different headings in the course syllabi, for example, performance estimation, power consumption, and circuit simulation. Additionally, the recent scaling of transistors to 22 nm and lower dimensions have brought to limelight the need for teaching the effects of variations in circuits due to dissimilarities in dimensions and dopant densities of transistors.

The circuits may originate from HDL (*hardware description language*) models, from schematics, and/or from Spice netlists. Regardless of how the circuits are initially created, their designers may have to create many, many circuit variants. A few dozen or a few hundred design variations may be needed just to meet a given design criterion, such as power consumption or performance. A few thousand or hundreds of thousands of (Monte Carlo) iterations may be needed to study the behavior of a circuit under parameter deviations, such as random changes in switching (threshold) voltages, manufacturing variability in device dimensions, etc. [2], [3]

Depending on the type of characterization being done on a circuit/cell, a set of input stimuli and the means of measuring the circuit behavior (current, delay, etc.) have to be included in the Spice netlists [4].

Creating the Spice circuits and their *testbenches* (that comprise of carefully crafted commands for stimuli, commands for measuring current, voltage, and timing) is a time-consuming and error-prone process. So a student (or any circuit designer, in general) may spend a significant amount of time just creating the netlists, instead of expending her energy on the larger issues of the design and analysis. This paper presents an online tool, named *SpiceGen*, that not only creates but also their testbenches.

In Section II, we briefly review related work on simulation of electronic components and circuits. Section III gives an overview of SpiceGen and its structure. Section IV presents the contents of a sample course on CMOS digital design and how SpiceGen can be utilized for the course. Two examples of student activities based on the tool are illustrated in Section V, followed by the description of classrom-deployment of the tool, in Section VI. Conclusions are given at the end of the paper in Section VII.

II. RELATED WORK

Over the years, curriculum for teaching of integrated circuit design has been addressed by many researchers [5]-[9]. Circuit simulation has for short-channel effects (SCE) modeling in MOS (Metal-Oxide Semiconductor) transistors [10], gate level-design [11], [12], and circuit theory [13], [14].

A Spice-driven website for teaching power electronics covers experiments on just a single component (a power diode) [15]. Hashimoto *et al*'s cell library generation tool has used for

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[1] http://www-inst.eecs.berkeley.edu/classes-eecs.html#ee; www.eecg.utoronto.ca/~najm/courses/ece451.pdf; www.ece.unm.edu/~jimp/vlsi/syllabus/sept2000.pdf; www.ece.unm.edu/~jimp/vlsi/syllabus/sept2000.pdf; www.muic.mahidol.ac.th/eng/wp-content/.../syllabi/EGCI433.pdf

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simulated annealing for creating cell layouts for 130, 180, and 350 nm technology nodes [16]. An offline tool called AutoLibGen [17] has allowed characterization of cell library with 65 nm node, but not the state-of-the-art nodes.

The author (of this paper) has conceived and developed an offline tool for automatic creation of Spice netlists for basic gate characterization. He has successfully used the tool for his research work in the past two years; now the web-based version of the tool is being presented with an emphasis on academic usage. None of the known online systems have the circuit construction capabilities that this tool offers.

III. SPICEGEN OVERVIEW

The flowchart in Figure 1 shows the overall structure of the SpiceGen tool. The Spice netlists and the corresponding testbenches generated by the tool depend upon many variables, the primary ones being:

- *Standard cell type*: one of 19 basic gates, such as inverter, NAND2, NOR2, etc. (termed as *unit-under-test*/UUT)
- *Technology size*: 16 nm or 22 nm
- *Supply voltage* (V_{DD}) and *operating frequency* (f_{max})
- *Variation type*: transistor dimensions and/or threshold voltage (V_{TH})

SpiceGen customizes the netlists and the testbenches based on the type of characterization being done. Currently, the three options are:

- DC/voltage transfer curves for measuring (and balancing) gate/cell rise and fall times, and *static noise margin* (SNM) (see Figure 2)
- Delay and power measurement (see Figure 3)
- Maximum operating frequency measurement with a ring oscillator of *n*-stages (see Figure 4)

Apposite *driver* (waveform-shaping gates) and *load* are included in the netlists. Customized stimuli based on V_{DD} and f_{max} are also added. Depending on both the UUT-type and the characterization-type, tailor-made measurement (".meas") commands are incorporated into the netlist.

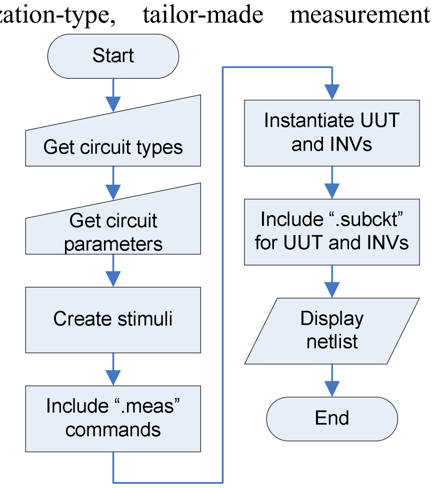

Figure 1. SpiceGen's flowchart

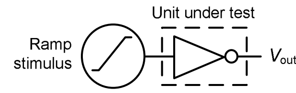

Figure 2. Test setup for acquiring DC transfer curve of an inverter

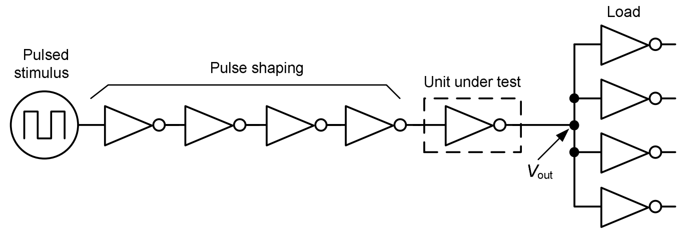

Figure 3. Test setup for measuring the current and delay of an inverter

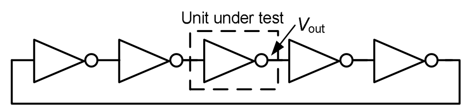

Figure 4. Five-stage ring oscillator for measuring the maximum operating frequency of an inverter

A screenshot of the tool's user-interface is shown in Figure 5.

IV. CMOS DIGITAL DESIGN – A COURSE AND REQUIRED TOOLS

Digital design courses are common components of the electronic and computer engineering curricula. The following is a list of topics in a sample course on CMOS digital design:

1) Basics of MOS transistor physics

2) Introduction to digital standard cell-based design

3) Design of common standard cells: INV, NAND, NOR and XOR gates; and flip-flops and memories

4) Design of arithmetic circuits: adders and multipliers

5) Cell simulation and characterization: noise margin, propagation delay and power dissipation

6) Introduction to HDL and synthesis

7) Introduction to placement, routing and assembly

8) Advanced topics: low-power techniques, near-threshold and sub-threshold operation, reliability, and effects of parameter variation

When feasible, commercial EDA tools (such as Cadence and Synopsys) are employed in a course similar to the one described above. The vendors offer these tools to the universities at a "nominal cost" of US $5-10K per year. However, complicated legal requirements and the need for skilled EDA support personnel are known challenges that accompany such tools. An additional issue is the inability of the students to run the tools on their own machines. So some institutions opt for more *portable* and free, open-source tools such as Alliance VLSI CAD System [18] and Electric VLSI Design System [19]. SpiceGen, the online netlist creation tool presented in this paper is anticipated to be a valuable addition to the other freely available EDA tools for tutelage, due to former's unique *push*-button capability of highly customized and automatic testbech generation. SpiceGen can be easily utilized for a course such as the one described in the beginning of this section. The tool can be used for hands-on work related to these topics in the course: (2)–(5), and (8). The users can use commerical or free Spice simulators (e.g., HSPICE, Ngspice, etc.) for circuit simulation.

V. SpiceGen Usage Examples

To exhibit the pragmatic applications of SpiceGen, we present two examples of how the students in a CMOS digital design course can use SpiceGen.

Example 1

The students are asked to study the measure the current (and the power) of a 22 nm inverter operating at 0.8V and 1 GHz frequency. The inverter sizing is W_{pMOS}/L_{pMOS} = 3/1 and W_{nMOS}/L_{nMOS} = 2/1. (Same sizing is also used for latter examples).

The students in this case choose the circuit configuration of Figure 3. SpiceGen automatically creates the complete Spice netlist as shown in Figure 6. The netlist as mentioned earlier includes the UUT, the stimuli, and the requisite measurement commands. By simulating the circuit netlist, one gets the input and output voltages, and the current for the inverter – the device-under-test (see Figure 7). The need for better fall- and rise-time balancing of the output is evident from the magnitudes of the positive and the negative current peaks. The average current is also included in the simulation log file.

Example 2

The students are assigned to study the effect of changing V_{DD} on power and energy consumption of a 22 nm inverter. V_{DD} ranges from well below V_{TH} to above-nominal voltage (0.8V), i.e., from 0.2V to 1V.

Nine different circuit variations (similar to the ones in Figure 3) are needed in this case. Simple settings in the SpiceGen user-interface let the users quickly create all needed netlists in an error-free fashion.

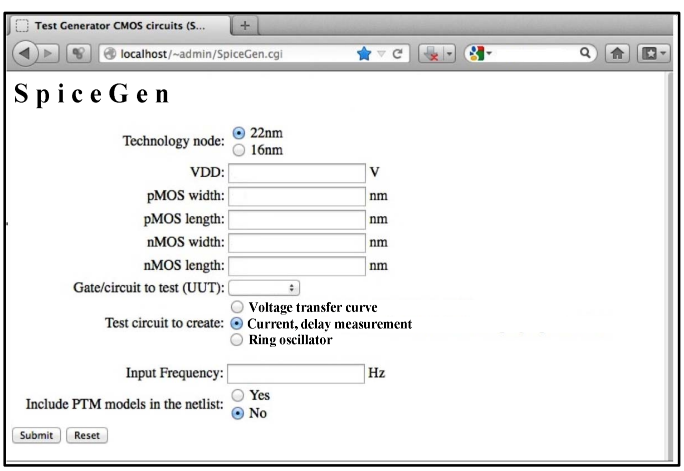

Figure 5. SpiceGen's user interface

```
* -- inv current, etc. --

.include 22nm_HP.pm

vdd    vdd    0 0.8V
vddUUT vddUUT 0 0.8V

.param
+ wpmos = 66nm
+ lpmos = 22nm
+ wnmos = 44nm
+ lnmos = 22nm

vin0 in0 0 pulse(0 0.8 0.5e-9 1e-13 1e-13 0.5e-9 1e-9)

xinv00 in0   in01   vdd 0 inv
xinv01 in01  in02   vdd 0 inv
xinv02 in02  in03   vdd 0 inv
xinv03 in03  ins0   vdd 0 inv
xuut0  ins0  out0   vddUUT 0 inv

xld00 out0 out00  vdd 0 inv
xld01 out0 out01  vdd 0 inv
xld02 out0 out02  vdd 0 inv
xld03 out0 out03  vdd 0 inv

.tran 2e-13 2e-9
.print tran v(in0) v(out0) i(vddUUT)

.measure tran ivdd AVG i(vddUUT) from=0 to=2e-9

.subckt inv (input output VDD VSS)
M1 output input VDD VDD pmos w=wpmos l=lpmos
M2 output input VSS VSS nmos w=wnmos l=lnmos
.ends inv
```

Figure 6. SpiceGen-generated netlist for measuring the current of an inverter

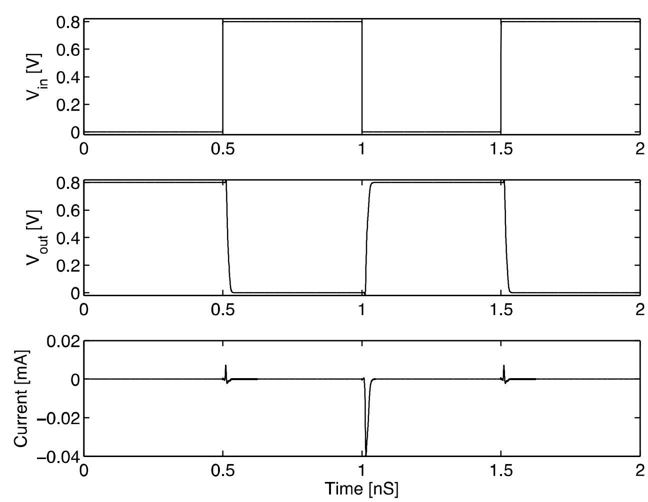

Figure 7. Simulation results of the netlist of Figure 6: inverter's input voltage, output voltage, and the current

After the circuits are simulated in batch-mode, the log files contain the currents and the delays of the respective circuits. A student can see that the inverter power consumption drops as V_{DD} is decreased (see Figure 8). She also observes that the gate delay has an inverse relationship to V_{DD}. Consequently, the *power-delay-product* (PDP) of the gate bottoms out at near-threshold voltage of 0.5V.

VI. SPICEGEN IN THE CLASSROOM

During the Spring 2013 semester, we deployed SpiceGen online and used it in an 18-student class. We allocated one lecture for introduction and hands-on practice. During this class, the students generated different circuits and simulated them with an open-source (Ngspice) simulator; this was followed by two home assignments. After the assignments were turned in, we conducted a survey about the tool, and found very favorable student responses, in terms of ease of use and the ability to conduct many experiments in a quick fashion. For further evaluation of and for any improvements in the tool, we intend to use it again in the Fall 2013 semester in two more courses; soon afterwards, we plan to publish a comprehensive report including a how-to-use guide and student responses.

VII. CONCLUSIONS

SpiceGen has promising applications in the teaching of different courses related to the design of CMOS circuits. We have seen encouraging response to the initial deployment of the tool for classroom use. In other institutions, dedicated courses on low-power circuits and on circuit reliability are also highly likely to benefit from the tool.

One way of expanding SpiceGen's capabilities is to integrate it with an online Spice simulation engine – an option we are presently considering.

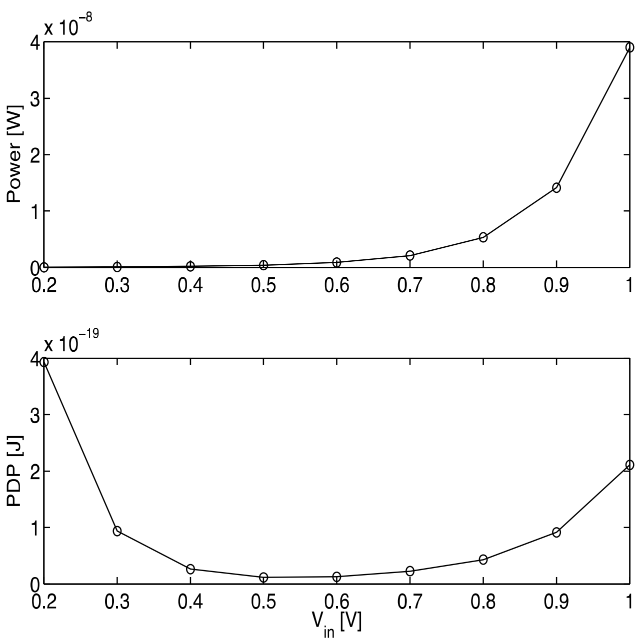

Figure 8. Power and PDP of an inverter as functions of supply voltage

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Issues of Recruitment and Retention for a New Engineering Provider

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***Abstract*— As a new provider of engineering, Victoria University of Wellington (VUW) faces a significant number of challenges in attracting and retaining quality students. As the primary funder of Universities, the New Zealand Government is providing conflicting funding directives, desiring an increase in student numbers, but penalizing poor course completion rates and banning funding on foundation or bridging courses. This paper details the development of a successful engineering programme, focusing on the modern "digital" aspects of engineering, in the face of these challenges.**

***Keywords*— engineering retention, pastoral care, student support, teaching and learning**

I. Introduction

New Zealand (NZ) lags behind many of its OECD partners in terms of the number of engineering graduates it produces [1]. This is reinforced by industry demands to the Institute of Professional Engineers NZ (IPENZ) to lobby for increased numbers of university engineering graduates since industry is being forced to recruit internationally for engineering capable employees. In response, the NZ Government in 2007 supported Victoria University of Wellington (VUW) to formalize the provision of a professional engineering degree. Initially this was a Bachelor of Engineering (BE), but soon afterwards this was extended to include both the Master of Engineering (ME) and the PhD. The decision was made to focus on, and extend upon, existing expertise in the areas of Electronics and Computer Systems (ECEN), Networking (NWEN), and Software (SWEN). This provision of an exclusive set of "digital" engineering specialisations was unique in New Zealand as existing tertiary engineering education providers offered only subsets of these specialisations. As background, approximately 50% of the University's funding comes from central Government grants and so changes in government policy can have a profound effect on university enrolment numbers, and type. Students are charged tuition fees, set by the central Government at approximately US$5000 per year per student and this comprises about 20% of the University's income.

This paper outlines the challenges faced in establishing a new engineering degree and how we overcame them, especially in the face of a major shift in Government funding to the universities and strong (and sometimes hostile) competition from existing established providers. Compounding issues include the effects of a radical change in student assessment at High (secondary) School which has dramatically altered the mechanisms of student learning and made it difficult to assess student ability for determining entry into our Engineering programme.

This paper will be divided into two parts. The first is the issue of recruitment – how to get a new programme known to the target students, their influencers and other stakeholders. We discuss how knowledge of our brand of engineering was established and differentiated in the minds of students from other engineering providers even though these topics are not presented at High School. This work is informed by marketing surveys, interviews with teachers and careers advisors, and an examination of the efficacy of various marketing tools. Following static results from traditional marketing approaches, an innovative "Geek" orientated marketing programme, combined with intensive High School outreach activities that targeted both students and teachers was implemented.

The second part of this paper details the retention issues that we have faced. Specific challenges begin with the University's policy of open entry into our engineering degree. In order to ensure the quality of our graduating cohort, students are required to achieve at the above-average level of B (65%) over their first year courses in order to progress in the BE programme. These first year courses include 2 computer science courses and a core first year engineering course for all engineering students, and selective mathematics and physics courses depending upon the specialization – ECEN students require calculus, algebra and core physics, NWEN and SWEN students require discrete mathematics, statistics and introductory level physics.

Given the variability in student ability, and the Government's decision to NOT fund any foundation courses at Universities, we currently suffer a first year student attrition rate of 60%, which can no longer be tolerated given the Government's current funding penalty schemes.

II. Recruitment

A significant barrier to the recruitment of students into University Engineering programmes is the absence of a specific engineering topic in High Schools. Target students in their final year of High School will typically take courses in physics, mathematics with calculus, mathematics with

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statistics, chemistry, and potentially biology. Typically they would have some engagement with these courses over at least three years of High School, and hence they become very familiar with the concept of Science. Some "technology" courses are presented, but these encompass everything from electronics, through to fabric technology. Engineering is not explicitly covered and students entering university often only have a vague and incorrect idea that engineering study entails building skyscrapers or bridges.

Our recruitment initiatives then, had the dual challenge of firstly informing students about what "digital" engineering entails (i.e. that there was more to engineering than the mechanical, civil, structural specializations) and secondly that VUW should be their institution of choice rather than one of our established competitors. It is fair to state that we learnt from our mistakes.

In our first year (2007) we went with traditional forms of advertising; newspapers, adshel posters, and hiring out a movie theater for a sponsored recruitment evening. This was complemented by outreach activities where students in groups of 20 were taught to populate, solder and code a microcontroller board. This hands-on exercise really helped to reinforce our message of "digital" engineering rather than bridge or skyscraper engineering.

We exceeded our business plan enrolment expectations in this first year, but faced a static enrolment figure in the following 2 years. In 2009 we decided to trial in-game advertising under the assumption that this would directly target our intended market. Under this arrangement, VUW Engineering advertising was embedded in "Massive" on-line games of our choice. The advert featured the VUW logo, and the caption "Don't just play it. Create it". We were charged by the number of 10 second cumulative views of the advertisement. Enrolments did not significantly increase in 2010 and we undertook the first of our annual student surveys to determine why. The response rate was 88 out of a total of 105 students for that year, and only 1% indicated that the in-game advertising was a contributor to their decision to enroll in Engineering at VUW [2]. Surveys have been conducted every year since to determine our marketing effectiveness. Students are asked to select each category that was a contributor to them finding out information on VUW's engineering program. There is surprisingly little variation year to year. Table I below presents the results from the 2012 student survey. There were 142 responses, 128 male, 14 female.

Newspaper advertising does not appear to be a direct influencer, with scores between 2 and 4% every year. However, the students are not the target of these advertisements; they are intended to influence and inform the parents. We do not yet have any mechanism to gauge the effectiveness of our marketing campaign to students' parents, and we are reluctant to completely abandon this traditional marketing technique since parental influence consistently ranks as one of the top contributors.

The TV advertising was undertaken by VUW central on a limited budget and did not have significant prime-time airing. It was a 30 second advertisement featuring a student and the presenting author of this paper promoting the robotics and rehabilitation work undertaken at VUW. It appears to have some limited impact, with scores ranging between 6 and 10%. Since such advertising is conducted by VUW central, and does not form part of our budget, we are happy to continue supporting such initiatives.

TABLE I. SUMMARY OF 2012 STUDENT RESPONSES {ALL: MALE: FEMALE} TO ADVISING ON HOW THEY FOUND OUT ABOUT VUW'S ENGINEERING DEGREE

Activity Description	Percentage of all students selecting option	Percentage of male students selecting option	Percentage of female students selecting option
Friends	69	58	79
Attending VUW Open Day	52	54	50
School careers advisors	47	39	50
VUW Website	32	30	50
School Visits by VUW Eng. Staff	22	22	14
Parents	21	19	36
High School teachers	19	31	21
Engineering Facebook Page	12	13	7
Publicity Posters	9	9	7
Television Advertising	9	9	7
Attending Eng. Outreach Activity	7	7	7
Geek Engineering website	4	4	7
Newspaper Advertisements	4	2	7
Programming for Girls Challenge	0	N/A	0
Other (TechHui, Google, Robotics comps, local uni)	14	14	21

Given the total failure of the In-Game advertising, a more effective marketing campaign needed to be implemented. We undertook two new initiatives. The first began with a thorough demographic study comprising our existing year one and year two engineering students and final year High School students. We were rather surprised to find a strong association with the label "Geek". When the authors of this paper attended High School, being called a Geek was a derogatory term, but now it seems to be almost a badge of distinction, embraced by both males and females.

Consequently, we undertook the design of both print and on-line material centered on this Geek theme. The print material took the form of a tongue-in-cheek, 24 page A5 size booklet that embraced and exaggerated the Geek concept. The front and rear covers of this booklet are illustrated in Figure 1. Internally the book contains information on digital engineering, the degree programmes offered, student and project profiles and career information, but all written in a student-friendly style – with NO corporate branding. This booklet was extremely successful, well over twice as many copies being distributed compared to the standard university information booklets (4500 have been distributed so far with another run of 3000 underway).

The intent of the website www.engineering.geek.co.nz was to again provide a student-focused repository of information on Engineering degrees and careers, hold information that would be useful for a High School teacher, feature cool projects and information, and generally be an evolving resource.

The effectiveness of the on-line website is somewhat questionable, rating a mere 4% in student responses. A significant challenge is the substantial resourcing required to keep this website up-to-date, fresh and relevant. However, our anecdotal evidence is that the hard copy booklet has been exceptionally popular with the High School teachers, careers advisors, and students themselves. For the 2013 survey we will ask a specific question regarding the impact of this booklet.

Fig. 1. Front and rear cover of our Geek Engineering recruitment publication.

As mentioned, the survey results consistently indicate the importance of High School teachers and careers advisors in influencing students' study decisions. To profile VUW's digital engineering in the science, mathematics and technology laboratories, seven informational posters and an additional flashy, non-informative poster for the careers advisors (Fig 2b) were developed. The informational posters covered:

- Ohm's law: series and parallel resistive circuits (Fig.2a)
- The battle between Tesla and Edison: DC vs. AC
- Conductors and superconductors
- Resistors, capacitors, diodes, transistors
- How Facebook works
- How the Internet works
- Digital data storage: (esp. music and images)

Fig. 2. (a) Information poster of Ohm's Law as an example of High School science laboratory poster (b) Careers Advisor office recruitment poster

These posters are designed to begin the association of Victoria University with Engineering in the minds of our prospective students, and hence inform them that there was an alternative to the well-known existing providers. They also serve to instruct High School teachers as to the nature of "digital engineering" and the specialisations VUW offers. This is vital since the lack of knowledge of digital engineering amongst the students' influencers meant that students were remaining ignorant of the opportunities and careers available to them in these areas. The High School teachers and careers advisors were also invited up to the University for the launch of our new marketing, with all attendees being given a copy of all the posters for their laboratories, our outreach Arduino microcontroller kit with suggested experiments to run in their laboratories and an invitation to keep in regular contact with us.

The overall results of our revamped recruitment initiatives were a very significant 36% increase in enrolments in 2012 compared to 2011. This increase was maintained for 2013 with a significant increase in computer science enrolments. We are noting a new trend in enrolments – students applying for multiple institutions. Our initial engineering applications increased by nearly 40% compared to 2012, however many of these students did not complete the enrolment process. We are in the process of endeavoring to contact these students to determine the reason for them not progressing to full VUW enrolment, but we strongly suspect that they accepted an offer from another institution. This trend has initiated a change to our recruitment process – historically we made no effort to market during the summer period when we expected all applications to be in. We will now personally contact each applicant and guide them through the enrolment process so that we do not lose them to other institutions.

As the primary changes since 2011 were the Geek initiatives and the posters, it is reasonable to attribute the bulk of this increase to these initiatives. Whilst we are thrilled with this result, further work is necessary to both improve the quality of students entering our programme (a slight decrease in quality was noted for 2013 enrolments) and to provide a better balance of equity; indigenous students and female students are very poorly represented.

In an effort to attract female students, VUW runs a programming camp for girls, mainly those mid-way through High School. This is a medium term recruitment effort – it will take 3 years before these students are eligible to enter VUW engineering; however an immediate goal is to ensure they continue with the engineering enabling subjects of mathematics and physics in their senior years at High School.

In future, we are hopeful of establishing a special relationship with six targeted High Schools in our immediate catchment region. We would like to run some lessons for these students, provide them with laboratory kit and training, and potentially have top students enroll in a VUW first year engineering course in parallel with the completion of their last year at High School. Perhaps being credited with a University course will make these students more likely to consider VUW as their preferred Tertiary Engineering education provider rather than one of our competitors.

At the time of compiling this paper, one of our student honors projects (4th year BE), MechBass went viral, (http://www.youtube.com/watch?v=5UYMnzXQEtw) with over 500,000 views. Successes such as this will certainly be the focus of 2013 recruitment activities.

III. Retention Background

Recall that in order to progress in our Engineering programme, students must attain an above average, B grade (65%) or above over the required first year courses. Progression figures are indicated in Table II. In this table, the first column indicates the student's first year of enrolment. Subsequent columns indicate the percentage of students who gain the B or above grade average over all the required subjects in that year. For example, of the students who first enrolled at the University in 2007, 22% of them passed this requirement in 2007, 10% in 2008 and 1% in 2009. The final column indicates the total percentage of students who successfully achieve this requirement. As Table II indicates, throughout our 6 years of offering the BE degree, we have faced an attrition rate of approximately 60%. Initially this was only of a moderate concern, after all we are offering a professional degree with essentially open entry, a high attrition was to be expected.

However, the NZ Government then introduced a set of conflicting directives [3]. First, all Universities are directed to enroll a fixed number of students for the following academic year. If the University cannot enroll at least 97% of this figure then it can be financially penalized. Similarly, if the University enrolls more than 103% of this number then it can also be fined. VUW responded to this by endeavoring to manage entry on the basis of High School grades, with students lower than some threshold placed on a wait list. This threshold was too high, and in order to meet the minimum 97% level, many waitlisted students were admitted. Engineering was unhappy with this since our analysis of their High School grades [13] strongly suggested that these students were unlikely to succeed in our Engineering program. Worse, this minimum attainment figure is being raised to 99% for 2013.

TABLE II. Percentage of students progressing past Part I (B average or above in required first year courses)

Entry	2007	2008	2009	2010	2011	2012	Total(%)
2007	22	10	1				34
2008		23	18	1	1		43
2009			28	9	5		42
2010				30	13	2	45
2011					22	21	43
2012						33	

The next directive from the Government was that a percentage of the Universities' funding would be "success based" with indicators of success being [3]:

- Successful course completion,
- Student retention,
- Qualification completion,
- Student progression.

Student retention measures an institution's success in retaining their students through to the completion of their qualifications. This is calculated by considering the fraction of students that either continue with their studies or graduate.

The qualification completion is calculated as being the number of qualifications (Diplomas, Bachelor/Master/PhD degrees) completed at an institution in a year multiplied by the number of courses that is required of that qualification, and divided by the total number of courses provided. This calculation does not differentiate between students who repeat courses because they have previously failed it and high performing students who take more than the minimum number of courses for their qualification.

Student progression is measured by the fraction of students who enroll in a higher qualification within 12 months in New Zealand after graduating. This does not count students who wish to take a gap year or enroll in an institution outside of New Zealand. The dollar figure of the penalties on these three criteria is still being determined, and hence the University has not produced a strategy and resources to mitigate any penalties that may be imposed.

However, successful course completion is penalized on course by course basis. In 2012 the ruling was that if any course did not pass at least 55% of students enrolled, then that course would receive no Government funding. This pass rate figure increases to 60% for 2013 and rumors are it will increase to 62% in 2014. This has devastating implications on our Department's budget, especially when large first year subjects are at risk.

An obvious solution is the introduction of a foundation or bridging level course to help prepare the students for the rigors of Tertiary Engineering study, particularly in the mathematics and physics. For reasons we still struggle to understand, such foundation level courses are explicitly excluded by the Government, they refuse to fund these at universities.

So we are under pressure from the University to expand our enrolment numbers, especially to help them attain their minimum 99% enrolment goal. However if we enroll weak students, then not only do we consider that unethical, we risk financial penalties unless we introduce grade inflation which we are not prepared to consider. This is a significant challenge for a programme that must expand (at least by 50%) in order to ensure its continued existence.

IV. Retention Solutions

Literature in the field of engineering education identifies many issues relating to students retention and success, for example Veenstra, Dey and Herrin [4] note nine specific factors affecting students in their retention model; High School Academic Achievement, Quantitative Skills, Study Habits, Commitment to Career and Educational Goals, Confidence in Quantitative Skills, Commitment to Enrolled College, Financial Needs, Family Support and Social Engagement. As this extensive list indicates that no single retention factor exists, rather there are a multitude of factors which contribute to student success and failure. A search through engineering education literature illustrates that the problem of engineering student success has not gone away in the last twenty years despite extensive research into the field. There are no miracle solutions that can be easily applied to the varying contexts of tertiary engineering institutions, however, many helpful ideas that can be trialed and adapted in the search for improvement.

New Zealand research into many of these areas [5-9] has informed our initiatives discussed below, which have focused on a programme of information gathering and intervention for our local context, Also, in line with international research by Tinto [10,11] that recommends putting student welfare ahead of purely institutional goals and that institutions commit to developing a supportive social an educational community, and New Zealand research by Zepke et al. [12] that also recommends monitoring student performance and establishing an early warning system, we proceeded with the trial introduction of a pastoral care agent located within the engineering programme. Discussion on this position is detailed later in this section.

Since 2011 we have engaged in a series of student surveys at the beginning and conclusion of the academic year. We also conducted student focus groups run by external experts from the Centre for Science and Technology Educational Research at Waikato University, and High School grade analyses. We found a number of factors that contributed to the attrition rate.

- Poor mathematics preparation
- Poor physics preparation
- A self-belief that they are academically prepared for university study
- Difficulty transitioning to university study, especially breaking poor study habits developed in High School
- Fear of accessing help and support services
- An unwillingness to engage in mathematics and physics courses, deeming these irrelevant to engineering study
- A frustration that first year university was less about immediate engineering and more about setting a mathematics and physics foundation

Again in 2011, we endeavored to overcome the poor mathematics and physics preparedness by forming a success predictor based on a combination of High School grades and an in-house developed mathematics diagnostic test [13]. Subsequent analyses and experience has led us to trust this success predictor. In 2011 we used this predictor to identify students who were at risk of failing (not achieving a B average). An individualized email was sent to these students, outlining our specific concerns and suggesting the most appropriate form of assistance for them to access. This initiative was spectacularly unsuccessful. Only 2 students out of the 60 notified actually accessed any help.

The surveys and focus groups identified reluctance, and in some cases an actual fear of accessing help, a finding that surprised us. It also identified that many students fully believed they were adequately academically prepared for engineering study. One cause of this is a radical change to assessment in New Zealand High Schools. Most students now participate in a National Certificate of Educational Achievement (NCEA). Problems with this form of assessment and are discussed in brief below with a more detailed discussion residing in [13].

A student will typically take five subjects in their final year of High School and undertake level 3 NCEA assessment. NCEA divides each subject into a number of modules. For example, Chemistry at level 3 is presented as modules in titration, redox, organic, aqueous systems etc. There are 6 chemistry modules in total, some being internally assessed, others by an end of year examination. Other typical subjects for a potential engineering student include Physics (5 modules), Mathematics with Calculus (7 modules), and Mathematics with Statistics (5 modules).

Grades are awarded for each module, not for the entire subject. An artefact of this NCEA module scheme is that students can mix and match modules according to their levels of interest. So for example, in theory it is possible for a student to “pass” level 3 Mathematics with Calculus without attempting the differentiation module. High Schools have also been known to regularly manipulate averagely performing students away from the perceived difficult subjects of Physics and Mathematics with Calculus in order to preserve or enhance their league-table standing.

A significant problem with NCEA is that only four grades can be awarded: {Not Achieved; Achieved; Merit; Excellence}. Although it is difficult to quantify, it appears that the “Achieved” grade actually spans an ability range of 40 – 70% (where historically 50% was the threshold for a passing grade). Consequently, students can enter university with a large number of Achieved grades from High School and yet be unable to cope with even introductory University courses, especially in mathematics. We find that many students aren’t motivated to attain the Merit and Excellence grades, and the absence of an actual percentage mark has resulted in many students “cruising”, doing just enough to attain an Achieved grade. An added barrier to students developing study habits that will assist them at university is that NCEA permits the re-taking of failed assessment items. It takes our students several years at university to comprehend that they will only be given one attempt at any University course assessment.

A consequence is that students do believe they are more able than they actually are. To quantify this, students were asked to rate how well prepared they felt they were for university study on a scale of 1 to 10 where ‘1’ indicated ‘not at all prepared’. On average, they rated their preparedness at 5.9 (± 2.2). The modal response (illustrated in Figure 3) is clearly ‘reasonably well prepared’, but the deviation is broad. Past analyses [14] reveal similar results indicating no significant change in High School mathematics curricula or delivery over the past 3 years. This survey was conducted in the first two weeks of first year university study, and interestingly conflicts with evidence obtained during interviews conducted by our pastoral care staff member (discussed later).

We were able to appoint a pastoral care agent in 2012 who was tasked with working with the marginal students to increase retention between first and second year engineering. Working with the NCEA High School data and the diagnostic scores, an early risk identification was made. To assist with identifying risk, programmers within our Department designed the "Big Sister" grade system that collated all assessment grades in near real-time over all first year subjects and graphically flagged a problem when a student began failing assessment. Big Sister can also identify when an assessment item for a specific course has been too difficult – it will again graphically indicate the number of students who struggled with, or failed, that assessment item. If that number is large, the problem is more likely to be in the assessment item itself than any individual student shortcoming.

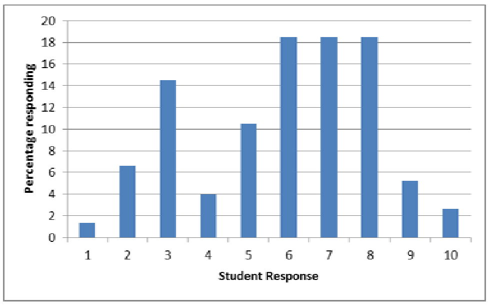

Fig. 3. 2012 Student response to academic preparedness, '1' = not at all prepared for university study, '10' = extremely well prepared.

Our Pastoral support person now personally engages with the identified student, invites them to a 50 minute, open ended interview where field interview notes are taken. The interview process is designed to identify the specific barriers to that student's success. These barriers turned out to be academic (as previously discussed), transitional (issues in transitioning from High School to University), personal, financial, or expectational. Indeed, a significant finding from these interviews was that we were not meeting many students' expectation of engineering study.

Of the 80 identified students interviewed in 2012, practically ALL of them stated that NCEA had not prepared them for the rigors of engineering study at university. This is in stark contrast to the earlier survey results (Figure 3). One of our challenges is to help students gain this realization earlier when there is still a chance to alter their study habits in order to pass the first trimester courses.

We are informed by our Pastoral Agent that the current generation of students is far more removed from our generation than we were from our lecturers 20 odd years ago. The current student expects immediate gratification, they are not prepared to blindly accept our assurance that physics and mathematics will be essential for future engineering work. They want to create and build immediately.

These findings motivated a complete revamp of our introductory engineering course (ENGR101). These changes were sweeping in nature. Historically the first lectures in this course were a soft introduction to engineering. High profile researchers did guest lectures showing the students what projects would be available to them in later years. This was intended to motivate the students, give them a goal to strive for. Now, substantial academic material is presented, and tested after one week. This serves as a shock for the students – an emphatic realization that university is considerably harder than High School and that they cannot just relax back and believe they can catch up later.

The text book was custom constructed so that it now contains information on study habits, learning skills, handling university life, as well as the core engineering content. The laboratory sessions have become more student guided rather than following a "set recipe" and are capped by the construction of an autonomous robotic vehicle to at least partially satisfy the requirement for instant results.

These changes, combined with the pastoral intervention have increased the B and above pass rates in ENGR101 from 52% to 63% (2012 compared to 2011). Student surveys indicate the students engage with this course far more than in previous years, better understand how engineering is differentiated from science, and indicate an increased satisfaction that their expectations of engineering study are being met. Following on from this success, an additional, second trimester engineering first year course is under planning, with expected delivery in 2014.

The results of the survey question asking students after their first trimester of 2012 whether engineering study at VUW was meeting their expectations are provided in Table III. The figure in parentheses indicates the responses provided in 2010. There has been a significant increase in the number of students for whom we are meeting all their expectations (20% in 2012 compared to 6.8% in 2010). There is no statistically significant variation between the 2012 male and female responses (the 2010 survey did not differentiate between genders). Informal student feedback has changed – in 2010 we were frequently hearing student dissatisfaction with the programme and students were withdrawing from BE study. This seldom occurs now except for very weak students who cannot handle the mathematics requirements of the engineering degree.

When asked qualitatively, which courses they found most difficult, nearly every ECEN student who had to take the core first year physics course rated this as being the most difficult. Further enquiries revealed that a significant contributor to this difficulty was poor underlying mathematics. Neither the physics nor the mathematics courses are run by our Department and changes are difficult to effect since these courses form the core for mathematics majors and physics majors respectively. Engineering students, whilst comprising a sizeable portion of first mathematic enrolments, are not in the majority and the University is not prepared to let us run our own courses in these subjects. However, we are engaging with the Department of Mathematics for them to provide an offering with an engineering emphasis – where real world examples are provided, proofs and theorems are de-emphasized and effort is made to cover the essential mathematics tools that engineers will require. We are also advocating that Engineering staff deliver at least a part of these courses. The reality is that first year mathematics will have to be substantially overhauled to accommodate our requests and we are hoping to have many of these changes in place in time for the 2014 academic year.

An obvious solution that we have not yet discussed to this high attrition rate is to restrict entry into the programme. However, this is where the Government's mixed funding messages intervene. New Zealand universities receive most of their funding from the Government. The bulk of this funding is based on the total number of students enrolled at the institution and any reduction in numbers results in reduced funding and potential financial penalties as discussed previously.

TABLE III. 2012 (2010) FIRST YEAR STUDENT RESPONSES WHEN ASKED IF VUW WAS MEETING THEIR EXPECTATIONS OF ENGINEERING STUDY

	% responses all students 2012 (2010)	% male responses	% female responses
All Expectations Met	20 (6.8)	20	21
Most Expectations Met	66 (78.4)	66	64
Some Expectations Met	14 (14.8)	13	14
No Expectations Met	1 (0)	1	0

V. CONCLUSIONS

In 2007 VUW established its Bachelor of Engineering degree and immediately faced the issues of strong competition from existing providers and general ignorance by students, parents, teachers and careers advisors as to what our "digital" offering of engineering entails. Following moderate marketing success from traditional modes of advertising, an innovative Geek oriented campaign was launched complemented by a dedicated campaign to involve High School teachers and careers advisors with our programme. These initiatives combined to provide a 36% increase in enrolments from 2011 to 2012. Future initiatives such as the Programming for Girls camp, and exploiting the viral MechBass bode well for increasing success in recruitment.

The attrition rate between year one of the degree where students must attain a B grade average or higher and year two is approximately 60%. Whilst such attrition rates are not atypical for professional degrees, they are no longer tolerable at VUW given the Government's position of imposing financial penalties for the University should it not attain 99% of its target number of students, and further penalties if any individual course does not pass at least 60% of its enrolled students. We are not in a position to impose restrictive entry requirements to the degree, and cannot create foundation level courses.

Given these constraints, we have created the Big Sister student assessment tracking system, developed a predictor based on NCEA level 3 grades and a bespoke diagnostic test and employed a pastoral care agent to use these tools to provide an early indication of student difficulty. Our pastoral agent identifies at risk students, actively intervenes, determines through interviews the source of the difficulty and then directs (hand-holding or coercive as appropriate) that student to the appropriate form of assistance.

Our first year core engineering course was substantially altered in response to our increased understanding of student expectations, and a "shock" test (or "epiphany" test as our first year course coordinator more delicately calls it) is delivered to jolt students out of poor study habits developed during High School NCEA assessment. A noted decrease in the quality of our 2013 intake has increased the number of students identified by our diagnostic test as requiring additional assistance. Mathematics continues to be a very significant issue and we are fully engaging with the Mathematics Department with the hope of them offering substantially altered first year courses in 2014. Also in 2014 we are hoping to have a follow-on course from the now very successful ENGR101.

First trimester results indicate an increase from 52% to 63% in the number of students achieving a B grade or above in ENGR101. Overall retention figures show the largest percentage of students attaining the B average in their first year of study (33%) and a significant increase in the number of 2011 students who have now attained that average (a further 21% gained the required grade in their second year). This certainly indicates some success with our first year initiatives – with further increases expected next as our discussions on a revamp of first year mathematics reach fruition.

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Integration of Funded Faculty Research, Capstone Experiences and Industry Requirements

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Abstract — **This paper presents a senior design strategy integrating funded faculty research and industry requirements. Students participating in this type of senior design are directly involved with all the aspects of a complete system development cycle focusing on user needs and requirements. All the aspects of the project represents higher quality and larger scale than typical senior design projects, and in this way better resemble industry projects. The case study presented herein is a practical industrial project sponsored by a faculty member the construction of a research quality electric machine dynamometer and test-bed.**

Keywords—capstone; industry requirements; ABET; faculty research; test-bed.

I. Introduction

Capstone or senior design projects are challenging and important components in Engineering and Engineering Technology undergraduate education and usually teach students valuable skills in design, prototype construction, testing, teamwork, and project management related skills [1], [2], [3], [4], [5]. However, a high percentage of the capstone projects deliverables do not result in an operable system that follows industry standards and guidelines, or cover a complete product or system development lifecycle with focus on sponsor and user needs [4]. A complete engineering project lifecycle includes planning and analysis, build and test, implementation and maintenance phases, among others. Usually, capstone engineering and technology projects are product-oriented, focusing only on the build and test phases of development [4]. This approach serves as an additional element in the gap between engineering curriculum and what skill sets employers expect new engineering graduates to have. As pointed out in [6], employers have indicated that new engineering graduates have technical competences but several lack professional skills necessary to manage a real engineering project lifecycle, work with others collaboratively, write and present proposals, among others. In [2]-[3], based on a comprehensive national study, the authors list the 22 primary topics covered in engineering and technology capstone projects. The topics range from written/oral communication to CAD design and layout, but it doesn't include any topic related to user needs or user testing. As a consequence, the focus is on the product end of the system development lifecycle neglecting the user-centered analysis, design, test, and implementation phases of the development lifecycle [4].

In this paper, the authors discuss a hands-on senior project consisting of collaboration among faculty, undergraduate and graduate students of the Electrical Engineering Technology (EET) program in the School of Technology and the Electrical and Computer Engineering (ECE) department in the College of Engineering at Michigan Technological University. The project gives the students the opportunity to be directly involved with all the aspects of a complete system development cycle focusing on user needs and requirements. In the EET program at the Michigan Technological University, students are required to complete a two-semester senior design project, which are typically industry-sponsored allowing students to work on real-world projects. More recently, however, some of the capstone projects were sponsored by faculty members instead of industry partners. This initiative serves to support some funded faculty research projects, and allows undergraduate students participating in the project to interact with graduate students, faculty members of the college of engineering and school of technology, and customers. Design, construction, system integration, software, and testing all involved other researchers instead of just the capstone team, which in turn, created new project management challenges such as team work, communication, documentation, scheduling, among others; resembling a larger scale project in industry.

The case study presented here is a practical industrial project sponsored by a faculty member the construction of a research quality electric machine dynamometer and test-bed. The project followed practical industry project standards and all the aspects of the project presents higher quality and larger scale than typical senior design projects, and in this way better resemble projects in industry. The test-bed will be used for externally funded research projects in several areas such as electric drives systems, electric propulsion systems, power electronics, and ac microgrids, among others. The test-bed was designed and built with the forethought to enable a wide variety of electric machine configurations and applications, as it provides a platform for testing of innumerous projects. In addition, the test-bed will be used for undergraduate and graduate education.

This project allows students participation in the research of possible solutions and the selection of the one that best meets the sponsor criteria and user needs, then they design, construct, and present a finished product. In addition to the application

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of knowledge learned in previous courses, students develop technical and soft skills such as: how to research and comply with current Occupational Safety and Health Administration (OSHA) standards for test-beds, learn how to use AutoCAD for test-bed layout and electrical schematics, practice industrial type circuit construction, components selection and acquisition, learn and use industrial communication protocols as well as team and time management. The students also further develop critical thinking and accountability.

The assessment methodologies for this senior design course uses indirect and direct measurements to assess the applicable ABET a-k criteria [7]. The assessment results indicate improvements in the student comprehension of key concepts, and increased students' confidence to start their careers in the industry.

II. RESEARCH PROJECT BACKGROUND

The goal of the capstone project that we present here as a case study was to design and construct a dynamometer test-bed with the capability to test electric machines of moderate sizes. Dynamometer systems are used for testing and verification procedures in several applications including automotive, industrial, and manufacturing. Dynamometers have the capability to simulate a wide range of loads a system may experience, precise controllability, and unit testing prior to the unit under test reaching the customer. Additional motivation for having a dynamometer test-bed comes from the increasing penetration of electric propulsion in modern automobile [8] and Michigan Technological University growth in hybrid vehicle education and research [9], [10]. Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV) both use electric machines for either full or partial traction of the vehicle. A dynamometer test-bed was developed with the purpose of research into various electric propulsion drives systems, including the flexibility to accommodate various types of machines. Such a test-bed would be a great asset to have in our power electronics research lab. In addition to the EV or HEV applications, a dynamometer test-bed could also be used to model a load in a small ac Microgrid. This load could mimic the load cycle of hydraulic pump systems or a heating, ventilation, and air condition (HVAC) system of a small building.

A. Design Requirements

The faculty sponsoring this project had specific industry type requirements that had to be followed by the team, including:

1. Testcell safety system following OSHA standards – also, devices must have adequate guarding to protect users from injury, use of cable tray to protect cables, safety relays;
2. Efficient use of space – cell must be as compact as possible to fit in the available room;
3. Wired communication with laptop for configuration;
4. Variable frequency drive (VFD) must communicate via Modbus RTU receiving its commands from the testcell PC;
5. VFD step-up transformer, since VFD operates at a higher input and output voltage than the testcell infrastructure voltage supply.
6. High accuracy torque/speed monitoring;
7. Testcell infrastructure controls must be PLC-based and independent of the VFD and inverter controls;
8. PC-based controls: user interface controller station with National Instruments LabVIEW GUI, dSPACE embedded controllers, Allen-Bradley Micrologix communication adaptor, and operator pushbuttons station;
9. Inverter with opto-isolated (fiber-optic) gate drive and fault signal output for electrical isolation and noise immunity;
10. Signal isolation to isolate any control signal input signal to the one that will be connected into the dSPACE embedded controller;
11. Electro-magnetic interference (EMI) isolation;
12. Easy operation;
13. User manual.

III. TESTCELL DESIGN AND CONSTRUCTION

The electric machine test-bed is a collection of various commercially available and custom made components. It is designed to enable a wide variety of electric machine configurations and applications, as it provides a platform for testing of innumerous projects. The current configuration of the test-bed features two identical 20 HP ABB induction machines in a back-to-back testing configuration. The "dynamometer" is controlled via an ABB (full 4-quadrant) variable frequency drive. The "prime mover" machine is driven from a custom IGBT inverter controlled via a dSPACE embedded controller. Both shaft torque and speed can be measured via a compact digital torque meter. The power wiring of the test-bed is controlled by a Motor Controller and Safety System Enclosure (MCSSE). The MCSSE includes a standalone programmable logic controller (PLC) system controlling the power flow throughout the system. The test-bed machine mounting tables, shown in Fig. 2, were built in modular fashion to accommodate various electrical machine types and sizes.

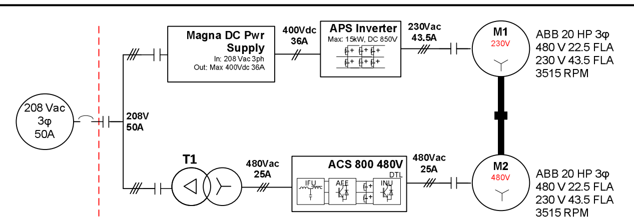

Fig. 1. One Line Test-bed Circuit

Fig. 2. Testcell – start of the project

Table I. Project Major Tasks

Phase	Task
I:	Cell Architecture Design
	Testcell Safety Research
	MCSSE Design
	MCSSE Parts Selection and Procurement
	MCSSE Construction
	Isolation Transformer
	Cabling and Connectors
	Embedded Controller/PC Station
II:	Initial Micrologix Program
	Expanded Micrologix Program w/ added
	Testcell Power/Control Wiring
	ABB VFD Drive Configuration
	ABB VFD LabVIEW Program
	Motor Coupling/Torque Sensor Specifications
	Testcell User Manual
III:	Signal Isolation and Interface Board
	Signal Gain Tuning
	Electric Machine Parameter Estimation
	System Performance Characterization

The capstone projects in the Electrical Engineering Technology (EET) Program at the Michigan Technological University are comprised of two academic semesters. However, this particular project, since also involved a graduate student, was completed in three phases: Phase I, during the fall semester of 2011, Phase II, during the spring of 2012, and Phase III, during the summer of 2012. In Table I we highlight the project major tasks in each phase. The graduate student participated on the team both as a technical advisor and as a project engineer. With this dual role he contributed both to the completion on the EET senior design project and a successful commissioning of the testcell system. The fact that not all students were involved in the last phase of the project didn't impose any problem for the overall students' experiences. Phases I and II consisted of all the construction, system integration, and documentation for the test cell. Phase III was for additional parameter estimation and performance characterization. All the students participated in Phases I and II.

At the start of the project at the beginning of fall semester in September of 2011, some previous work was already done to: acquire donations for the electrical machines and VFD, testcell electrical machine table was designed and constructed, mounting hardware attached to the wall, various components for use in the testcell purchased. The various components are comprised of DC power supply, several inverters, and electrical power meter with accessories.

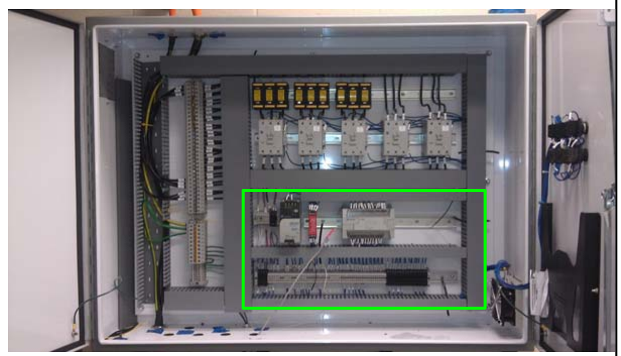

Fig. 3. Testcell infrastructure: subpanel

During Phase I of the project, the team researched and designed an architecture approach, ordered, and constructed the Motor Controller and Safety System Enclosure (MCSSE). The first task completed was the design of the test power architecture shown in Fig. 1. The testcell at the start of the project is shown in Fig. 2, and the infrastructure enclosure MCSSE and subpanel is shown in Fig. 3. The completion of these tasks included knowledge of the operation of the individual components and specific placement of the contactors to control electrical energy flow. The team researched and selected the components to be used in the MCSSE, which included the Allen-Bradley Micrologix controller, contactors, fuses/fuseholders, safety relay, terminal blocks, enclosure fan, DIN rail mounts, DC power supply, and wire way. The team also was responsible for the enclosure layout scheme and placement of the components on the back panel. The wiring schematic used to construct the MCSSE and testcell cabling was developed and guided the team with good practices in assembling the sub-plate and enclosure. Along with the enclosure and subpanel, the team ordered the materials necessary for the complete testcell power cable routing. Several other components were also researched and ordered, including the isolation transformer, operation station computer, dSPACE embedded controller, PLC, safety relays, and high voltage shielded power cables and connectors.

During Phase II of the project (spring 2012), the team continued to research and order several components needed to complete the testcell. This would include the motor flexible coupling, torque sensor, motor coupling guard, embedded controller, and control signal isolation modules. The conduit used for the ESPB enclosures/operations was bent, and the wiring of the high voltage and communication cables was completed. The team also installed the analog control signal wiring between the work bench and controller station. Also during phase II the team programmed the initial Micrologix program that allowed running the testcell system. The graduate student worked very closely with the EET team member who was responsible for the VFD communication LabVIEW program. They specifically set up the drive with the appropriate parameters to allow communication between controller station and VFD. The team also completed the power and signal routing, and complete the safety items necessary for operation of the dynamometer. Table II summarize the main objectives and deliverable of the EET students.

During the summer semester of 2012, Phase III of the project, the final items were completed to have a fully functional system. These final items included control signal gain tuning, electrical machine parameter estimation, baseline system data collection, and testcell performance testing. The completed testcell system is shown in Fig. 4 and Fig. 5. The test-bed is primarily comprised of off the shelf commercial products. The components are integrated together to form a functional electric machine dynamometer test-bed. The one-line system is classified into two distinct portions; the "prime mover" and dynamometer. In Fig. 5, the top branch of the circuit, prime mover, consists of the A (DC power supply) and B (DC-AC Inverter). The lower branch of the one-line diagram is classified as the dynamometer and consists of E (isolation transformer), F (variable frequency drive), and the second induction machine, Motor 2.

The current test-bed configuration includes two 20 HP ABB induction machines in a back-to-back testing configuration. The dynamometer is controlled by a four quadrant ABB Variable Frequency Drive (VFD). In addition, a DC power supply and a couple of voltage source inverters (VSI) were available for use in this project. All of these components served as the essential components in the testcell system; however system integration including some form of safety system was needed to safely control the behavior of the testcell. The testcell architecture was designed for two machines "back to back" testing. A one-line schematic is shown in Fig. 1. The two identical induction machines are mechanically coupled together via flexible motor couplings and torque sensor. There is only one source of electrical energy for the motors, a 208 Vac 50 Amp 3 phase receptacle, which is supplied from a power panel in the test-bed room. This source would supply two "loads"; the magna DC power supply/inverter and an ABB frequency drive. The Magma DC power supply powers the APS inverter, which in-turns supplies power the "Prime Mover" electrical machine, M1. Because the frequency drive operates at a different voltage than the main source power a transformer is needed. The frequency drive would then supply the "Absorber" electrical machine, M2. The high level control scheme of the testcell safety system puts the system in one of five states; "Ready", "Enabled", "Powered", "ON" and "Fault". These states dictate what, if any, combination of contactors and indicating lights are on.

Fig. 4. MSSCE Panel Layout

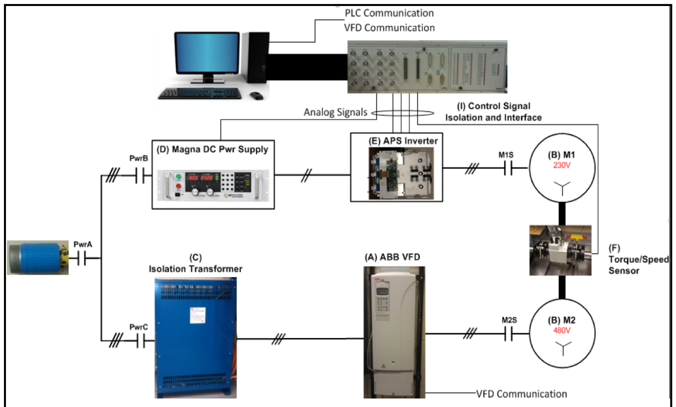

Fig. 5. Test Cell System and Component Integration Overview

TABLE II. TEAM OBJECTIVES AND DELIVERABLES

Phase I – Fall 2011	Phase II – Spring 2012
Project proposal	Incorporate PLC control of start/shut down procedure
OSHA Report	Fault detection
Components: Researched, selected, ordered	Sensor Integration
AutoCAD	Communication (ModBus) integration
Functional System	User documentation
Report/Presentation	Final Report/Presentation

IV. BENEFITS

The team members received numerous benefits from involvement with this type of capstone project that they would not get in a traditional senior design project. The first major benefit was working on a real collaborative multi-disciplinary project among faculty, undergraduate and graduate students of the EET program in the School of Technology and the ECE department in the College of Engineering. Another very important benefit team members received is determining real system design requirements. Although not unique to this senior design project, but very important, is that students obtain skills in both technical report writing and oral presentation. Each semester the team was required to write progress reports and to give presentations. These reports consisted of many aspects of the team's progress as well as procedures the team followed regarding safety. What is different in the reports and presentations from the traditional class room report and presentation setting, is the audience. The audience consisted of professionals from industry as well as faculty members and fellow students. The team was given feedback from these individuals and was expected to change or explain any issue that was presented. This demonstrated to the students the level of expectation for formal report writing and presentation skills, and gave them prior experience to the expectation level they will encounter in industry. Students were also exposed to industry tool such as CAD design and layout, dSPACE embedded controller, National Instruments LabVIEW VFD control, PLC programming, Allen-Bradley Micrologix Program, communication (ModBus) integration, sensor integration, fault detection, OSHA safety standards. Graduates will be able to use the technical knowledge from the use of the development tools they were exposed to during all phases of the project as well as some experience to complex system level problem solving.

Potential industry employers and faculty sponsors also benefit from this collaboration. Potential employers will benefit from hiring graduates exposed to project following industry type requirements. The faculty sponsoring this project will use the test-bed as a research platform for externally funded research projects in several areas such as electric drives systems, electric vehicle propulsion systems, power electronics, ac MicroGrid, among others. The test-bed was designed and built with the forethought to enable a wide variety of electric machine configurations and applications, as it provides a platform for testing of innumerous projects. In addition, the test-bed will be used for undergraduate and graduate education; the test-bed is currently being used for two specific laboratory classes: Introduction to Power Electronics and Introduction to Motor Drives.

V. ABET Capstone requirment and assessment

Capstone senior design experiences are both a graduation requirement for engineering and technology majors and a requirement for ABET accreditation of these programs. The capstone or senior design experience is typically the last bridge for students between their undergraduate engineering curriculum and the engineering profession. The ABET-ETAC Criteria−5 [7] states "The Integration of Content - Baccalaureate degree programs must provide a capstone or integrating experience that develops student competencies in applying both technical and non-technical skills in solving problems." The integration of capstone experience and externally funded faculty research projects is an effective way to actively engage students in challenging engineering design problems. In addition, the senior capstone experiences are a primary source of documentation of the achievement of the ABET Criteria 3 – Program Outcomes [11]. Criteria 3 requires that engineering technology programs must demonstrate outcomes (a-k), and includes: (a) an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities; (d) an ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives; (e) an ability to function effectively as a member or leader on a technical team; (g) an ability to communicate effectively. The project example that we discussed in this paper successfully satisfies all these requirements, as previously discussed in this paper. Project participants have the opportunity to determine real system design requirements, work with graduate students and faculty members, to obtain both professional report writing and presentation skills, and to be exposed to industry leading development tools and hardware. Moreover, a broad range of educational and professional benefits results for students participating in projects that integrates capstone experience and externally funded faculty research, which focuses on a real world problem.

The assessment methodologies for this senior design course used indirect and direct measurements to assess the applicable ABET a-k criteria. The success indicators were based in direct and indirect quantitative measures such as written reports, oral presentations, student surveys (midterm and end of semester), and instructor/students meetings. The assessment results indicated improvements in the student comprehension of key concepts, and increase in students' confidence to start their career in the industry. In Table III, we summarize the key skills acquired and applied by the students based on the EET curriculum and specifically project related. In Table IV (on page 6), we show the summary of student achievement of the student learning outcomes (SLO) for this capstone and quality of instruction as required by ABET for the capstone group of fall 2011/spring 2012. The results show the correlations between the project objectives and capstone requirements. All the SLO had acceptable results with exception of SLO 2 (organize research and data for synthesis), which is attributed to the lack of experience of the undergraduate students in working on research level projects. We intend to emphasize this objective during the next capstone cycle. The direct measurements included technical reports and technical presentations open to faculty, students, and Industrial Advisory Board members. The technical reports and the presentations have standardized scoring rubrics (which will be presented during the FIE meeting presentation). The students also developed a user documentation manual for the test-bed. The capstone team technical presentation scored slightly higher among three industry sponsored capstone projects presented at the same time. The overall quality of the project received positive comments for all the members. The test-bed has been used for classes and serving as project demonstration for visitors from industry, prospective students, among others.

TABLE III. CURRICULUM AND PROJECT RELATED SKILLS

EET Curriculum	Project Related
Wire Specifications	General Safety Practices for test-beds
Electrical Machine Operation	AutoCAD
	ModBus
	Component Selection Process
	Industrial Type Circuit Construction
	PLC Hardware and wiring

VI. FINAL REMARKS

The integration of funded faculty research and industry requirements in a capstone project can provide distinctive benefits to undergraduate students, graduate students, and faculty involved in the project. All the aspects of the project consisted of higher quality and larger scale than typical senior design projects, and in this way better resembled projects in industry and better prepared students to enter the workforce. In particular, students participating in this type of project developed useful project skills, and had the opportunity to be directly involved with all the aspects of a complete system development cycle focusing on user needs and requirements, in addition to follow practical industrial project standards. For the cases that we investigated there is no significant difference in the students' perceptions whether their capstone project is sponsored by faculty or industry as long as the project gives the students the opportunity to develop a broad range of skills. However, students' participating in these types of faculty sponsored projects have the potential for more employment opportunities due to the projects similarities with industry projects. Most of the industry sponsored projects in our program have a relatively small budget as compared to our case study, which can limit the complexity of the industry sponsored projects.

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Table IV. Summary of Student Achievement of Course Objectives and Quality of Instruction

Student Learning Outcome (SLO)	*Relates to Program Outcome(s)* [a]	*Assessment Instrument for This SLO*	*Standard*	*Results*
1. Be able to research on applied electrical engineering technology.	3a, degree 2 3b, degree 2 3f, degree 2	Weekly meetings, project development phases;	70% of students will score 70% or better.	80% of students scored 70% or better
2. Organize research and data for synthesis.	3a, degree 2 3b, degree 2 3c, degree 2 3d, degree 2	Weekly meetings, project phases	70% of students will score 70% or better.	67% of students scored 70% or better
3. Prepare written reports.	3g, degree 3 3k, degree 3	Weekly memos, Bi-month reports, End of semester report, Final Report.	70% of students will score 70% or better	87% of students scored 70% or better
4. Prepare and present oral reports.	3e, degree 3 3g, degree 3 3k, degree 3	Weekly meetings; University Expo Capstone Conference, Final oral presentation.	70% of students will score 70% or better	80% of students scored 70% or better
5. Work in teams.	3e, degree 3 3g, degree 3 3h, degree 3 3i, degree 3	Weekly meetings, project development phases, oral presentations, written reports/memos.	70% of students will score 70% or better	100% of students scored 70% or better
6. Coordinate and work to meet scheduled deadlines and facilities, manage resources, etc.	3e, degree 3 3g, degree 3 3i, degree 3 3k, degree 3	Project development phases, and scheduled deliverables.	70% of students will score 70% or better	87% of students scored 70% or better
7. Learn general safety practices for test beds	3c, degree 3 3d, degree 3 3f, degree 3 3j, degree 3	Project design, construction, testing following OSHA requirements.	70% of students will score 70% or better	94% of students scored 70% or better
8. Be able to make industrial type of circuit construction.	3a, degree 3 3b, degree 3 3c, degree 3 3f, degree 3	Project design, construction, testing, and scheduled deliverables in line with sponsor requirements and approved by sponsor.	70% of students will score 70% or better	100% of students scored 70% or better
9. Learn how to make component selection and ordering.	3c, degree 3 3d, degree 3 3k, degree 3	Project design and budget requirements approved by sponsor.	70% of students will score 70% or better	100% of students scored 70% or better

a. In the second column, "Relates to Program Outcome(s)…", the degrees are a way of prioritizing course outcomes. Degree 3 implies that the course places significant emphasis on that outcome, degree 2 implies moderate emphasis, degree 1 implies some but minimal emphasis.

A Builder and Simulator Program with Interactive Virtual Environments for the Discovery and Design of Logic Digital Circuits

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***Abstract*—This paper describes the features and applications of a computer program for building and simulating digital circuits with standard and custom integrated circuits, virtual environments and other useful and practical elements such as interactive tutorials and schematic circuits. By using virtual logic modules users can insert integrated circuits into breadboards, trace wires, change switches and check outputs in displays, almost like in a real life laboratory. Also students can use virtual environments to test circuits as if they were in the real world. Users can design digital applications with more components and reuse their designs to show additional examples and study more applications while saving time and money. This program supports several instructional methods. In inquiry-based learning students can be guided to experiment with integrated circuits and logic symbols in order to discover truth tables for basic logic functions and then search for patterns, principles, abstractions and applications. In project-based learning students can try solutions for virtual environments such as traffic light controller, water tanks, kinematics experiments and elevators, and then build solutions in the real world with more confidence. Earlier versions of this software have been used on many high schools and universities in Europe and Latin America.**

Keywords— logic circuit design; project-based learning; self-learning; virtual environments; inquiry-based learning.

I. Introduction

Digital technologies are embedded on many devices and systems and it is required for all engineering students to understand digital systems and computational tools [1]. Introductory digital logic courses are designed to teach the fundamental principles, design techniques, and practical applications of digital circuits [2]. A typical approach is teaching basic principles with standard TTL/CMOS integrated circuits. Then, instruction continues with programmable logic design techniques, high-level hardware description languages, and microcontroller design and programming.

In Peruvian institutions logic design courses typically include data representation, Boolean algebra, transformation and simplification techniques, combinatorial and sequential circuits, finite state machine, technological issues, and occasionally programmable logic and hardware description languages. In order to validate the theory learned in class, students design their logic circuits by using many manual techniques and then they draw schematic logic circuits in order to build digital circuits on a testing board or breadboard. On the breadboard students insert chips and wires to connect the circuits and test their designs. When building the circuit the students usually face an error-prone and time-consuming task because of mechanical and electrical issues such as broken links or damaged chips. Also misconceptions can arise even after completing the course [3].

Many research-based studies [4] recommend effective methods for teaching and learning. For example, it is recommended that the curriculum and instructional objectives are designed to promote higher levels of thinking, and to apply constructivist methods such as project-based learning [5, 6] and inquiry-based learning [7].

Industrial design tools have limitations for educational use because of they require prior knowledge of the topics, and for novice students many software features can be overwhelming.

This paper describes a computer program for building and simulating digital circuits with support for project-based learning by using virtual environments, circuits and instruments. It was designed for an initial course in digital circuits, either in high school or college. This tool allows users to create logic circuits with various types of representations such as schematic diagrams, standard integrated circuits, application-specific integrated circuits (ASIC), programmable logic devices (PLD), and flowcharts. This feature helps students to learn design concepts and methods from several perspectives.

The purpose of the program is to help teachers and students in an introductory logic design course, by providing tools for both virtual manufacturing and virtual testing of digital circuits with their environments. Thus they have more design and experiment opportunities and fewer limitations such as component availability and costs.

The distinctive features of the components of this program, as well as its editing and simulating characteristics, are described in Section 2. Using this application with instructional methods is illustrated in section 3. Experiences in high school and university classrooms are shown in section 4, and the conclusions and future work are stated in section 5.

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II. Application Features

This program provides all the essentials for: making circuit diagrams, placing integrated circuits on breadboards, simulating with typical inputs and outputs and for advanced testing in virtual environments.

A. Virtual Laboratory

For making and testing virtual circuits this software provides integrated circuits (chips), breadboards, a DC power source, a timer board, input and output boards, virtual environments, and logic analyzers. By using the mouse chips are inserted into breadboards and all interconnections are made. The program prevents short-circuits and incorrect insertions of chips. The DC power supply provides the power lines (VCC, GND) for integrated circuits and other boards. The timer board provides four timing signals with frequencies of 1, 2, 5 and 10 Hz. Input and output signals are provided by simple switches, debounced pushbuttons, leds, and seven-segment displays. Fig. 1 shows all the interface boards and a chip inserted into a breadboard.

Chip models include standard TTL and CMOS chips, some ASICs, and basic microprocessors and microcontrollers. All chips are modeled without propagation delays. TTL and CMOS chips contain logic gates, adders, multiplexers, flip-flops, ALUs, memories, registers, decoders, etc. ASIC chips include traffic light controllers, chronometers, parking controllers, elevator controllers, radio-alarms, robotic-arm controllers, frequency meters, number guessing games, and others. Microprocessors contain academic and instructive models. Microcontrollers contain programs to illustrate typical interface applications and operations, as adding, selecting, coding, writing, reading, etc.

Virtual environments (scenarios) are environment models for the operation of the circuits. They can operate in standalone mode or interactive mode. In standalone mode, the scenarios show a predefined behavior where users can change directly input conditions and see the responses in order to understand the problem and determine solutions. In interactive mode, the scenarios are handled by circuit signals. Scenarios include crossroads, water tanks, elevators, car parking, robots, and chronometers. Some scenarios help to teach fundamentals of electrical circuits and laws of kinematics. This approach reduces risk, resource usage, design time and overall design cost. For example, Fig. 2 shows a traffic light controller and a crossroad with vehicle sensors; signals of interest are shown in two logic analyzers.

Logic analyzers have nine signal channels and provide two capture modes. In asynchronous mode, all signals are captured when a signal changes on any channel. In synchronous mode, capture occurs with a change of the signal on the last channel.

B. Abstract Representations

The tool includes logic symbols, flowcharts and programmable logic devices (PLD). These elements have propagation delays of 100 milliseconds, which is useful to analyze timing aspects and feedback circuits. Logic symbols comprise logic gates, flip-flops, decoder, multiplexer; programmable functions; function generators; and 4-bit adders, counters, comparators and registers. They can be used to verify logic circuits before designing with chips.

Flowcharts allow high-level descriptions of logic functions using algebraic expressions that can be placed on condition and assignment boxes. They can be used to describe the same logic functions with different logical expressions. These flowcharts can be used to introduce basic concepts about hardware-description languages.

PLD models are represented with their schematic form in order to make connections directly using the mouse. There are a basic programmable logic array (PLA) and a simple programmable logic device (SPLD). Both circuits are useful to illustrate circuit operations and to prototype custom logic functions. Fig. 3 illustrates a full-adder and a 4-bit binary counter. PLDs are useful to introduce programmable logic technologies.

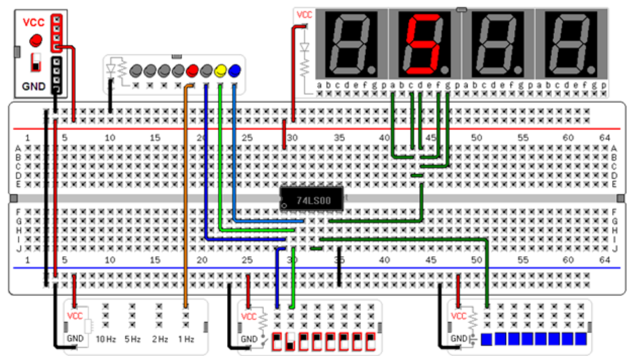

Fig. 1. Main boards and a simple test of an integrated circuit.

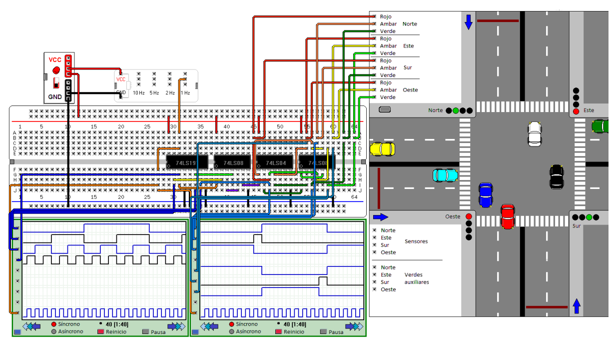

Fig. 2. A cross-road, logic circuit and logic analyzers.

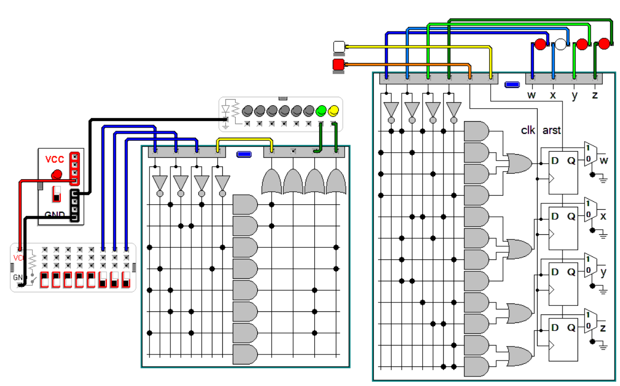

Fig. 3. A PLA-based full-adder and a SPLD-based 4-bit counter.

III. Support for Design and Instructional Methods

Following pedagogical recommendations [4], this program was designed to foster constructive and independent learning by providing multiple circuit representations as well as many analysis and design opportunities. It can be used in universities as well as in high-schools with many design and learning methodologies for custom teaching and learning. Also, this software gives more design opportunities by overcoming logistic and economical limitations.

A. Logic Design in University

A logic design process at university level is illustrated in Fig. 4. White boxes are typical steps for introductory logic circuit courses. By applying transformation techniques schematic circuits are drawn in order to build and test circuits. In a typical lab, students draw the schematic circuit on paper and then they go to the lab. Using this program, many errors and logic mistakes can be noted before going to the lab by building and testing the circuit in the computer, as indicated by green boxes. Blue and green bars show comparisons in design and testing time; students concentrate more time in design, and less in finding mechanical errors.

B. Course Content and Delivery

A custom curriculum is illustrated in Fig. 5. Horizontal cyan bars inside the boxes indicate a relative measure of how this tool can help to learn the concepts and to understand the applications in each item. Instruction starts by analyzing NAND gates and all small-scale integrated circuits, including latches and flip-flops. Concepts such as glitch, universal functions and programmable logic can be introduced in this learning stage. Medium-scale integrated circuits are studied next with counters introduced before adders and then instruction follows with comparators, multiplexers, decoders, and coders. In this analyze phase students practice with more design options and their learning styles can be supported by developing custom tutorials. This constructive approach also serves to know what it is possible to do with logic circuits.

In a design phase state machines and data-paths are studied in order to design practical and more complex circuits such as microprocessors and microcontrollers. In this way students develop a deeper abstract reasoning. Because many industrial circuits are made with programmable logic and hardware description languages by the end of the course all concepts can be revised using computer-aided design tools to show the state-of-the-art in circuit design.

Finally, in the engineering phase students and instructors working as teams bring practical solutions to real problems. As instruction progress students gain more learning responsibilities and instructors can dedicate more time for inquiry and assessment activities. Instructors can prepare customized tutorials to address student learning styles, misconceptions, and curiosity, as illustrated in Fig. 6 for a NAND tutorial. For example, students with global thinking can be trained with more abstract representations (flowcharts, programmable circuits) meanwhile students that favors serial thinking can be addressed by using step-by-step guides, from concrete things (integrated circuits) to abstract circuits (logic symbols).

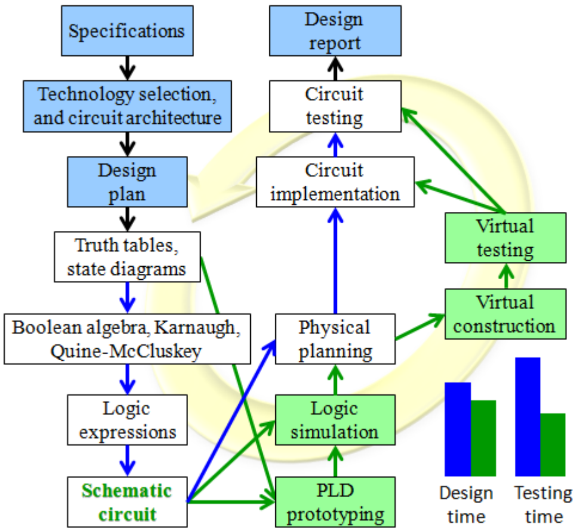

Fig. 4. A logic circuit design methodology.

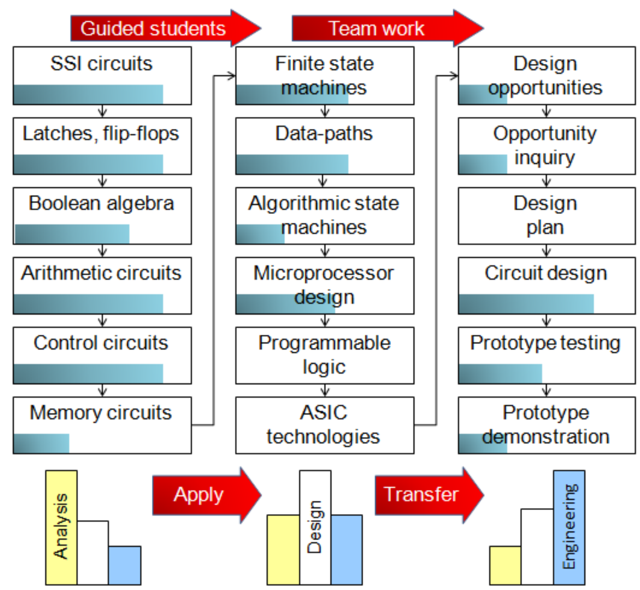

Fig. 5. A logic digital design course content.

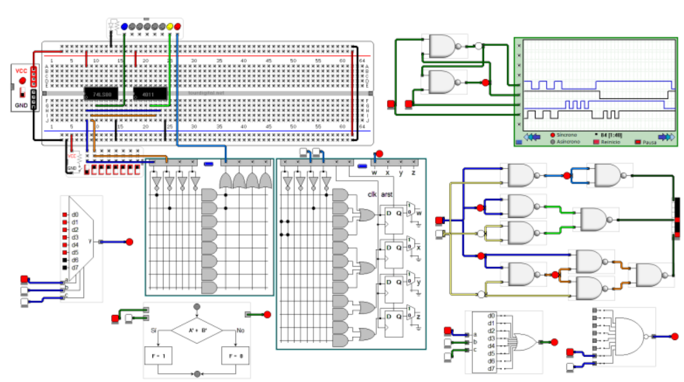

Fig. 6. A tutorial for NAND descriptions and NAND-based circuits.

C. Course Content and Delivery

At high-school this application can be used in inquiry-based learning to foster STEM (science, technology, engineering, mathematics) education. For example, by applying scientific inquiry, students can conduct experiments to discover pattern and basic principles about logic design. These concepts can be reinforced by using Boolean algebra. Engineering design can be applied to make optimal and practical circuits using the component library and virtual environments.

The 5E instructional method [8] can be used to guide the behavior and applications of logic circuits in an introductory class. This method has five phases: engage, explore, explain, elaborate, and evaluate. Fig. 7 and Fig. 8 show how the program can be used for the discovery and design of a NAND-based AND circuit:

1) Engage: Students see many circuits working in real and virtual versions, answer some surveys and post questions about logic design and circuit applications.

2) Explore: Students learn step-by-step how to build and test a NAND circuit on the breadboard, build the circuit in the computer, find output and input logic states and write a truth table for the NAND function. Then the students build the same circuit with real components, test the logic functions and verify each gate in the chip.

3) Explain: Students analyze the NAND truth table, experiment with flowcharts, look for patterns and write pseudocodes. They can use the flow diagrams to validate their circuit descriptions. Next the students prepare oral and written presentations to share their understanding on the matter and post some questions.

4) Elaborate: Students apply their understanding by discovering more NAND circuits and using other integrated circuits with similar functions. They examine a special circuit, deduce the circuit truth table and verify their table by simulation. Next the students think how to connect the new circuit and how to build and simulate the circuit. When the circuit works fine they build up the real circuit and verify it.

5) Evaluate: Students compare their initial understanding about logic circuits with their current achievements and then make plans for new designs.

This process is repeated to analyze a biestable circuit. Students see a video about water supply in the world and explore a water tank with a bomb pump. Then they simulate a NAND-based SR latch using logic symbols and a logic analyzer to see the circuit behavior on the time. Next they adapt this circuit to handle signals from the water tank.

Concluding this lesson, it is expected that students are able to know many basic gates circuit descriptions, understand how build many circuits to do the same functions, apply logic concepts to discover more functions, analyze schematic circuits, identify circuits on breadboards, design circuits to control water supply, evaluate and communicate their results for feedback and valorize their work and learning process.

As students know more functions and techniques, they can design more complex circuits, like the circuit in Fig. 9, where students bring solutions to a practical problem for an optimal use of water and energy. In the process, they learn about seven-segment displays, number systems, coders, and decoders.

In this approach, students can learn about logic design by walking through many ways and by studying circuits according to personal interest but maintaining a common concept core.

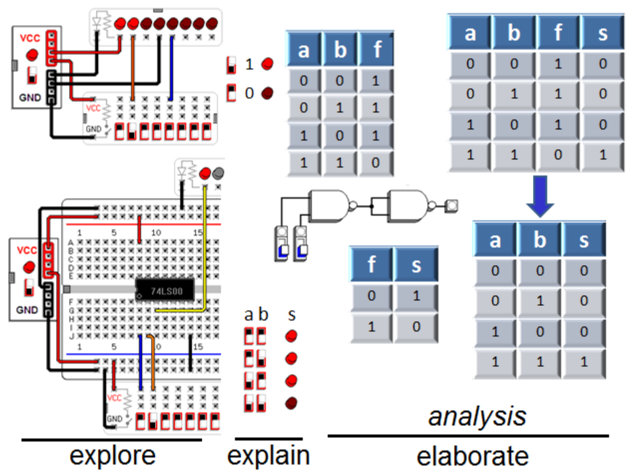

Fig. 7. Discovery and design of an AND function, part I.

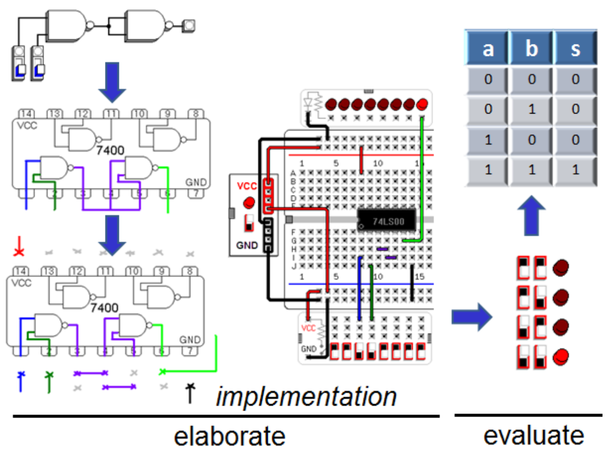

Fig. 8. Discovery and design of an AND function, part II.

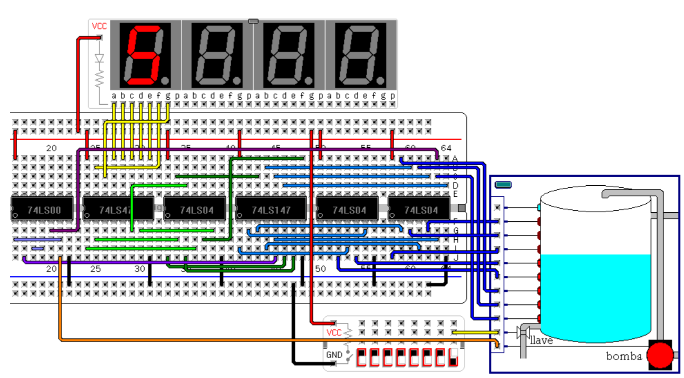

Fig. 9. A water level controller.

D. *Project-Based Learning*

In project-based learning (PjBL) students develop practical solutions to real problems [7]. PjBL begins with a search of design opportunities and concludes with a public presentation and demonstration of the product or prototype. This software can support many stages of the PjBL process for introductory logic design. For example, with teacher-made environments, students can find and analyze opportunities by determining operation conditions and by specifying problem sentences. With the virtual digital module and the breadboard students can simulate their designs and check results and also build and test other design alternatives. With interactive tutorials students can learn special items at their own pace. When the work is ready on the computer students build their circuits in the real world.

Fig. 10 shows a tutorial to aid students in understanding and resolving a kinematics problem. They use a tutorial to learn how gravity acts on falling bodies. Students deduce free-falling and compound laws, and prepare a design to calculate local gravity acceleration. They learn how to choose component values for resistors and other sensors. Fig. 11 shows a 4-stage up-down counter with frequency selector that can be used for kinematics experiments as well as athletics races, person counting, etc.

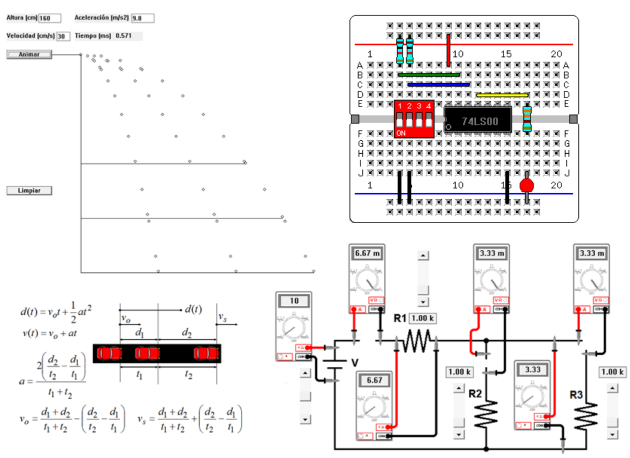

Fig. 10. Tutorials for kinematics and elecrical experiments.

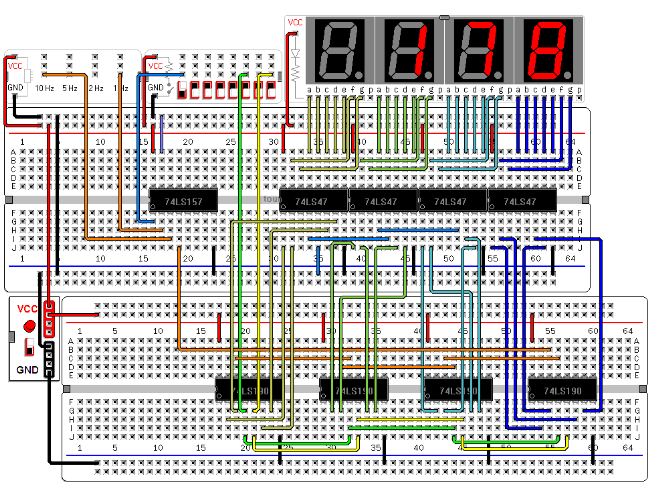

Fig. 11. A chronometer for kinematics experiments.

IV. Users of the Software

We have used this software as a support tool in workshops and lab-based classrooms in Peruvian high schools and universities. A number of extracurricular workshops have been developed at public high school José Pardo y Barreda, in Chincha, Peru. In those workshops students first explored electronic parts and instruments and then learned how to use the computer program. When their simulations worked fine they built the real circuits. The students developed more working applications compared to traditional instruction and a couple of projects won honorary places in national technological and scientific fairs. Fig. 12 shows some pictures from a workshop for instructors and students.

At a public university the students used this tool to learn circuit simulation with standard chips and then used industrial tools to learn about programmable logic devices. At the end of the course students showed their projects and prototypes in a local technology fair. Students at a private university have used the program before going to the lab. In a couple of university workshops the students used this tool to discover circuit properties and analyze logic functions.

Previous versions of this tool have been shared freely in the Internet [9]. The program page appears in the top search results with the Spanish words: *simulador digital, simulador circuitos digitales, enseñanza circuitos digitales*. This tool has been used by many instructors and students from schools and universities in Europe and Latin America. Many comments and observations have helped to improve the software functionality. Some users say:

- "The simulator has been very useful for getting a better understanding of the digital circuits".
- "The program is very helpful before building the circuits on the breadboard".
- "We do not have constant access to the laboratory, but we can experiment at house".
- "If I have had studied with these tools, I would have saved a lot of money."
- "It is a didactic, simple, and practical tool".

Fig. 12. A workshop session at the Jose Pardo y Barrera public school.

V. Conclusion and Future Work

It has been described a computer program for building and simulating digital circuits. The program allows users to create logic circuits with various types of representations such as schematic diagrams, standard integrated circuits, ASICs, programmable logic devices and flowcharts. Besides the typical applications in introductory courses the software facilitates the study of more complex circuits such as state machines, data-paths, microprocessors and microcontrollers.

This tool has special characteristics like delay propagation through symbols and logic analyzers with two capture modes that are useful in analyzing timing issues. The program features help students to reinforce design concepts and methods from several perspectives. While students work with the tool, instructors have time to focus in different teaching topics such as customize their methodologies according to the student learning styles in order to meet instructional outcomes.

The program supports many stages of the inquiry- and project-based learning for introductory logic design and it has been useful for students and instructors in introductory courses of digital logic circuits.

The next version of the program will be designed to support cooperative design on the Internet. Also this tool will incorporate artificial intelligence agents in order to guide students when they are designing circuits.

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Integration of SCORM packages into web games

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***Abstract*— This paper presents a model that enables the integration of SCORM packages into web games. It is based on the fact that SCORM packages are prepared to be integrated into Learning Management Systems and to communicate with them. Hence in a similar way they can also be integrated into web games. The application of this model results in the linkage between the Learning Objects inside the package and specific actions or conditions in the game. The educational content will be shown to the players when they perform these actions or the conditions are met. For example, when they need a special weapon they will have to consume the Learning Object to get it. Based on this model we have developed an open source web platform which main aim is to facilitate teachers the creation of educational games. They can select existing SCORM packages or upload their own ones and then select a game template in which the Learning Objects will be integrated. The resulting educational game will be available online. Details about the model and the developed platform are explained in this paper. Also links to the platform and an example of a generated game are provided.**

Keywords— SCORM; Game-Based Learning; Learning Objects

I. Introduction

Many studies show that pupils are more motivated to learn with educational games [1], [2]. They feel more engagement and learn easier. This is mainly because they have grown up with computer games, they feel comfortable using them [3] and even more with the increasing popularity of video games and the spreading of handheld devices such as smartphones and tablets.

Educational video games can be really improved with the introduction of new technologies. But the development costs are very high (even higher if we consider the opportunity costs of developing another kind of video game) and teachers or educational institutions usually cannot afford it. Therefore, teachers usually have to resort to existing games. However, most of them are focused on specific topics and cannot be reused in other academic subjects. The type of educational content used in the game (e.g. video, images or audios) or the content´s language are important parts of the game that need to be adequate for students bearing in mind their context (e.g. age, level, etc.).

On the other hand e-Learning standards such as SCORM (Sharable Content Object Reference Model) [4] are widely used nowadays in Learning Management Systems (LMSs) and Learning Object Repositories (LORs). They offer a good possibility for teachers to easily manage their contents, reuse them or export them from one system to another. Teachers can also create their own resources in these standard formats using different e-Learning authoring tools.

The research presented in this paper aims to build a bridge between both worlds to create adaptive educational video games. Teachers will be able to customize the learning contents inside the games and game developers will be able to create adaptive educational video games in an easier way and following a standard for the integration of the learning contents and the communication with them. Hence the intended audience of this research is the teaching community and the game developers' community.

This research is based on the possibilities that SCORM standard offers. SCORM packages can be integrated into web games the same way they are integrated into a LMS. The Learning Objects (LOs) or activities inside the SCORM package can be shown to the players when certain conditions are met or when they do specific actions. For example, when they need a special weapon they would have to consume a LO to get it. The LOs can communicate with the game the same way that they do with a LMS. For example, a quiz would assess that the pupil have passed it and so he can get an extra life in the game.

The rest of the paper is organized as follows. The next section reviews the state of the art in educational games and the SCORM standard. Section 3 introduces the possibilities of integrating SCORM packages into web games. Section 4 presents the model including its architecture and interface. Section 5 describes the SGAME platform that we have developed following this model. Finally section 6 presents some conclusions and future work.

II. Related Work

According to [5] Game-Based Learning can be defined as "the use of a computer game-based approach to deliver, support, and enhance teaching, learning, assessment, and evaluation". It is a growing trend in recent years. As educational games have potential to improve students' motivation [6], promote self-directed learning [7] and develop social and cognitive skills [8], [9]. In [10] we can find a broad literature review of the educational impacts and outcomes of computer and serious games, where 129 papers were analyzed.

The potential for educators to become involved in the development of educational games is substantial [9]. Interesting initiatives are providing frameworks to develop adaptive educational games, where teachers can create and evaluate their own games and simulations from scratch.

A good example of this can be the game authoring tools provided by e-UCM, a research group from Complutense University of Madrid with several related projects and research lines like Game-Tel [11] and e-Training DS [12]. There are other software tools available that make easier to create computer games, replacing part of the programming by mechanisms in which games are constructed from simple building blocks. Examples are StageCast [13] that is particularly aimed at young kids, the products by ClickTeam [14] or Game Maker [15].

Other initiative to involve educators in the authoring of games is to make it even easier for them introducing game templates. This concept comes from the non-digital world with the *Frame Games* described back in 1980 by [16]. Frame Games are board games which are designed so that they can be filled with arbitrary educational content (for example by putting it on blank playing cards). As an analogy in the digital world, game templates are a certain type of gameplay which can be configured and filled with content by an author [17].

On the other hand e-Learning standards are widely used to package and interact with LOs. One of the most used is SCORM. This standard was created by ADL (Advance Distributed Learning) from the US Department of Defense to promote interoperability, reusability and durability of digital educational contents. SCORM arose as an application profile that integrated several existing standards and specifications from the e-Learning field to simplify their implementation in systems and tools. It acquired the category of technical report by ISO (International Organization for Standardization) in 2009 (ISO/IEC TR 29163).

SCORM is intended to import and export LOs to and from LMSs and LORs. But as it offers a run-time environment to communicate with these LOs it can be used in other contexts. A good example of this kind of use is described in [18].

III. SCORM AND GAMES

As an introduction to the model we present in this section a summary of the SCORM standard and an analysis of the possibilities of integration in games.

A. *Inside SCORM*

SCORM standard has been introduced in the related work section, but now we will summarize the standard to understand the possibilities it offers for the integration of the SCORM packages in other scenarios different from a LMS. SCORM 2004 4th edition is composed of three technical documents that describe different aspects and provide guidelines for the creation and use of these SCORM packages.

- *Content Aggregation Model*: Specifies the structure and format of the file known as manifest and indicates how to tag or label the content (based on the Learning Object Metadata or LOM [19] standard) and how to package the Learning Objects (with IMS Content Packaging). The SCORM package is a zip file containing all the source files with the learning resources and the manifest file. A resource can be a SCO (Shareable Content Object) or an asset. A SCO is a content object that will use the SCORM API (Application Programming Interface) to interact with the Run-Time Environment when it is launched and while it is running. An asset is a content object that will not use the SCORM API but that can still be used for an activity. For example, it might be a text document or an image.
- *Run-Time Environment*: Defines how the contents have to be executed, the data model for SCOs and the way of doing this communication (IEEE 1484.11.2). SCORM specifies both an IEEE standard communication data model (IEEE 1484.11.1 known as CMI model) and a custom data model. The CMI data model contains several categories of data, among others:
    - Completion and success status.
    - Score.
    - Data about various types of interactions and their status including learner responses.
    - Entry and exit status, used to determine how the SCO was launched and how and why the SCO is being terminated.
- *Sequencing and Navigation*: Defines the order in which the content will be presented to the pupil together with the navigation options that are offered. It is based on the IMS Simple Sequencing specification to define flow conditions in the activities.

B. *Possibilities of integration*

According to the Content Aggregation Model a SCORM package is a zip file containing all the resources (SCOs and assets) together with a manifest file. All SCOs and assets inside the SCORM package can be integrated into a website (such as a LMS) so they can be integrated into a web game. In fact there is a required *type* attribute into each resource element of the manifest file to indicate the resource type, but this is always set to *webcontent* by recommendation of the SCORM standard.

Although there are no technological constraints to integrate these resources into web games we can find a huge limitation with the resource learning time. Due to the nature of games they cannot be interrupted for a long time. For example, although a one hour video can be a very good learning resource it should not be integrated into a game.

Fortunately LOM specifies an attribute for this called “typical learning time”. LOM also has other attributes that can be useful to determine if a resource should be integrated or not, those are “duration” (to indicate full duration for videos, audios or animations), “typical age range” and “difficulty”. But if these parameters are not specified in the manifest file the user will be the one in charge of deciding if a resource should be integrated or not.

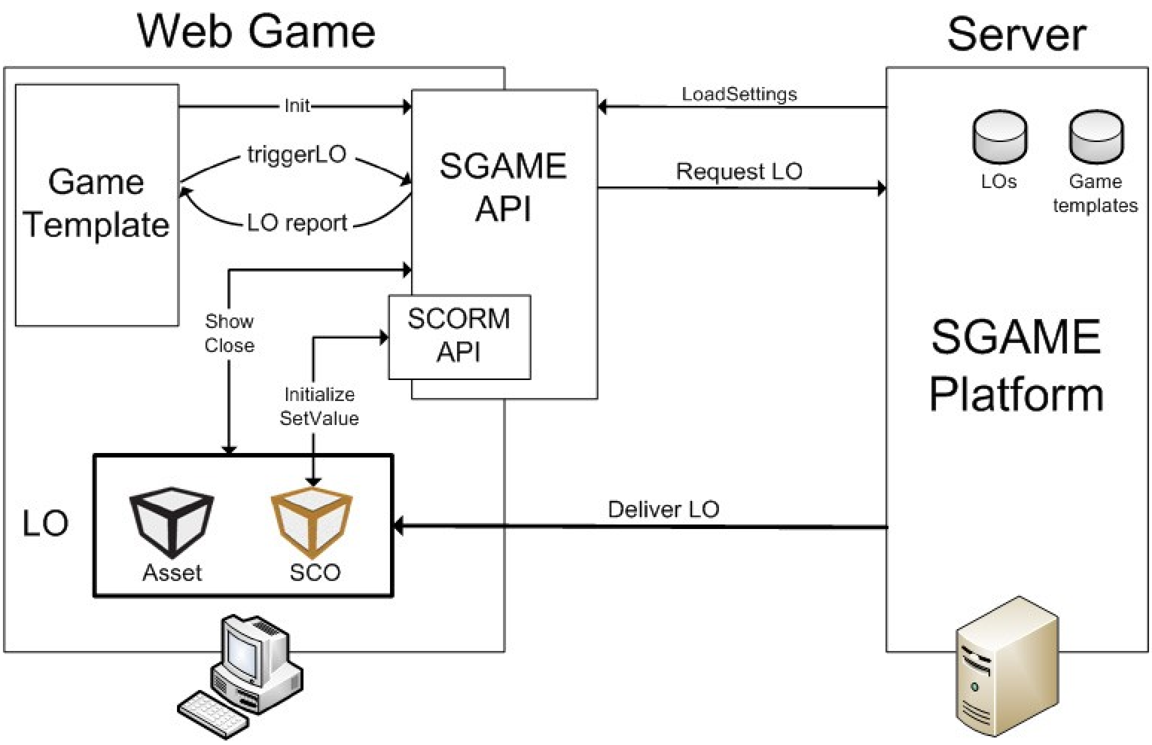

Fig. 1. SGAME Architecture

SCOs communicate their status to the LMS using the Runtime Environment, i.e. the API that SCORM defines for this communication. This status can be a score, a success flag or a completion status among others. By the integration of this API into the game it will be able to get information about the interaction of the player with the learning activity or LO. For instance, if the player answers a quiz correctly the SCO will communicate the success status through the API. The game gets this information assessing that the learning activity has been passed and the game is resumed giving the player a reward like an extra life or a better weapon.

This interface is only used by SCOs. Assets on the other hand do not communicate any status to the LMS so they also will not do it to the game. The game can show the asset but when the player closes it the only information that can be obtained from the interaction is the time period that the asset has been displayed.

Finally although for an LMS it can be very useful, the Sequencing and Navigation part is not useful for the integration into games. The game presents the LOs to the player when the conditions are met or the actions are performed, not in a specific strict order.

IV. SGAME MODEL

In order to allow the integration of SCORM packages into web games we have defined a model called SGAME, which name is the result of the contraction of the words "SCORM" and "GAME".

This model defines the architecture and the API that allow the integration. Both will be explained in this section together with the conventions that a game developer would have to follow in order to create a game compliant with this model.

A. SGAME Architecture

Fig. 1 shows the detailed architecture and interactions between the different components of the model that are carried out for integrating SCORM packages into web games. In the figure we can see the different pieces that take part in the process.

We have already introduced SCORM related concepts but before explaining this figure we should introduce the other ones.

- A *Web Game* (or game instance) is a game composed by a game template and a set of LOs. These web games are presented to the users as conventional games, but they show educational contents under certain events. Therefore, in a specific moment a Web Game can be showing the game to the player or a LO to be consumed.
- *Game Templates* are full games with specific events that may call external LOs to be shown when they are triggered. They use the SGAME API to request them.

Taking a quick look to Fig. 1 we can see two main parts, the SGAME Platform and a Web Game. The SGAME Platform is in the cloud so it can be accessed from anywhere and at any time. It stores the SCORM packages, the game templates and the web games. This server has a very simple functionality, extract the LOs from the SCORM zip files, i.e. SCOs and assets, and create the web games linking these LOs with specific events defined in the game templates. The Web Game runs on the user browser. It includes a Game Template and the SGAME API. It communicates with the SGAME Platform using the SGAME API to request and show the corresponding LOs.

Finally we will use an example to explain the interactions that take place to show a LO when playing one of these games. When a specific event occurs in the game, for example the player opens a chest, the Game Template calls the API to show one LO with the function *triggerLO* passing the identifier or name of the game event as a parameter. The SGAME API will call the platform that will deliver the LO together with its metadata, and it will be shown to the player. In the example a quiz with a couple of questions would appear and the player would have to answer them.

Whenever the player closes the LO the Game Template receives a LO *stats report* with information collected during the LO display time. In the example, the game would receive the number of questions that the student have correctly answered and will give the player 20 coins per each correct answer.

B. SGAME API

The SGAME API is the main contribution of this research. It is the one that enables the integration of SCORM packages into web games, i.e. the one that a game developer would have to use to create an adaptive web game or to edit his/her already developed games in order to convert them to a game template compliant with this model.

This API is quite simple. It only has two methods to communicate with the game template.

- An *Init* method with two options. Firstly a *togglePause* function to stop the game when showing a LO and resume it when the LO is closed. Secondly a *background image* for the display box where the LO is shown, this way the LO seems to be totally integrated in the game. Calling the Init method is not mandatory. It can be omitted if the game handles the pause/resume by itself. However, this way the LO will always appear with the default style, i.e. a white display box.
- A *triggerLO* method with the name or identifier of the game event. This is the main method in the API and will communicate with the SGAME Platform to request a LO and show it. Whenever the player closes the LO the game will receive two parameters: a true/false value called *success* indicating if the player consumed or passed the LO, and a *report* with some statistics about what the player did with the LO. The values will vary depending on the LO being an asset or a SCO:
    - If the LO is an asset the only information that we have about what the player did with the LO is the time spent (*tspent*). So the *success* parameter will follow a very simple algorithm: *true if tspent > tmin*, being *tmin* a percentage of the "typical learning time" if present and a minimum time (that we initially set to 15 seconds) if not. Anyway, the report contains this *tspent* for game developers who want to implement their own algorithm based on this data.
    - If the LO is a SCO it will automatically communicate with the Run-Time Environment that is also included in the SGAME API. Thus it gathers much more information: completion rate, number of attempts, success indicators, etc. In this case the *success* parameter will be extracted from this information and the *report* will contain all the information gathered.

C. Conventions

A game developer who wants to follow this model would have to follow the next conventions when creating games:

- Include an index.html file that launches the game.
- Include a file describing the events that can be linked to the LOs.
- Include the SGAME API.
- Implement a function to pause/resume the game when the LO is shown/closed.

V. SGAME PLATFORM: A CASE STUDY

Following this model we have developed a web platform that we have also called SGAME. In this section we will explain the main functionalities and an example of a generated game.

This platform is open to the public [20] and anyone can use it without registration being needed. In this version we have introduced three game templates. Two are existing games (Sokoban and Onslaught Arena) that are open source and we have modified to use the SGAME API, and another one called Natural Park that we have developed from scratch.

This platform is open source and the repository of the code can be found in GitHub [21]. Anyone can download it and it is open for contributions from the learning or game development communities. Furthermore, all the future works presented at the end of this paper will be also included in this repository.

A. Functionality

SGAME is an online e-Learning authoring tool to create educational web games by customizing the LOs and activities in them. Fig. 2 shows the main page of this platform.

The functionality is quite simple, the user has to choose a game template, some SCORM packages and click on the "create" button. A small form will be displayed to write a name for the created game and add an avatar to recognize it. After this the generated game is shown for the user to try it. The game will be always available in that URL so it can be easily shared. A "gallery" button to access a page with all the created games is also available.

In this screen users can also upload their own SCORM packages. This way they are not limited to use the existing ones.

Finally, there is a button where users will be able to add new game templates the same way as SCORM packages are added, although this functionality has not been implemented yet in the SGAME platform.

Fig. 2. SGAME platform

B. Example

Several examples of generated web games can be found in the SGAME platform gallery. We explain below one game example based on the game template Onslaught Arena.

This game is available online [22]. It is a medieval fantasy game where the user plays the role of a fighter that has to shoot different kind of monsters to get gold and weapons. Each time a player tries to get a new weapon (Fig. 3) a LO is shown (Fig. 4). The player will only obtain the weapon by accomplishing or consuming the LO.

In Fig. 4 we can see that we have also included a semaphore that will show a red, yellow or green light as a feedback for the player. The status of this semaphore depends on the "typical learning time" parameter of the LO metadata or on the information gathered from the Run-Time Environment API if the LO is a SCO. If the player closes the LO before the green light is on, he/she will not get the reward in the game, in this case the weapon. In this figure we can see a quiz where the player has to drag and drop the weapon names to their corresponding pictures. After finishing this learning activity he/she will be able to continue playing.

Fig. 3 Game example

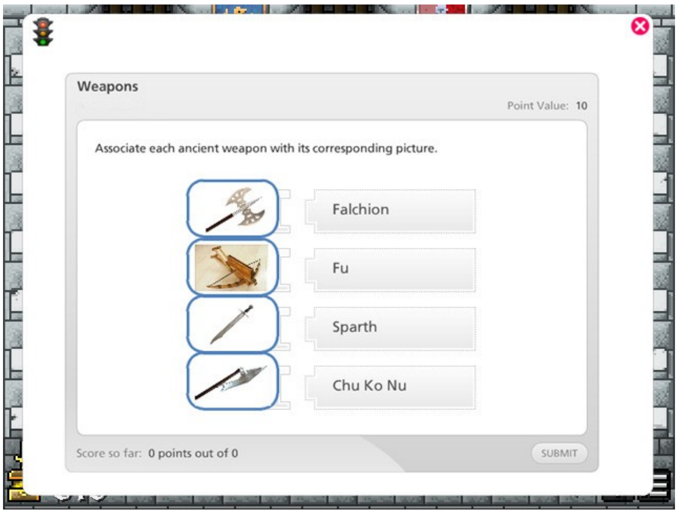

Fig. 4 Quiz shown in the game

VI. Conclusions and Future Work

In this paper we have presented SGAME, a model to integrate SCORM packages into web games. The main piece of this model is the SGAME API that games have to use to allow this integration. This API has been explained together with the model, architecture and interactions that occur when playing one of these generated games.

Following this model and to validate it we have developed an open source web platform (also called SGAME). We have also described it in this paper together with its functionality and an example of a generated game available online.

This model can bring closer the game developers community and the teaching community. The API is quite simple and can be easily integrated into existing web games or in new ones created from scratch. The possibilities that this model offers to the teachers are huge as they can customize games with their own learning content, this way adapting them for their students´ age, language, subjects and areas of interest.

The immediate next step in this research consists of extending the model to other standards such as IMS Common Cartridge. In the platform the next work will be to allow a more flexible integration of the LOs with the events in the game, maybe with a second step in the creation process where the user links each LO with a specific event in the game. Together with this, it would be very interesting to allow the edition of the metadata, as we have seen that the information included is very important. We could for example allow the user to specify the "typical learning time" of each LO inside the SCORM package in case it is not included.

Finally we would like to use the SGAME API in other contexts different than games to allow the integration of SCORM packages in them, for example in Android-iOS native applications.

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An Educational Simulation Model Derived from Academic and Industrial Experiences

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*Abstract***— Simulation games are gaining increased interest among academic researchers and practitioners where conventional teaching approaches are not adequate. In the Software Engineering field, simulation games are commonly used for enhancing the learning and understanding of complex themes such as software processes. This complexity is represented by intrinsic software development characteristics such as multiple feedback loops and cause-effect delays. One fundamental aspect for the development of a simulation game is the definition of its simulation model. A simulation model contains some dynamic features and phenomena of the system it represents. It typically involves a set of assumptions concerning the system operation and it is used to translate the underlying system model, with given inputs, producing its behavior pattern. In this work, we describe an approach to create an educational simulation model derived from academic and industrial experiences. We focus on the systematic activities executed during its development. The created model was applied in a Software Process Improvement simulation game, named SPIAL (*Software Process Improvement Animated Learning Environment*). A set of important issues were identified. Our work can help developers during the creation of simulation games for educational purposes.**

Keywords- simulation model; software engineering; simulation game; software process improvement

I. INTRODUCTION

Over the past years it was observed a movement towards more active and experiential based learning, especially using simulations and games [1]. In the Software Engineering field, we observed that it is very difficult to train students in the real situation of a software development organization, due to the very nature of software applications and the great diversity of organizational cultures. A number of simulation games were developed for enhancing learning and understanding of Software Engineering [2]. The use of simulation games represents a shift from "learning by listening" to "learning by doing" model of teaching [3]. Using simulation games, it is possible to increase students' interest [4]. In addition, the aspects presented within a simulation game can allow the application of concepts learned in the classroom in a more compelling environment [5], [6].

A fundamental aspect for the development of a simulation game is the definition of its simulation model. Simulation models are valuable tools to practitioners because they help them to understand complex issues of the represented system [7]. The Software Engineering concepts are difficult to model, mainly because of their intrinsic characteristics, mostly involving human behavior, such as, non-linear relation of cause and effect, feedback cycles, dynamic behavior and socio-cultural issues that can affect them [8], [9]. A Software Process Simulation Model (SPSM) focuses on a particular software process which can be represented as implemented in the present time or as planned for future [7]. Zhang and others [10] discuss one of the earliest software process simulation modeling in the Software Engineering field - the work of Abdel-Hamid and Madnick [11]. Since then, it has gained increasing interest among academic researchers and practitioners alike as an approach for [7]: strategic management, planning, control and operational management, process improvement, technology adoption, understanding, training and learning.

In this work, we described the activities carried out to design an educational Software Process Improvement Simulation Model (SPISM) based on academic and industrial experiences. This model is intended to raise the students' awareness for the effects and results of improving software development processes. These effects and results can be very difficult to estimate and predict. The created model was applied in a SPI (*Software Process Improvement*) simulation game, named SPIAL (*Software Process Improvement Animated Learning Environment*). SPIAL is a graphical and interactive game-based simulation environment focused on SPI [12], [13], [14]. SPIAL's evaluations suggest that it is a useful complementary approach to teaching or reinforcing SPI and Software Engineering concepts.

Our research result consists in an SPISM that incorporates some industry's process improvement issues and some Software Engineering best practices. Our main research motivation is to support game developers and instructors during the creation and selection of simulation games for educational purposes.

The remainder of this paper is structured as follows. Section 2 outlines the basic concepts of SPSM and a brief description of SPIAL. Section 3 presents an overview of the steps carried out during the simulation model design. Section 4 discusses the lessons learned during SPIAL and its SPISM development and Section 5 presents the final considerations and future work.

II. BACKGROUND

A. *Software Process Simulation Model*

A model is a simplified representation of a real or conceptual complex system [7]. Modeling means capturing and abstracting significant features and characteristics of the system. A simulation model is a computerized model which represents some dynamic features or phenomena of the modeled system

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[7], [15]. A simulation model typically involves a set of assumptions concerning the operation of the corresponding system [16]. It is used to exercise the represented model with given inputs to observe its pattern of behavior. The simulation is a viable alternative when the costs, risks or logistics of manipulating real systems are prohibitive [7].

The diversity and complexity of software processes have been represented by different modeling approaches. The most widely used techniques in SPSM are **System Dynamics** and **Discrete-event** simulation as a representative for dynamic and discrete simulation categories, respectively. As presented by Zhang and others [10], from 1998 to 2007, 49% of the SPSM researches apply the System Dynamics paradigm and 31% Discrete-event simulation. The **System Dynamics** models represent the system as 'flows' (e.g. error generation rate) that accumulate in various 'levels' (e.g. the current number of errors). The flows can be dynamic functions or the consequence of other variables. As the time advance, in small spaced increments, the levels and the flow rates are changed [17]. Its focus is not on specific individuals or events, but on patterns of behavior and on average individuals in a population [18]. The **Discrete-event** model is efficient when the process is viewed as a sequence of activities. It is often used to represent entities with unique values for attributes (e.g. error rates or the impact of different programmer capabilities) [17].

The different aspects of software development projects need both mechanisms in order to be suitably simulated. For instance, the duration and effort of activities are rarely predicted without some uncertainty, and the size of artifacts or programmers experience may differ. In addition, several aspects vary over time, for example, the schedule pressures and programmer's fatigue. SPIAL's SPISM can represent both types of simulation approaches. It models the activities of a software development organization and also its dynamic environment.

B. SPIAL

SPIAL is a graphical, interactive, and adaptable simulation game [12], [13], [14] (Figure 1). The game goal is to improve the Software Engineering learning, using simulation. Several Software Engineering topics are explored within the context of Software Process Improvement project. These aspects were based on CMMI-DEV version 1.3 [19]. CMMI was chosen because it is the most widely known SPI reference model. CMMI defines 22 process areas. Each process area consists of a set of goals and these must be implemented by a set of related practices in order to satisfy the process area. Levels in CMMI describe an evolutionary path recommended for an organization to improve the processes it uses. CMMI supports two paths (or defines two forms of representation) using levels. One path, **continuous**, enables a selection of process areas customized to the organization goals. The other path, **staged**, enables the improvement of a set of related processes by incrementally addressing successive sets of process areas [19]. **Continuous representation** is defined using capability levels while **Staged representation** is defined using maturity levels. In SPIAL the simulation model can be tailored to simulate continuous or staged improvements.

SPIAL was developed with the goal to provide students with a more realistic experience in software development processes within the academic environment**.** SPIAL allows students to practice SPI techniques and the best practices of Software Engineering. SPIAL is a single-player game in which player takes on the role of a manager of an SPI group in a software development organization. SPIAL's scope covers both a development project and an improvement project. The player is given a process improvement task and he or she can interact with other stakeholders (high level management, project manager, team member, consultant, or customer) represented as non-player characters, i.e. a character controlled by the computer (see Figure 1). The type of improvement that is required is stated at the beginning of the game and it can include, for example, reduce defects, improve the productivity, and reduce costs. In order to complete the task, the player can make investments for improving specific process areas of a software development project. A good investment strategy will result in improvement of process areas and a bigger budget for further investments. The player can visualize project estimations, indications of process areas capability level and decide in which process area to invest. During the development project, the player can visualize the effects of his/her selections on the outcomes (productivity, defect, cost, and time-to-market measures) and, if needed, change his/her investments. The final outcome is a score that represents how close the results are to the initial proposed target. During the game, the non-player characters communicate the effects of the player's actions through bubbles over their heads.

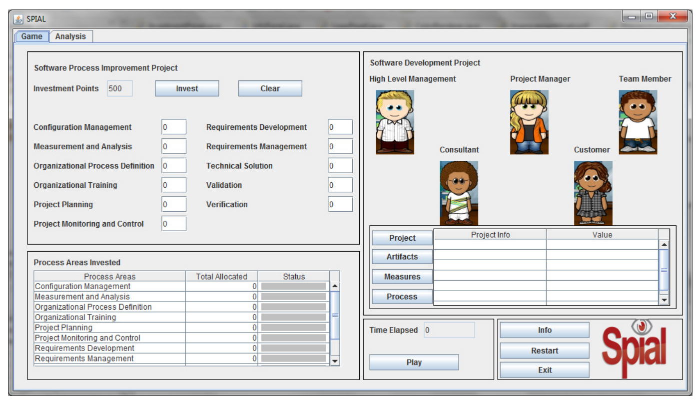

Figure 1. SPIAL Graphical User Interface.

III. SPIAL'S SPISM DESIGN STEPS

SPIAL's simulation model is interactive. It allows to build and enhance the comprehension of how complex development process and improvement program behave by experimenting and "playing" with different scenarios. In the course of SPIAL's SPISM design we adopted an incremental and iterative process, comprising the following activities:

A. Conceptual Representation

The set of concepts to be covered by the game should be defined according to the students' needs and the instructors' teaching objectives. It is not possible to address all the content of an introductory Software Engineering course. Our first task involved the organization of the conceptual content to be represented in the simulation model. The conceptual content was designed around SPI, Software Engineering rules, and Software Engineering processes explained ahead.

We investigated the domain of our simulation game. Since a simulation game should reflect what happens in the real world, we analyzed the main results reported by organizations in research papers regarding their SPI initiatives [12]. Through a systematic literature review [20], we gained an up-to-date view of the SPI area, allowing us to identify and characterize the actual results of SPI initiatives. In the SPIAL context, the results of this study provided the basis for the simulation model and requirements definition. We assessed 91 studies related to the results of SPI efforts [12]. Most of the data came from large companies which are mainly focused on improving their management project processes, requirement engineering processes, software review processes, and establishing organizational level processes. This encompasses mainly process areas of maturity levels 2 and 3 of CMMI. Considering all types of organizations, CMM/CMMI is the most frequently used improvement models. We observed that SPI initiatives do not bring "dramatic" changes (the works report improvements between 5 and 35%), and the main common reasons for launching SPI efforts are the reduction of the defect rates detected during development and after delivery, the improvement of productivity, the reduction of time-to-market, i.e. the time needed to deliver the product, and costs. A considerable percentage of data originated from interviews, observations or questionnaires revealing that most of the organizations have difficulties to measure and analyze their improvement quantitatively. Additionally, the studies have limitations in terms of rigor, credibility, and validity in their findings. They do not provide enough information about the software development organization context and the correlation between the process improvement and the effects in the organization environment. This lack of information prevented us of producing a better assessment.

As a result of this literature review, we adopted the latest version of the CMMI-DEV model as the subjacent theoretical background of our simulation model. This reference model guided the definition and validation of the mathematical framework represented in our simulation model. We observed that it would be impractical to represent all CMMI concepts in a simulation game. Therefore, we selected a subset of them to support our research hypothesis for improving student's Software Engineering knowledge. Based on the main results of the literature review, in the first SPIAL version, we considered an organization with maturity level 2 and an incomplete 3, with capability levels of process areas varying between 0 and 3. The player can invest on a set of 11 processes areas (level 2 and 3 process areas), making investments for improving specific process areas of a software development project.

In order to make our simulation model closer to what happens in development organizations, we also collected studies discussing software practitioner's motivators and de-motivators factors for SPI [21], [22]. This information was collected directly from software companies and represented in the simulation model. Examples include: The team is resistant to the change (to give up learned habits), the staff is committed with the change, and customer pressures is working as a barrier to process improvement.

In addition to SPI concepts and factors, we also collected 123 Software Engineering rules from text books [23], [24], and from other Software Engineering simulation games [5], [6]. Our goal with SPIAL was also to teach some best practices of Software Engineering area to students. The rules provide ways to reward and penalize students' actions during the game. This set of 123 rules includes rules that are imprecise (do not specify values) and rules beyond the Software Engineering area, including a wider range of business processes ones. For each rule, we mapped related measures and process areas. From this set, we selected the ones related to the SPIAL process areas, resulting in 57 Software Engineering rules. Three examples of rules and their mapping are:

Requirements deficiencies are the prime source of project failures. [23], [25] **Process area**: Requirement Development **Measure**: Defects.

Matching the tasks to the skills and motivation of the people available increases productivity. [5] **Process Area:** Project Planning **Measure**: Productivity

Rigorous inspections can remove up to 90 percent of errors from a software product before the first test case is run [24]. **Process Area:** Verification **Measure**: Defect

We also represented concepts of software development process in the simulation model. The software process works as the glue that ties coherently all the other concepts together. The simulation game play happens during the development of a software project that follows the prescribed process. The player can make investments for improving specific process areas and also observe their effects. In SPIAL first version, we modeled the Waterfall development process, with requirement, design, implementation, and test phases. The measures employed to evaluate whether the process has improved were defect, cost, productivity and time-to-market (see Figure 2). All these concepts and their relations were represented in a specific mathematical framework described in the next section.

B. Mathematical Framework Definition

Several techniques can be applied for the construction of a model. The SPIAL's SPISM was inspired by the mathematical model proposed by Birkhölzer and others [26]. The aim of their model is to provide an environment where the user, acting as a top-level manager, can interactively change the investments in the level of a software development organization, improving his/her understanding of the SPI results. It was developed following a top-down approach, considering 15 process areas of CMMI as states, and deriving 27 business measures from the company strategic goals (in their study at Siemens) [27]. The inputs are the investments that the user can make in each process area and the outcomes are the real value of the business measures. The simulation model focuses on the organizational level abstracting the specific aspects of software production processes.

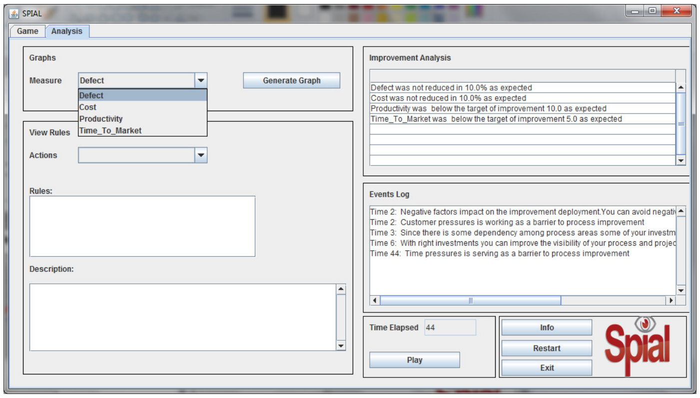

Figure 2. SPIAL Analysis Tab sheet.

The items listed below described the motivation to apply this mathematical framework:

- The original framework represents the overall direct and indirect effects of an SPI initiative. These effects can be very difficult to estimate and predict;
- The original framework integrates business measures that can be used as performance and informative feedback during the whole simulation game; and
- It seems that the original framework can be adapted to other SPI reference models, since the prerequisite to apply it is to have a simulation model with process areas characterized by capability levels.

We promoted some changes that turned the model more suitable to an educational environment. The reasons to adapt this model are:

- Besides the organizational-level, we simulate aspects of the project-level improvements, abstracting specific issues that have been extensively exploited by other Software Engineering simulation games (e.g. the project planning task).
- This framework has ten configurable parameters that constitute a considerable burden in populating the model with adequate values for them [26]. In its original application, these values were estimated by experts and turned out to be a tedious work. This could be a de-motivation factor for instructors and we tried to avoid this problem reducing the number of configurable parameters.
- We included Software Engineering rules and SPI motivators and de-motivators factors into the simulation model.
- In order to facilitate the students' evaluation of the causes and effects of their choices, we did not include advanced concepts in the initial version of SPIAL.

The SPIAL mathematical framework for such a model is a linear, time-discrete, state-space model (these categories are discussed by Pearson [28], and Kitagawa [29]):

$$\vec{x}_{t+1} = \vec{f}(\vec{x}_t, \vec{z}_t) \quad (1)$$

$$\vec{y}_{t+1} = \vec{h}(\vec{x}_{t+1}) \quad (2)$$

$$t \in \mathbb{N}, \vec{x} \in \mathbb{R}^n, \vec{z} \in \mathbb{R}^m, \vec{y} \in \mathbb{R}^p$$

Where t denotes the discrete time between each player interaction, $\bar{x}_t = (x_{1,t}, \ldots, x_{n,t})$ denotes the n-tuple of the internal state variables, $\bar{z}_t = (z_{1,t}, \ldots, z_{m,t})$ denotes the m-tuple of input variables, $\bar{y}_t = (y_{1,t}, \ldots, y_{p,t})$ denotes the p-tuple of the output variables, f and h denote functions that relate subsequent states.

In this model, the internal state variables represent the capability levels of the process areas of CMMI and the output variables correspond to measures that should be used by players to evaluate process improvement results, for example, productivity and cost.

The dynamic behavior of the model is described by the following equations:

$$x_{i,t+d_i} = level(y_{i,t} \cdot (1 + p_{i,t})), i = 1, \ldots, n \quad (3)$$

$$p_{i,t} = \sum_j \beta_{ij} \cdot x_{j,t} + \sum_j \gamma_{ij} \cdot x_{j,t} \quad (4)$$

with

$$level(arg) = \begin{cases} x_{i,t} + 1 & \text{if } arg \geq c_i \cdot d_i \\ x_{i,t} & \text{if } arg < c_i \cdot d_i \\ x_{i,t} - 1 & \text{if no investment is made during 100 clock ticks} \end{cases} \quad (5)$$

$$d_i = \alpha_i \cdot g_i \quad (6)$$

$$\alpha_i = \frac{\sum \mu_i \cdot \rho_i}{\sum \mu_i} \quad (7)$$

In equations (3) and (4) the term $p_{i,t}$ consists of the feedback from the other states. In SPIAL, 11 process areas are mapped with their dependencies (prerequisites process areas) and impacts according to CMMI. For example, the process area *Project Monitoring and Control* (PMC) depends on process area *Project Planning* (PP). Therefore, if PP is at capability level 0, investments in process area PMC will be quite ineffective. In the same way, improvements in process area *Measurement and Analysis* (MA) impacts positively on process area PMC, i.e., with higher capability levels of MA will ease the improvement of PMC. The effects of improvements can only be observed after a delay d_i period. We modeled the delay as a term affected by the motivators and de-motivators factors for SPI [21], [22], α_i, and by a predefined delay for each process area g_i. In α_i equation, the μ_i term represents the impact of a factor and ρ_i term is the probability of its occurrence. For values of α_i lower than zero, the state can react fast on changes, in contrast with values greater than zero where reaction is slower.

The *level(.)* function represents the capability level of each process area. Investments greater or equal than the cost of improvement needed during the improvement time $t + d_i$, will increase the process area capability level. We also modeled a decreasing of the capability level, after a predetermined simulation time without investments. In equation (4), β_{ij} and γ_{ij} serve as weights for the influence (dependence and impact) of the j-th process area on the i-th process area.

The actual value of each measure (the output) is calculated as a linear mathematical function.

$$y_{i,t} = mat(\sum_j \delta_j \cdot x_{j,t}) \qquad (8)$$

where δ_j denotes the weight of each process area on the measure value, which was derived from the Software Engineering rules. One *mat(.)* function was defined for each measure. For each time step, these functions are calculated based on the influence among the process areas and the impact of the motivators and de-motivators factors on the investments results.

The player operates with a budget A_t of investments points, which is characterized by the equation below:

$$A_{t+1} = A_t + \sum_{i=1}^{p} \theta_i \cdot x_{i,t+1} - \sum_{i=1}^{m} z_{i,t} \qquad (9)$$

Investment points are the amount necessary to maintain (or improve) a capability level of a process area. The budget of investment points consists of the previous balance, A_t, the previous investment, $z_{i,t}$, and the weighted sum of the internal states, $x_{i,t+1}$.

Therefore, making right investments will increase the budget of investment points and wrong investment will decrease this budget.

C. Simulation Model deployment

The simulation model represents aspects of the world to be simulated. The applicability of a simulation model depends on the model builder's ability to capture these aspects [30].

We decided to use an XML file to represent the SPIAL's SPISM. Editing the XML file, instructors can tailor a simulation model according to their course. This model allows the representation of: (i) an active role for players, e.g. as a project manager they can hire or fire employees; (ii) reaction to events; (iii) feedback and (iv) different participants to actions. We used some modeling constructs similar to those defined by SimSE [5]. Three SPIAL's SPISM elements are shown below followed by a corresponding XML excerpt. A complete list of these elements can be found in Peixoto and others [14].

Object types: The object types define the templates for all the objects. The object type consists of a name, a boolean value indicating whether a log will be generated for each object, and a set of attributes. For each attribute, its name, type, and two boolean values can be defined. The boolean values indicate the visibility of the object (i) during the game and (ii) at the end of the game. Unlike SimSE, there is no object type creation restriction.

```
<type name="ImprovementProject" log = "false">
<attribute name="InvestmentPoints" type="integer" visible = "true" visible-end="true"/>
</type>
```

Initial state: The initial state contains a set of objects that are active at the beginning of the simulation. Each object is an instantiation of a given object type, containing initial values for their attributes.

```
<object name="IProject" type="ImprovementProject">
<attribute-value name ="InvestmentPoints">500</attribute-value>
</object>
```

Rule(s): Rules specify the effects of the execution of an action. They modify the objects attributes that participated in the action. Each rule identifies the time of its execution, which can be: trigger, destroyer, or continuous. Trigger rules will be executed at the time the action is triggered. Destroyer rules will be executed when the action is destroyed. Continuous rules, on the other hand, will be fired every clock tick, representing continuous behaviors of the model. Rules also specify the order they will be executed in the "priority" parameter.

```
<rule name="investmentRule" description="Investment made in some process area" timing="trigger" priority="3" class="br.ufmg.dcc.engsoft.spial.rule.RuleDiscreteInvest"/>
```

The simulation game behaviors were implemented using Java classes. These classes must be referenced in the simulation model XML file. When the simulator parses these classes' names in the simulation model, it learns which classes should be instantiated in the Java code.

D. Model Calibration

One important issue for obtaining an effective and efficient simulation game is populating the model with suitable quantitative data. There is a considerable work in populating simulation models. The designers need to find data according to the simulation game domain. Also, this data should be suitable for an educational environment.

Despite all simplifications that we made in the simulation model design, still there were important issues in SPIAL calibration. One first barrier for the calibration of our model was the lack of specific values for the Software Engineering rules. Since most of these rules are quite imprecise, it is not possible to map them directly into the simulation model. In addition, most of the SPI industrial studies reported only qualitative evaluations. When the quantitative evaluations were available, the information was limited, or with validation problems, preventing their application in our model.

Since most of the parameters could not be deduced from the literature data, they were estimated for their initial usage.

The criteria to find a good parameter value corresponds to the ability of the model to reproduce a situation close to the ones presented in the industry; and its ability to allow students to understand its intrinsic behavior. We incorporated rules and SPI results by experimenting them with different values and we selected the values that were most suitable for an educational environment. We made sure that the real system is approximated sufficiently well by the simulation model and students would be able to check the effects of their actions.

E. Model Validation

The last activity was the validation of the model. We not only checked the simulation model but we also validated the simulation game results. Inspections and experiments were carried out.

First, an inspection was conducted by a specialist and communicability breakdowns were identified and corrected. This inspection applies an interpretative and qualitative method of the Semiotic Engineering domain [31]. The focus is on the analysis of how a software designer communicates with a user through the software's interface. According to the specialist, despite feedbacks given during the whole game, such as measurement charts and improvement analyses, important aspects to understand the core behavior were missing, such as the reason why sometimes investments do not produce any improvement. Then, experts in Software Engineering and SPI also inspected SPIAL. In their opinion, the game interface could be improved in a next release, but its behavior was acceptable for the inspected version, which covered an introductory Software Engineering course.

The educational aspects were verified in a pilot experiment. The aspects addressed in the experiment included the capability of students to understand, remember and apply Software Engineering concepts in the context of a CMMI based SPI initiative and students' impressions of the game. Our evaluation suggests that SPIAL is a useful complementary approach to teaching SPI and Software Engineering concepts. Students found it quite enjoyable, and they had fun during the game play. They learned new concepts and reinforced concepts taught in Software Engineering course [12], [13].

IV. LESSONS LEARNED

The following lessons were learned during the incremental and iterative development process employed for the creation of SPIAL and its SPISM.

A. Definition of simulation model concepts

Clear simulation model concepts make more realistic the expectation about the modeling results. Model builders are expected to have a deep understanding of the benefits, the results, and the educational goals of the simulation model.

The lesson learned is that sufficient time should be spent in the beginning of the modeling to understand all the basic concepts to be covered by the simulation game. These concepts should be coherently identified according to the modeling goals and the educational expectations. The model builder needs to be realistic and accepts that a simulation model can't represent all the issues about the reality of a software organization.

B. Identification of a reference framework

It seems to be difficult to find a suitable reference framework for the simulation model development. Starting a model development project without a well-defined reference model, has a high probability of undesired consequences. The definition of a reference model works as the subjacent theoretical background, helping in the model development and validation. The reference framework helps to clarify what kind of results the students can expect, the information that is required to be learned about certain area, the identification of relationships among the concepts, and the type of measures that can be used.

The lesson learned is the importance of having a core theoretical reference model in order to assist the simulation model definition and validation. During the preparation of experiments, this model can support the questions definition.

C. Decision of the model size

The more details are included in a model, the more difficult is the comprehension of the relationships and the model calibration. This is especially true for students that are not experts at the modeled subject. A suitable simulation model tries to represent a minimal set of variables that are sufficient to generate behavior closer to the realistic system. Too many parameters may prove to be an unpleasant work for populating the model with adequate values.

The lesson learned is that a simpler model for an introductory Software Engineering course is better than a complicated one, which would be difficult to model and validate. The validation is an important step for the simulation model development. Therefore, it is more efficient to model and validate small parts of the behavior and then integrate them.

V. CONCLUSION

This work presented the activities carried out during the design of a SPISM. The design comprised five steps: (1) Conceptual representation; (2) Mathematical framework definition; (3) Simulation model deployment; (4) Model calibration; and (5) Model validation.

Our experience with SPIAL's SPISM has highlighted some important aspects that can be used to enhance the field of Software Engineering education and simulation game development. The most concrete result is the SPI simulation model itself. The other results are the activities carried out and the lessons learned during the model development.

Although no rigorous empirical validation has been done, the simulation verifications carried out were in agreement with expectations of experts and students. SPIAL's SPISM reflects industrial aspects of a software development organization in a comprehensible manner.

We believe that simulation can provide strong support for teaching different type of disciplines, such as SPI. Unfortunately, no simulation model can replicate the world exactly, and predict the future with certainty. However, much of the students' guesswork can be reduced with this technology, forcing them thinking in a quantitative way.

As a future work, other phenomena that happen in the real world will be incorporated in the simulation model. This will provide to students experiences that resemble more closely those in industry. We will also carry out additional experiments in order to assess the simulation model results; for example, comparing them with an industrial grade SPI simulation model, validating SPIAL's SPISM with professor, developer and other roles, and comparing with other traditional educational approaches (e.g. reading from a textbook or hearing lectures).

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Adding Social Elements to Game-Based Learning – An Exploration

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***Abstract*—Game-based learning is to present the instruction by games in learning, with the main purpose of triggering learners' motives instead of instructing the courses. Thus, increasing learning motive by game-based learning becomes a common instructional strategy to enhance learning achievement. However, it is not easy to design interesting games combined with courses. In 2011, Echeverria proposed a design to combine characteristics of games with elements of courses by matching the virtual scenarios in games with proper courses. However, in the past game-based learning, students were gathered in regular places for several times of game-based learning. Students' learning was limited by time and space. Therefore, for students' game-based learning at any time and in any places, based on theories of design elements of online community game Aki Järvinen, this study treats Facebook as the platform of games. The development by online community game is easier, faster and cheaper than traditional video games. In 2006, Facebook allowed API program of the third party. Therefore, by Facebook, this study provides the platform for students to learn in social lives to explore students' activities in online community games. Questionnaire survey is conducted to find out if the design of non-single user game is attractive for students to participate in game-based learning.**

Keywords—Social Network game, Facebook, game-based learning.

I. Introduction

Game-based learning has been proven to be a kind of learning method that allows students to organize knowledge through the game content in the game process and in turn elevate learning motivation [1]. Compared to traditional education in which students passively receive knowledge, game-based learning allows students to actively participate in game activities [2], which not only strengthens but also maintains student learning motivation, making them willing to spend time on learning [3]. However, in view of the fact that it is not easy to design a system that combines game elements and course content, Echeverria proposed the design method for course knowledge systems, combining game elements and course knowledge. The fictional story of the story or the interaction with fictional characters corresponds to suitable course content, in turn combining the course and the game [4]. However, since traditional game-based learning tends to cause temporal and spatial constraints for students, in order to break through these constraints, so that students can conduct game-based learning at any time and place, this study uses Aki Järvinen's theory of social network game design elements as the basis to create the game in Facebook [5]. Other than using the 2006 feature of Facebook that permits third party development of apps, at the same time the development of social network games is relatively simpler than traditional video games, as well as faster and cheaper. Facebook provides a platform for students to learn as they socialize, and this is used to explore the activity process of students in social network games, further using questionnaires to explore whether the design of social network games can attract students to conduct game-based learning. In order to understand the gaming intentions of students, this study also uses SPSS to conduct reliability and validity testing on questionnaire questions, in hopes of understanding how social network games affect the learning intentions of students.

II. RELATED WORK

A. *Design of social network games*

Traditional game design usually focuses on game content and rules, but the design of social network games includes the element of interaction with friends, so interactive mechanisms are an important part of design for social network games. Thus, in social network game design, Aki Järvinen proposed five important design points [5]: symbolic physicality, spontaneity, inherent sociability, narratively and asynchronicity.

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III. SOCIAL NETWORK GAME LEARNING SYSTEM

In order to establish the "social network games learning system" on the basis of curricular elements, and at the same time strengthen student impression of course content, the adventure game element is added. Students can engage in adventure and exploration to solve every question in the game step by step. Based on this, the story focus of the game will be on island exploration. When the user first signs into the system, he is asked to name his pet, and when the name is decided, the game begins.

The story of the game begins on a deserted island. The user's pet was abandoned and drifted to this island. The user needs to bring his pet to explore this unknown island, and try to survive under difficult circumstances. The detailed functions and processes of the game are as follows:

Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

- Explore the island

To enable students to become more familiar with the course content through the game, this study uses the instructional materials conceptual diagram for operating systems. The sequence of concepts allows students to gradually increase their familiarity with concepts, but also allows them to use the conceptual diagram to enhance concepts they are less familiar with in the learning process. The areas on the deserted island are the different concepts on operating systems, and arrows are used to guide students in gradually finishing island exploration (based on the conceptual sequence in the conceptual diagram, answer the questions in each concept). However, since game design begins with the concept, before the game begins students still must understand the knowledge and principles of the concepts in order to explore the island with their pets. In order to give pets greater ability differences, the system design involves money and experience points (regardless of accuracy) from exploring the island, and when an area is successfully explored (with correct answers), they can also gain OS points. Student will be able to use OS points to trade for feed that can greatly increase pet abilities, and increase the probability of success in fights. However, if they do not successfully explore the region (with incorrect answers), other than being unable to proceed to the next unknown realm, they are also unable to gain OS points. Thus, these game mechanisms can stimulate students in wanting to defeat others in challenges, elevating the number of times one can successfully explore the island, ad can also enhance student familiarity with concepts.

- Feeding pets

Feed is the key to determining pet ability and characteristics. If the pets are not fed, it would increase the probability of failure when fighting wild animals on the island, so students must take note of the stomach fullness of their pets. However, in order to prevent students from feeding pets without restriction, the system only permits students to buy feed by answering the questions correctly to earn money to buy feed. The system also sets limits on the fullness of pets, students must return online to take note of the fullness value, feeding them at appropriate times to maintain pet movement. In addition, in order to elevate the fun of the game, so students can feel that their pet is unique, so the feed types will be diversified, and students can give pets different types of feed to improve different abilities. At the same time, when the pets reach certain levels, the preferences of feed would also determine how they develop.

IV. EXPERIMENTAL PROCEDURE

The experiment course is the 2012 Operating Systems, the course content used are the first three chapters on operating systems, which are "introduction to operating systems," "computer system structure," and "operating system structure." The purpose is to analyze whether the course knowledge system on social networking platform Facebook affects student learning motivation. The experiment is divided into four steps. The first step is the pretest motivation questionnaire, used to find out student learning motivation before conducting the course knowledge system. The second step is the game-based learning. The third step is the posttest learning motivation questionnaire; pretest and posttest learning motivation questionnaires are compared to analyze changes in student learning motivation after the course knowledge system. The fourth step is the game questionnaire, to find out more about student views toward social network games.

V. QUESTIONNAIRE ANALYSIS

98 students participated in this experiment, and 98 questionnaires were retrieved. Analysis is conducted after retrieval. Questionnaire evaluation is conducted using principal component analysis in SPSS. KMO measure of sampling adequacy and Bartlett test of sphericity are first conducted. The KMO value is 0.935, the Bartlett test of sphericity value is 1750.249, and significance is 0.000, which means that this data can undergo factor analysis.

Statistical testing involves using principal component factor analysis to extract common factors. The number of factors is determined by eigenvalues greater than 1 as the standard for extraction. The result is one single principal element, with accumulated explained variance of 69.501%, which means that the principal component analysis can explain 69.501% of the raw data .935 Bartlett test of sphericity Close to chi-square distribution 1750.249 Degree of freedom 105 Significance .000

Factor analysis shows that each question in the game questionnaire fall into the same dimension, and the corresponding factor loading of each question is greater than 0.6, which shows that it has good construct validity.

After validity analysis, this study uses Cronbach's α to conduct reliability analysis for internal consistency. The Cronbach's α coefficient is 0.956, since it is over 0.700, it means that the 15 questions in the game questionnaire have homogeneity, meaning this scale has reliable consistency.

VI. EXPERIMENTAL RESULT

The means show that in the posttest stage, learning motivation has a rising trend. In addition, the bar graph of pretest and posttest motivation questionnaire distributed among the students in Fig. 2 shows that after social network game-based learning, their learning motivation increased.

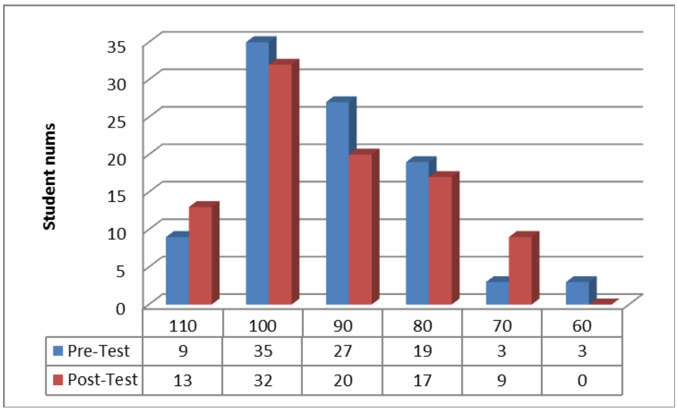

Fig. 1. pretest and posttest motivation questionnaire distributed among the students

The result of students filling out the game questionnaire, from which 98 valid questionnaires were collected. Results show that students approved the images, animation, and sound effects of the social network game, but there are still students who said they would be more attracted to complete the game if the game screens could be improved upon. In terms of game interaction, students believe that winning in fights in island exploration makes them happy, but still hope for improvements in interaction, and also hope to increase interaction with peers. This shows that when students play games, other than increasing their ability in games, they also hope peers can stimulate their improvement.

Results in the game questionnaire also show that students agree with the temporal and spatial convenience brought be building the game in Facebook, so that learning is no longer constrained by time and space. With the assisted learning from the game, it can improve upon boredom while learning, and can also help students review the knowledge they have learned, enhance their understanding of concepts, and in turn decrease their rejection for operating systems.

In addition, this study explores the reason for which students enjoy games on Facebook. Number 13 of the game questionnaire shows that one reason students think Facebook games are fun because of the people playing with them but not because of the game itself. Thus, when more peers are playing the same game, students would become more interested. On the whole, students approved the system, and are happy to recommend it to use by younger students.

Since students need to explore the island and answer questions to gain money and experience points, data shows that students spent a lot of time exploring the island. Further, concept completeness shows that out of 98 students, 54 completed all the concepts ("introduction to operating systems," "computer system structure," and "operating system structure"), which shows that without temporal and spatial constraints, students can have sufficient time to engage in game-based learning. Compared to games with time limits, it can enhance student conceptual learning effects.

VII. CONCLUSION

Statistics on the game questionnaire and experiment data show that students use time effectively to go online for the game, and there are even students who sign into the system early in the morning. This shows that the course knowledge systems on Facebook can indeed make students willing to enter the system to learn after school, to conduct game-based learning without the constraints of time and space. However, this study also finds that in game-based learning, if the same system is used continuously, long time use would result in lowered curiosity or even annoyance at the system, resulting in decreased learning motivation. Thus, the effective addition of new game elements can not only increase student learning motivation but can also help the game to be expressed in more diverse ways.

Questionnaire feedback from students shows that students like social network games because of their peers. Thus, an issue worthy of deep consideration in the future is how to effectively use the characteristics of social network games so that students can also interact with peers while engaging in game-based learning.

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Using Game-Based Learning and Simulations to Enhance Engineering and Management Education

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***Abstract*— Simulations allow students in an educational environment to experience tasks and the results of their decisions, which they will be asked to perform upon graduation. In the construction industry, many employees are hired that do not have the training or coursework at the university level that provides them access to such simulations. Simulation and gaming is not new to higher education but in the past was done in a very narrow vein and because of the complexity and development time required to produce them. Most have not been robust enough to engage students. Managing engineering and construction involves being able to make decisions that involve balancing time, cost, quality, resources, and identifying and solving a variety of issues related to the selection of equipment, labor, and tools. The skills required of today's construction engineering and management professionals are a combination of management skills and technical knowledge. This paper describes the development and implementation of Construction Industry Simulation (COINS) designed and developed at California Polytechnic State University, San Luis Obispo (Cal Poly) to prepare construction engineering and management students for the real world.**

Keywords—game based learning, simulations, engineering education

I. Introduction and Contribution

Construction Industry Simulation (COINS) is a computer simulation built to simulate the business environment for a construction company. The players, participants, play the role of contractors, competing in a market with variable demand for construction work. The simulation immerses students into the day-to-day operations of a construction company, requiring them to management specific aspects of the company with the goal of procuring and managing construction work in terms of its planning, scheduling, and resource allocation. Students have a choice between commercial construction company, a heavy construction company, or a company that does both. Players are required to set up a complete business strategy including the following tasks:

- examine available information
- determine the best portfolio of jobs to bid on
- create strategies to improve bonding limits
- set strategies to create negotiated work
- develop bid prices for desired jobs
- monitor their financial position as work progresses
- monitor and create strategies to improve company's appraisal metrics
- choose and modify their construction methods to meet due dates and reduce costs
- interpret their competitors' strategies
- respond to changing conditions and situations proposed to the company and driven by the decisions and actions of the company

A. *Projects and Activities*

Each period the simulation generates a list of projects available for the teams to estimate, schedule and propose on. The type of projects include the following: highways, bridges, site development, mass excavation, and underground utilities

All projects have nine (9) activities that the teams need to schedule, generate and cost estimate. The activities that must be scheduled and estimated include the following: clear and grub, rough grading, excavation, underground piping, concrete forming and placing, backfill and compaction, placement of aggregate base, asphalt-concrete paving, and finish grading.

In addition the simulation creates an Estimated Time and Cost Report for each job. Using the this information, each company must decide which jobs to bid on, the bid price, and which of the five methods to use for each of the activities.

Every activity has five (5) different construction methods that vary in time and cost. The Estimated Time and Cost Report gives labor and material costs and the amount of time required for every activity using each of the five methods. Heavy construction bids are generally unit price bids while commercial bids are lump sum.

II. Game PlaY Simulation

During the simulation, students experience three distinct phases playing through the simulation. These are:

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A. Phase 1 - Project Planning and Design

Students begin the simulation in Phase 1 by being presented with a list of potential projects to review. Considering market conditions, student teams proceed by selecting a project to plan and then designing a project control system for the project. This is accomplished by selecting methods for each project activity and balancing the schedule and cost considerations. In Phase 1, students compete against their peers as well as the simulation's virtual companies for award of the project. Award of projects is based on the team's accuracy and proximity to the simulation's internal estimate. Teams that are not initially awarded a project for their efforts must continue with the simulation, refining their plans, until their plans are awarded a project. Thus, the COINS simulation enables students to learn from their mistakes.

B. Phase 2 – Construction Engineering

When a student team is awarded a project, they enter Phase 2. In Phase 2 student teams must manage their project by monitoring and controlling the project activities, analyzing the schedule and costs in reference to the methods to the activities they selected for each activity. Throughout the duration of their project, students are presented with real-life scenarios which they must respond to, thus measuring, testing, and validating the design of the project control system. Therefore, students are able to utilize their knowledge and hone their skills at controlling the process through modifying their project control system. The simulation provides feedback to the students which they then can use to continuously improve their model throughout the duration of the simulation.

C. Project Closeout

Phase 3 begins after students have completed each activity for their virtual project. They have the opportunity to evaluate their performance using several predefined metrics, including Schedule Variance, Cost Variance, Cost Performance Index, and Schedule Performance Index.

D. Student Learning Process

III. Student Learning Process

As mention above, one of the first activities for the students is to determine what positions will make up their main office overhead. This is reevaluated each period, and hire/fire activity is performed by the team. A report is given to the company telling them how they are handling their personnel and it's requirements. Work scheduling is very important in the selection of the methods so projects can be completed by the contractual deadlines, and the costs reduced as much as possible. Each bid price submitted should cover all the firm's direct and indirect job expenses, its main office overhead costs, and the desired profit. At the end of each period the simulation will determine which company is awarded each available project. The lowest bid will not necessarily win since the computer takes into account several other factors:

- Is the firm's cash-on-hand adequate to provide enough liquidity with regard to the bid price?
- Is the bid price below a minimum amount, computed by the program? If so, then the bid will be disregarded as irresponsible and be rejected.
- Is the bid price higher than the unknown contractors, the presence of this simulated company assures a competitive, uncertain environment with realistic bid prices.
- Is the firm within it bond limits?

At the end of each period, teams receive a progress report for the previous two month period, giving a statement of the firm's work progress on each of its jobs during that time. It shows the amount of work completed as well as the expenses incurred for each activity in every one of the company's projects. The amount of work completed during a period depends not only on the methods selected for the various activities, but also on uncertainty factors during that time such as the weather conditions, labor availability, and the fluctuating cost of materials.

An end-of-period financial report is also provided to the participants showing the expenses incurred during that period. It lists amounts spent on direct construction services, bidding costs, delay fines, taxes incurred, and interest on borrowed money. It also shows payments to the contractor by the owner according to the payment requests and gives total cash-on-hand at the end of the period. Each firm may at any time apply for a loan to improve its financial situation. Loans granted are amortized over a one year time period. Changes in company ratios are also logged along with changes to the company's appraisal metrics.

- Is the firm within it bond limits?
- Financial Liquidity
- Financial Success
- Responsibility
- Pace
- Ethics
- Name Recognition

At the end of a period, the firms examine their Progress Reports and decide on the effectiveness of the methods chosen for the various work activities. If they wish, they may change them and specify different methods for the following periods. The choice of methods allows companies to utilize slower but cheaper methods if they fear budget overruns, or faster but more expensive methods if meeting contractual deadlines is the main concern. In addition, overtime may be used to speed up certain activities, greatly increasing the labor costs. Firm must be concerned with the amount of liquidated damages on each project as they vary from project to project.

At the conclusion of the simulation, the program provides each participating company with a final report, forecasting the expected results of any on-going projects or their position at that point in time. It also shows the final total worth of the firm. Teams should consider maximization of profit as one of their main objective, and one of the primary criteria used to evaluate each firm's performance. As the simulation progresses, evaluations of company ratio, and appraisal metrics can be used to determine successful completion of the simulation.

IV. Assessment of Student Learning

The simulation has a built-in grading module that can be used to obtain statistic on the various companies for comparison or to use in the classroom for grading the simulation. Each faculty can have their own method of grading. The following criteria can be used by faculty for assessing participation and student learning:

- Is the firm within it bond limits?
- Number of jobs bid
- Minus the jobs rejected (i.e., not enough bonding capacity, substantially low cost estimate, etc.)
- Number of times the number jobs you are the lowest cost
- Number of times the company retained earnings
- Company’s appraisal metrics

V. Discussion and Recommendations for Future Implementations

To assist in the development of COINS, the developers have developed an Industry Advisory Board (IAB) from the construction industry as well as a working group of educators to continue the development and ideas for changes. Because of the idea of module development COINS can turn on and off some of its modules, making it a better fit in different classes. For example, estimating can be turned to an automatic mode which in a construction accounting class helps the student focus on accounting and not on the estimating itself which can be very time consuming and complex. Periods can move much quicker giving the students more accounting to analyze and in a shorter time in which they can see the changes that occur within a company without being bogged down in the estimating/procurement of work. Billing can be turned on to auto mode and additional projects can be added to each team to create additional project or backlog. The game play between commercial and heavy/civil construction is also modulized so a faculty can play only commercial, heavy/civil or both can be played in one game. Future additions are also planned as modules, i.e. personnel additions, case studies, and wide use of equipment management.

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Making In-Class Competitions Desirable For Marginalized Groups

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Abstract—**Inspired by research that indicates that direct competition is not always comfortable for female students, we redesigned an existing class competition to permit students to choose whether they wished to participate in either direct or indirect competition. We pilot tested it in the Spring of 2013 in a undergraduate/graduate class on introductory artificial intelligence at the University of Oklahoma. Although the results for female students are inconclusive due to their small number, we observed that international students embraced the indirect competitions. This suggests that allowing the option of indirect competition may also appeal other groups of students who can be marginalized in engineering. Our results indicate the international students prefer the less risky option of indirect competition.**

I. Introduction and Motivation

We have previously successfully introduced a game-based environment used to motivate students to learn about artificial intelligence and to create a significant learning experience [1], [2]. With our previous experience in games and and literature that demonstrates the games are motivating for students [3], we wanted to continue to use games to motivate students but to adjust the type of competition to make it more appealing for all students. Based on existing literature that demonstrated the first person shooter games were not motivating for women [4], we designed our game to not to contain any first-person shooting or blood. The game that we designed is called Spacewar and it is based on the classic game of Asteroids [5]. In the original version of our game, the students competed to have their spaceships survive as long as possible while being controlled by programs they wrote using artificial intelligence techniques.

In order to encourage creativity and early completion of projects and to promote active engagement in the subject matter, our previous work used a game ladder where all groups of students competed against each other. The competition was run each night by having all combinations of three students and three professor created agents play simultaneously. Scores from all runs were averaged to determine the winners. This competition provided extra credit for students who performed in the top three positions of the game ladder. Although the students who competed in the ladder enjoyed the competition, there were a number of students who chose not to participate. We hypothesized that this is based on the type of competition that was required to participate in the ladder.

Direct competition occurs when competitors are permitted to interact with and hinder other opponents (e.g. a stock car race or boxing match). Students using Spacewar were competing directly since damaging or destroying other spaceships was permitted and encouraged in the game ladder. Indirect competition occurs when competitors are judged independently against a single standard (e.g. a beauty pageant or golf)[6]. We were concerned that using direct competition in the class might be uncomfortable for the women students, so we redesigned the projects and simulation system to allow students to choose either direct or indirect competition.

This work in progress paper focuses on our pilot test in the artificial intelligence class in Spring 2013. We provide two separate but equal tracks for projects. Our hypothesis was that students who are members of marginalized groups (e.g., traditionally underrepresented groups and international students) will choose indirect competition over direct competition.

II. Related Work

Many computer games are focused on direct competition. The computer gaming industry has extensively studied girls' response to competition in games. Much of this research is proprietary but one company released some of their research results without peer review [7]. Their study shows that girls tend to be horizontal competitors with covert competition and a desire to establish relationships and friendships. Their social status tends to be determined by affiliation and exclusions. Boys are hierarchical competitors (also supported by [8]) and tend to favor overt competition with a desire to establish physical superiority and power. Often their social status is determined by achievement and physical domination. Gendered competition preferences of Germans in games were studied by Hartmann and Klimmt [4]. They demonstrated that more than women prefer competitive games and identified first person shooter games as particularly unappealing to women.

The literature on how other groups, such as racial and ethnic minorities or non-native speakers of English, might prefer to compete in games is thin. Amory and Molomo [9] have compared video game playing by South Africans by gender but did not consider race in their analysis. Similarly, Joyner and TerKeurst [10] found differences between British and Japanese gaming preferences. This data supports the well-established idea that gaming and competition preferences are culturally situated; an idea also established using a gender lens [11].

The role of gaming self-efficacy and feelings of competence was discussed as a factor related to girls' enjoyment

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of computer games [12]. Kiesler, Sproull and Eccles discuss gender differences in poker playing behavior, where women prefer video poker and men prefer to play face to face. While both forms of poker risk money, face to face poker also requires deceit and assertiveness. Playing poker face to face requires direct confrontation with more experienced (usually male) players [11], which may require more self-efficacy and tolerance of risk taking. The link between gender and risk taking behavior was shown to be different in all female groups than in mixed gender groups. Female students in an all-female context were shown to exhibit patterns of risk taking behavior that were similar to males, where females in a mixed gender environment exhibited less tolerance for risk taking [13].

Joyner and TerKeurst created a model that considers interactions between motivating needs, interpersonal motivations, and entertainment preferences[10]. It is not unreasonable to hypothesize, that just as stereotype threat [14] can be demonstrated in many marginalized groups, marginalization could impact self-actualization, self-esteem, and a sense of belonging of a variety of marginalized groups in similar ways.

Competitive structures have been used previously in artificial intelligence [15] and other CS classes [16] although these efforts have not examined whether the competitive aspects had a differential impact on marginalized groups. [3] discusses the use of games in computer science classes but does not study the effect of competition on marginalized groups.

III. Method and Current Results

A. Spacewar2: The New Design

In order to accomplish our goal of having the two tracks be separate yet equal, we had to redesign Spacewar. The version that we pilot tested in Spring 2013 began with the goal of having the ships collect resources. Spacewar2 still has the students controlling spaceships in an asteroid filled environment. In the new version, the resources come in two forms: energy beacons and mineable asteroids. The energy beacons provide energy to the ships necessary for their navigation and survival. The mineable asteroids provide money.

At the beginning of the semester, the goal was to collect monetary resources. We introduced the question of what the students would like to buy with their monetary resources in a class discussion. After a passionate discussion, teams were given the power to buy additional ships, bases, and a variety of power ups to the ships and the bases. We included a balance of power ups that were offensive and defensive.

B. Competition ladder

Both the indirect and direct competition ladders rank the teams based on the amount of money brought back to the base. In the direct track, students compete against each other. The top three teams receive extra credit every day that the student remains at the top of the ladder (2 points for first place, 1.5 points for second, and 1 point for third). In the indirect track, students compete against known heuristics. Any student who can outperform the heuristic consistently can receive up to one point of extra credit per day. Student groups choose one of these two tracks on a project by project basis. Each competition is available for 10 to 14 days before the project is due, with extra credit being awarded daily. In either track, the student must outperform a specific heuristic that is provided ahead of time in order to receive extra credit.

Groups participating in the competitions by type

		Indirect	Direct
Project 1	**International**	5	4
	Female	3	2
	Non-URM	7	1
Project 2	**International**	8	1
	Female	4	1
	Non-URM	5	3
Project 3	**International**	9	0
	Female	2	2
	Non-URM	7	2
Project 4	**International**	7	2
	Female	2	1
	Non-URM	8	1

TABLE I. Number of groups participating in each competition. 'International' has at least one international student, 'Female' has at least one female, and non-URM groups have no under-represented minorities (URM) or international students.

C. Student Choices

The pilot test for this project was in Spring 2013. We had four class projects. For each project, we tracked which type of competition the students choose (indirect or direct), how early each group entered the competition (intermediate or final), and their success in the competitions and in earning extra credit. The competition ladders are published daily. This enables students to see the results of their work quickly.

The majority of students worked in pairs, which influenced their competition choices. At the start of the semester, we had 42 students enrolled. This included ten members of underrepresented groups (including women and members of racial and ethnic groups that attended high school in the U.S. and are underrepresented in engineering). This number was obtained through observation with discreet questions in case of ambiguity and likely under-estimates the true number of members of underrepresented groups due to group memberships which may not be physically identifiable (specifically biracial and Native American students). We had 13 international students. Most pairs stayed together for the semester but a few changed due to compatibility issues, affecting the counts very slightly.

Table I summarizes the choices of the student groups in the projects. Overall, more students are choosing the indirect competition over the direct competition. Although the numbers were small for the groups of international students or female students, there is a pattern. The international students primarily preferred the indirect competition. In project one, it was almost an equal split, but the remaining projects demonstrated that the international students chose indirect competition instead. Groups with female students had a more mixed picture, with their choices being approximately equal in projects one and three. Most of the females are grouped with White male students and most of the females are also not international students. This likely affected their views on risk taking. Although there are female international students, the numbers are too small to analyze separately.

Beginning with project 2, we asked them to explain their choice of competition in their write-up. Many of the groups

Student persistence in choice of competition	International	Female	Non-URM
Project 1 to Project 2			
Indirect persistence	5	2	3
Indirect to direct	0	1	2
Direct to indirect	3	1	0
Direct persistence	1	0	1
Project 1 through Project 4			
Indirect persistence	4	0	2
Direct persistence	0	0	0

TABLE II. STUDENT GROUP PERSISTENCE: CHOICES WERE ONLY RECORDED FOR TEAMS PARTICIPATING IN AT LEAST 2 COMPETITIONS.

who chose the indirect competition stated that they knew how well they would perform there because the heuristic was provided. The direct competition involved risk of not knowing if they would win. Although the payoff was higher for the direct competition, the risk was also higher. In informal discussions with groups of mixed underrepresented minorities and non-underrepresented minorities, this risk was a big factor in their decision making. In project 4, we changed the extra credit structure for the direct competition to address the risk factor (3 points for top place, trickling down to 1/2 point for the 4th place) but nothing changed in the student choices.

During this study, an interesting aside developed. The results of each competition are available publicly on the primary author's website. Students were asked to choose a name for their teams. We asked them to include some part of their name in the team name to make it more efficient to assign the extra credit. Two of the groups containing underrepresented minorities did not want to put part of their personal names into their team name. This may be a response to the additional visibility that can come from being a member of an underrepresented group (called spotlighting [17]) or it may be related to the risk-avoidance behavior also observed in the international students.

Student groups are permitted to change their competition preferences for each project. Table II examines the trajectory of the student groups' competition choices across projects. Interestingly, no group persisted in the direct competition for all four projects yet four international groups persisted in indirect competition. We also measured choices from project 1 to project 2 and there the choices of the underrepresented groups can be seen more clearly. They chose indirect or moved from direct to indirect at a higher frequency than the groups with no URM students.

IV. Discussion and Future Work

Although this change in classroom practice was designed to support women students, the primary beneficiaries appear to be the international students. While we don't typically consider international students within the framework of underrepresentation in engineering, these are students that can be marginalized in the classroom by lack of fluency with English (real or perceived) and social customs. The U.S. higher education system also places these students under more pressure since their ability to remain in the U.S. is dependent upon their academic success. International students may be strategically choosing to avoid an outcome with a high penalty (failing a course) by taking the less risky indirect competition route.

While international students may have benefitted most from this innovative practice, two groups of White male students also chose to persist in the indirect competition. As is often the case, this shows that course design changes that are made to support specific groups can be beneficial across the board.

Future work in this area should include a deeper and more comprehensive analysis of: student motivation, choices in competition selection, and direct queries of students to determine group membership and identity and decision making patterns. An analysis of choices made by marginalized students if teams are allowed to display or conceal their individual identities could also be fruitful.

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Evaluation of Computer Modules to Teach Metacognition and Motivation Strategies

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***Abstract*—Two e-learning modules are being developed to improve self-regulation and lifelong learning readiness. More than 150 mechanical engineering students completed first versions of the two modules in 2012. An evaluation of the module results suggests that students are learning the module content and tend to enjoy taking the modules. The modules were also tested as an intervention for improving lifelong readiness as measured by the SDLRS. Comparing scores of the SDLRS taken before and after the modules showed a statistically significant gain ($p<0.1$). Comparisons were also made between the 2nd and 3rd year classes and between women and men. Suggestions for improvements to the modules have been identified.**

Keywords—e-learning; self-directed learning; learning styles; motivation

I. INTRODUCTION

Engineering work is changing due to globalization and the rapid advance of communication and other technologies. Engineering education is changing too with the advent of more online delivery. Personalized learning will grow as adaptive e-learning software develops. Are engineers and engineering students prepared for these changes? One of the most valuable skills that engineering students can learn is the habit of lifelong learning. To be effective in their careers and in school, engineers will need to become independent learners. Senior design and graduate projects are effective for developing independent learning ability. Are there other less expensive interventions that can accelerate student development?

Pintrich identifies four areas of self-regulation: cognition, motivation/affect, behavior, and context [1]. This project focuses on the first two areas—cognition and motivation. Our objective is to develop and test two e-learning modules that raise student awareness of their own cognition and motivation and subsequently provide strategies for improving learning.

II. METHODS

For the metacognition module we focused on learning styles. The goal for this module was for students to experience the difference in learning when material is presented in a way that targets different learning styles. The motivation module manipulated two aspects of motivation: task value and control beliefs. Again, the goal was for students to experience what it is like to learn with different motivation levels. In evaluating the modules, two aspects are of interest in this paper. First, did students experience what we intended? Second, did the modules have an effect on lifelong learning ability?

Lifelong learning ability was measured using the Self-Directed Learning Readiness Scale (SDLRS) instrument [2]. Other researchers have done factor analyses of SDLRS results. For example, Hoban, et al. [3] used the SDLRS to identify four dimensions of lifelong learning readiness: curiosity, self-confidence in learning abilities, responsibility for one's own learning, and the attitude that learning is a tool for life.

Starting in the spring 2012 semester we recruited students to take the modules along with the SDLRS as both a pre and post-test to the modules. Mechanical engineering students were recruited from both a second year manufacturing class and a third year design class.

III. DESCRIPTION OF E-LEARNING MODULES

Although learning styles have been widely used by educators, their usefulness is not without debate [4]. A number of classification schemes have been adopted. We chose the Barsch Inventory [5] for our e-learning module because it is simple and can be used free of charge with permission. It identifies four learning styles: visual, aural, tactile, and kinesthetic.

The learning styles module teaches about two biology topics—Punnett Squares and mitosis. Biological topics were selected because it seemed likely that few Mechanical Engineering students would have taken classes in the subject beyond high school ensuring that all would start at the same level. (This turned out not to be the case, however.) Four presentations were prepared for each topic—one for each learning style. Students are presented with information about one of the topics in their most preferred learning style and the other topic in their least preferred learning style. For the visual presentations, the module presents PowerPoint slides. For the aural presentations, the module directs students to Khan Academy videos; these combine both visual and aural. For the two topics selected, a purely aural presentation would probably have been ineffective. For the tactile presentation, the module

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asks students to view a video and take notes. For the kinesthetic presentation, the module presents interactive flash animations that were created specifically for the module.

After the learning styles questionnaire, students take a pre-test on one of the biology topics, then proceed through a tutorial on the topic, and then take a post-test. This procedure repeats for the second biology topic. Next, the students learn of their Barsch Inventory results, and they go through a tutorial about learning styles and suggested strategies for different style learners, followed by a post-test. The module concludes with evaluation and reflection questions.

The motivation module follows a similar format as the learning styles module. It starts with the Motivated Strategies for Learning Questionnaire (MSLQ) [6]. Students are asked to consider the course in which they are assigned the module when answering the questions about motivation. This questionnaire is based on an expectancy-value theory for motivation and measures control beliefs, extrinsic motivation, intrinsic motivation, self-efficacy, task value, and test anxiety.

The module then has learning tutorials in which two components of motivation are manipulated: task value and control beliefs. To manipulate task value, the module has tutorials on two quite different topics that would have different levels of interest for students: osmosis and the Northern Lights. Before the task value tutorials, the module asks students to rate their interest in the two topics. We anticipated that the Northern Lights topic would be more interesting for most students, but it was not for all students, and it was not necessary for that to be the case. After completing the two tutorials that include pre and post tests, students answer questions about their reflections on task value. For the control beliefs manipulation, the module includes two topics about which we anticipated an engineering student would have different confidence levels. The module introduced the photosynthesis topic by stating that it would be difficult material for a mechanical engineering student. The introduction to the aluminum can manufacturing tutorial indicated that it would be easy for a mechanical engineering student to learn.

Next, the module informs the student about their scores on the MSLQ, and it describes where motivation comes from. It then gives learning strategies that address the components of the MSLQ [7]. Like the learning styles module, the motivation module concludes with a series of questions asking students to reflect on the module experience and finally evaluate the module with suggestions for improvement.

IV. RESULTS

A. Data Collection

Data was collected in the spring and fall semesters of 2012. In the spring 2012, there were both intervention and control groups. Unfortunately, in this semester, we lost many research participants from the beginning to the end of the semester and had relatively few matched pairs of pre and post SDLRS scores. Also, we noticed that pre and post scores on the SDLRS could vary widely which suggested that students rushed through it the second time. In the fall 2012 semester we took a different approach. We asked half of the students to take the SDLRS prior to the modules and the other half to take it after the modules.

B. Learning Style Module Evaluation

Learning style preference scores for the students who took this module reflect earlier studies with engineering students where the most preferred learning style is visual and the least preferred is auditory.

Pre and post-tests were used to gauge students' learning of key concepts from the biology topics tutorials. According to pre-test scores, students were much more familiar with the Punnett Square than they were with Mitosis. The average pre-test score on the Punnett Square test items was 55.0% (s=34.13%) and the average pre-test score on the Mitosis items was 30.0% (s=31.0%). Gain scores on the Punnett Square items (24.9%) were slightly different than gains on the Mitosis items (30.2%); however, the differences in gains were not significant. Further, gains were not statistically different between the groups based on whether they were utilizing their most preferred or least preferred learning style. Thus, it appears that the students were able to adapt to learning through their least preferred style and still gain from the experience.

Students were also given a post-test that assessed their understanding of differences in learning styles. The average score on this test was 71.2% indicating that by the end of the module, most students had an acceptable understanding.

Table I shows the questions used to obtain attitudinal measures. In this and subsequent tables, SA=Strongly Agree, A=Agree, N=Neither Agree Nor Disagree, D=Disagree, and SD=Strongly Disagree. The results for 163 students suggest that the majority enjoyed working with the module and felt that they learned something from it. Additional open response questions provided further insight. For example, many students responded that they have taken some type of learning styles instrument before and thus they were not surprised about their most and least preferred learning styles. However, many believed that the strategy suggestions would be helpful to their learning. Also, for many the biology topics were not interesting and the module was boring. Based on this feedback, we are developing content on additional topics, and we are investigating the feasibility of using a different and perhaps less familiar (to the students) model of Felder and Silverman [8] for the learning style instrument and tutorial presentations.

C. Motivation Module Evaluation

The motivation module concluded with a similar set of evaluation questions. Table II shows the results from this evaluation from the 152 students who took the motivation module. This module is longer and had more difficulties in terms of browser compatibility. That meant that some students had to take the module with more than one browser to get it to work, creating frustration. A number of open-ended questions were also asked in this module. The results suggest that the manipulations of task value and control beliefs may not be having the impact we are looking for. Also, students complained about the module being too long and boring. These are areas for improvement.

TABLE I. STUDENT RESPONSES TO ATTITUDINAL QUESTIONS ABOUT THE LEARNING STYLES MODULE (N=163)

	SA	A	N	D	SD
I thought the module was easy to use	39%	43%	15%	3%	0%
I understand differences in learning styles after completing the module	26	60	12	2	0
I enjoyed working with the module	14	44	26	15	1
I was surprised to find out my most preferred style	7	25	37	23	8
I was surprised to find out my least preferred style	3	23	33	29	12
I think the listed strategies of my preferred learning style will help me become a better learner	15	44	31	8	2
I will apply what I learned through completing this module to my learning in this class	12	48	29	5.5	5.5
I will apply what I learned through completing this module to my learning in other classes	14	50	25	6	5
Overall I would rate this module	E 7	VG 39	G 37	F 14	P 3

TABLE II. STUDENT RESPONSES TO ATTITUDINAL QUESTIONS ABOUT THE MOTIVATION MODULE (N=152)

	SA	A	N	D	SD
I thought the module was easy to use	14%	64%	15%	6%	1%
I understand different aspects of motivation after completing the module	15	67	13	4	1
I enjoyed working with the module	5	46	31.5	15.5	2
I was surprised by my motivation scores	10.5	42	31	15.5	1
I think the strategies for improving motivation will help me become a better learner	9	59	23	8	1
I will apply what I learned through completing this module to my learning in this class	8.5	57	21.5	11	2
I will apply what I learned through completing this module to my learning in other classes	8	60	20	10	2
Overall I would rate this module	E 6	VG 30	G 43	F 20	P 1

D. Assessment of Intervention

The intervention in this case is the taking of the modules. We believe that lifelong readiness will improve if the modules make students more aware of factors that affect their learning. To test this hypothesis, we compared SDLRS test scores before and after taking the modules. The average SDLRS score for the 258 students who took the test as a pre-test was 216 (50^{th} %ile for adults) while the average for the 79 students who took it as a post-test was 221 (57^{th} %ile). A two-tailed (with the assumption of equal variance) t-test of the difference between these two groups produced a p value of 0.074. The four factors from the SDLRS were also compared. Self-confidence, responsibility for one's learning, and curiosity were all higher in the post-test ($p<0.1$).

This is an encouraging result but we need to look more closely at the two groups of students. For example, the students who took the post-test had to follow through and complete the two modules. In other words, students doing the post-test may have already started with a higher level of traits such as responsibility and curiosity.

In a second analysis we compared the SDLRS results of the second year manufacturing class and the third year design class. In the second year course, the average pre and post scores were 215 and 219, respectively. In the third year course, the average pre and post scores were 218 and 223, respectively. The differences between the second year takers and the third year takers are not quite statistically significant ($p=0.16$). Interestingly, the only factor with a statistically significant difference between the older and younger students (combining both pre and post test takers) is self-confidence. A third analysis showed no significant gender difference for the SDLRS score or the sub-factors.

V. CONCLUSIONS

With the goal of improving student awareness and lifelong learning readiness, the project team has developed two computer modules that teach about learning styles and motivation. The modules take between 30 and 60 minutes to complete and thus represent a very short intervention. More than 150 students have taken the two modules. As an intervention, the evidence so far indicates the modules may be having a modest effect on lifelong learning readiness. We are examining additional data collected by the modules to identify ways to improve the modules.

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On Mentoring Relationships: How to Become a Good Mentor

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***Abstract*- Engineering faculty have many types of relations with their students. In class, they are primarily the facilitators of learning. Also, act as advisors guiding students through their years of education. In some cases, the relationship between the student and the professor evolves into a mentoring relationship –which is the topic of this paper. This paper takes a practical look at the challenges and rewards of experienced engineers and educators becoming mentors for students or young practicing engineers. The author recommends an approach to mentoring that is deep in self-evaluation, one that considers the intellectual, social, cultural, and professional development needs of students and young professionals, and the need for taking little steps—one person at a time—that may make a big difference in student's performance and attitudes towards learning. It is argued that such an approach to mentoring will help encourage more underrepresented groups, such as women and minorities, to pursue careers in engineering. The paper, also, describes some attributes of mentoring and suggests how a faculty member might become a good mentor to students.**
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Keywords-mentoring relationships, mentoring attributes, helping students meet their needs, how to become a good mentor.

I. Introduction

Mentoring is not a new concept. Many of us have benefited from a trusted mentor. Perhaps we called them a friend, family member, or an advisor, whose opinions and experiences we trusted. They created an intangible bond with us through their experiences, opinions, and the time they took to give us advice and counsel. As professional engineers, many of us have the same opportunity—by getting involved in two aspects that are vitally important to the engineering profession. The ***first*** is to make a positive impact on the life of a young, aspiring professional or student. The ***second*** is to help solidify the role of engineering in a fast paced, diverse landscape. How best to start? Begin by assessing what we have to offer as mentors. The main role of a mentor is to stimulate students or young professionals to think in new and creative ways. One of the biggest values to bring to mentoring is a broad perspective—and how that perspective can be of value to students.

From author's experiences, a key issue in "starting where they are" relates to our own preconceived notions about students and their abilities to evolve into the field of engineering. It is all too easy to consider general educational trends that indicate a woeful lack of most students' preparation in math and science. The logical extension of such thinking is: They don't have what it takes to succeed in engineering. Let us not waste our time and resources. In light of this, do we simply give up? Or do we rally our resources to help students do better? There is only one real option - how do we meet students where they are in their educational preparation, and how do we help them develop their core competencies so they could one day become engineers?

The paper takes a practical look at the challenges and rewards of experienced engineering educators becoming mentors for students or young practicing engineers. The author recommends an approach to mentoring that is deep in self-evaluation, one that considers the intellectual, social, and professional development needs of students and young professionals, and the need for taking little steps—one step at a time—that makes a big difference. Such an approach to mentoring will help encourage students, particularly underrepresented groups, to pursue careers in engineering.

The relationship between the mentor and the student may last for many years after student's graduation. Often it is difficult to define, in a clear manner, what mentoring is and how a professor can become a good mentor. The paper describes some attributes of mentoring and sketches out how a faculty member might become a good mentor to students.

II. How to Become a Mentor?

So how does one become an effective mentor of engineering students? Perhaps we could list the attributes of good mentors and simply say "go ahead and do that." But this approach is not without precedent. The National Academy of Sciences takes this approach in its book, *Advisor, Teacher, Role Model, & Friend* [1]. It advises new mentors to try to implement most of the following:

- Listen patiently to their mentees.
- Try to build long lasting relations.
- Don’t abuse your authority.
- Nurture self sufficiency.
- Establish “protected time” together.
- Share yourself.
- Be constructive.
- Don’t be overbearing.
- Seek the advice of your own mentors.

But such lists are not enough. Listing the instructions for being a good mentor is like trying to learn to ride a bicycle from an instruction book, where you are instructed to: Sit down on the seat, Grasp the handlebars, and Pedal with your feet. These are good instructions, but of little value without actually getting on the bicycle and trying it out [2]. Learning to be a good mentor requires dedication and effort, although knowing some of the rules, just as in learning to ride a bicycle, are useful and helpful, but not enough.

To start the journey toward becoming a mentor, he/she will need to thoroughly understand the role of mentoring. Look at a role they are already familiar with. Most of us have had a supervisor, a boss or coach who has made a positive difference in our lives. Those people wore many hats. They acted as: role models, cheerleaders, policy enforcers, advocates, and friends. As mentors they will wear these same hats. Mentors, presumably, understand the need to assume a number of different roles during the course of a mentoring relationship, but successful mentors also share the same basic qualities [3].

- A sincere desire to be involved with a young person.
- Respect for young people.
- Active listener.
- Empathy.
- See solutions and opportunities.
- Be flexible and open.

To start, new mentors should attempt to develop relationship with their mentees; exploring values, interests and goals. Soon will find themselves making a difference and having a positive effect on their life. What they may also be surprised to see is that they will be learning more about themselves. Mentoring doesn't just affect the young person. Mentoring is a shared opportunity for learning and growth. Many mentors say that the rewards they gain are as substantial as those for their mentees. Being a mentor enables them to:

- Achieve personal growth and learn more about themselves.
- Improve their self-esteem and feel they are making a difference.
- Gain a better understanding of other cultures and develop a greater appreciation for diversity.
- Feel more productive and have a better attitude at work.
- Enhance their relationships with their own children.

An effective mentor is willing to take time to get to know his/her mentees, to learn new things that are important to the young person, and even to be changed by their relationship. Undoubtedly the mentor has to accept the challenges and rewards of mentoring a young person. Also, he/she will experience the benefits that will last a lifetime [3].

III. The Mentor as a Friend

Some academics believe and advice strongly in maintaining a business-like relationship between mentors and mentees. They claim that a professor should not have any casual relationships with students, and such relationships “conflict with our fundamental obligations as faculty members” [4], and the ethics of the relationship require that the faculty member remains “dispassionate,” avoiding any appearance of partiality. The faculty member should “not seek to be their psychiatrist, friend, or lover.”[5]. While some of us may agree about the psychiatrist and lover part, many of us do not agree that friendship between students and faculty members has ill effects and should not be allowed. Too often we tend to be overly cautious and keep students at a distance, not offering them the encouragement and support they need.

I firmly believe that teachers, at all levels, should try their best to offer friendship as part of their professional role. There are times and situations where friendship is exactly what is needed in the mentoring relationship. Such a friendship does not have to be destructive or result in unjust impartiality [2]. A note of encouragement, a friendly gesture, asking underachieving student to chat, answering e-mail, paying attention to students’ extracurricular activities and achievements----are all indicators of friendship and do mean a great deal to students[2]. As pointed out by Richard Baker, “The key ethical point is that the professor-both inside and outside the classroom- should act as a friend” [6].

There is a clear difference between a “friend” and “pal”. The professor/mentor has a clear position and special power relationship with the student/mentee, and may be called on to evaluate performance and to do so “dispationately”.Therefore; a mentor can not be a pal, shooting hoops with students, spending time with them in “restricted” places such as taverns and bars, or joining them in night activities such as dancing, etc. A mentor trying to be a pal may destroy the fragile relationship between student and professor that is such an integral part of education [2].

IV. How to Get Started and Proceed Onward?

How best to start? Begin by assessing what you have to offer as a mentor. As a mentor your role is to stimulate students or young professionals to think in new and creative ways. One of the biggest values a faculty member can bring to mentoring is a broad perspective, and how that perspective can be of value to students. From author’s experiences, a key issue in "starting where you are", relates to our own preconceived notions about students and their abilities to evolve into the field of engineering. It's all too easy to consider general educational trends that indicate a woeful lack of most students' preparation in math and science. The logical extension of such thinking is: they don't have what it takes to succeed in engineering. For example, numerous international studies indicate that, compared to peers in other countries, U.S. students underachieve in math and science.

The French-based Organization for Economic Cooperation and Development (OECD), comprised of more than thirty member countries, conducted an international comparison in 2003 of mathematics, reading, and science skills among fifteen-year-olds [7]. More than 250,000 students in forty-one countries participated in the assessment. On the mathematics scale, the United States ranked twenty-fifth; on the science scale, the United States ranked twentieth; and on the reading performance scale, the United States ranked twelfth. Other educational indicators are equally alarming. Nearly half of all high school students in some of the nation's largest cities drop out before receiving their diplomas [8]. In some parts of the country, about a third of all high school students fail to graduate [9], and among those who do receive their high school diploma, many find that they are not prepared for the rigors of college academics. Equally alarming, more than a third of first-year college students received or planned on getting remedial help in math during their freshman year [9]. And finally, even though males and females take similar math classes and achieve similar scores in the K-12 environment, the participation rate of males in math is far greater than that of females after high school [10]. In light of these findings, do we wave the white flag and simply give up? Or do we wave a red flag to rally our resources to do better? There is only one real option. Yet, ***how do we meet students where they are in their educational preparation***, and how do we help them develop their core competencies to become engineers?

As faculty members, we must remember that not all students coming into the college or university environment will be developmentally ready for the academic challenges they face. Our role is to help students develop their potential and capabilities so they can earn an engineering degree. How do we develop them? The best way, in my opinion, is to approach one's development from intellectual, social, and professional vantage points. In my role as a faculty member, I work to develop the intellectual capability of my students. But the other elements—social and professional development and maturation—are equally important. All of these attributes carry equal weight because they come together in the same package. In increasing fashion, we must develop students not only intellectually, but in the other dimensions as well so they can lead, compete, and participate in, or contribute to, a complex and increasingly diverse workplace [11].

It is not just the students who stand to benefit from an effective mentor. Engineers, new to the profession, also, need mentoring, often until the point of professional licensure and even beyond. Effective mentoring of young engineering professionals is a two-way street. A young professional's energy, new ideas, thirst for information, and willingness to learn give any organization spirit and momentum. In mentoring a young professional, it's important to provide opportunities for the mentee to take part in team building, brainstorming and planning sessions, and to build relationships throughout the organization. Such processes and experiences are of significant benefit to the mentor as well. Mentoring is perhaps the best way to ensure that one's intellectual and experiential legacy can be tapped, improved upon, and be of continual benefit to the organization. Let us not forget that engineering is a profession in which learning occurs continuously [11].

It begins with formal education and continues through various developmental experiences, including a positive, long-lasting mentoring relationship. It was noted above that mentoring provides organizations with spirit and momentum. That is true. In addition, it is the personal nature of these relationships that give organizations their strength. Mentoring, however, is one part of the picture. Life experiences are another. We must continue to push for new ways to expose students to diverse experiences. That is how they will grow. It is one thing to watch and listen, and another entirely to be in the middle of a real-world situation experiencing it. Students gain from activities that include profession-related travel abroad, cooperative experiences, and community involvement projects that put them in contact with a wealth of opinions, new ideas, and alternate ways to approach an issue. How do we accomplish our lofty objectives? ***We start where we are and help the next generation through mentoring.***

V. Mentors' Attributes and Outreach

The most effective mentors, irrespective of their field of study and/or concentration, share similar attributes. What they have are abilities to listen, question, challenge, and offer feedback and support. These are the qualities central to faculty roles as mentors. What mentors also have are young people who stand before them with a variety of backgrounds, educational preparations, and aspirations. The mentors would strive to raise their capabilities and help them develop in a holistic fashion intellectually, socially, and professionally. Each student or young professional is a collection of his or her individual backgrounds, traditions, and aspirations. They, also, each represent an opportunity for teachers as mentors to use their resource as reservoirs of experiences in helping them prepare for an engineering career to last a lifetime.

A call to mentorship should not be an unusual thing to read. As educators and professionals, we have an obligation to help those who need to be nudged along the way. Mentoring a young professional or a student is part of the package of professional responsibility. We do not need another study to make this happen. Just look at each student individually, on a case-by-case basis. That's the secret. We just have to move beyond what engineering has historically been good at—systematic problem solving—and apply our special skills to solve a problem that could one day undermine the profession: a paucity of ideas and creative solutions that could only come from the mindset of those who are currently unheard throughout the profession[11].

In general, there are many qualities of good mentors. Some are not easily attainable, and do require firm commitment, self discipline, training, and patience. The author has noted in Table 1, some of these qualities that all mentors need, accept, affirm, abide by, and resort to when the need arises.

TABLE 1. QUALITIES THAT MENTORS SHOULD POSSESS

THE MENTOR IS:
• Approachable and welcoming in the office and outside. • Shares information, knowledge and experience openly. • Has good communication and listening skills. • Understands the field of engineering and related areas. • Has a network of contacts within the college, university and industry. • Is motivating, encouraging, positive and empowering. • Is willing to set aside/commit time to mentor someone. • Is committed to making a difference, one individual at a time. • Does not wait to be asked, approaches mentees when he/she feels there is need.

It's amazing the differences that a personal commitment can make to the life of another. We cannot expect to change the professional makeup of engineering overnight, and perhaps not even in years. But, with individual commitments, we can take positive steps, one person at a time [11].

VI. Mutual Acceptance and Satisfaction

The relationship between the mentor and the mentee can be mutually satisfying and rewarding to both party, but may also be the cause of anguish and pain. One may ask if the mentor/mentee system is a reliable one, or if some other system may be better? For example, consider a situation where every faculty member in a department advises every student in that department on equal bases. In time, would students not seek out one or more professors whom they have the strongest rapport and whose advice they begin to appreciate and value? Also, would the professors not begin to identify those students they most would like to advise and in whom they see their vision and aspirations become a reality? In other words, positions are subject to change and students will eventually migrate to those professors/mentors who they most desire to be their mentees.Therefore, the mentor/mentee system can neither be selected nor imposed, but rather a natural outcome of feelings and convictions of the two parties involved.

Unfortunately, the advising system in most universities is not ideal and may force a student to accept an advisor without mutual consent, or changing student's field of study may force a change in advisors, or the faculty member may leave the university or go on leave, thus forcing a change in advisors. The process is dynamic and the relationship that looked good at the beginning of student's journey can go sour with student's maturity or as a consequence of added responsibilities. It is therefore possible for students to face what is referred to as "toxic mentors" [2]. Students caught in a trap with a toxic advisor can either live with it or attempt to graduate as fast as they can, or try their level best to change their advisor. Neither is easy. Changing advisors is often difficult and almost impossible in some universities, due to rules and regulations on advising. An incompetent and /or an impatient advisor is often the cause of dropping out, or failure of students to accomplish their goals in engineering programs.

VII. Building Trust with Students

Underlying almost all aspects of learning is the element of trust. Trust between teachers/mentors and students is the affective glue binding educational relationships together. Not trusting teachers has serious consequences for students. Students are unwilling to submit themselves to the uncertainties of novel and unfamiliar approaches to learning. They do want to avoid risks and keep their deeply felt concerns private. The more profound and meaningful the learning is to students, the more they need to trust their teachers and mentors [12]. The importance of trust is experienced, time and time again, in students' critical incident responses, i.e., when students are off track and/or lose patience, and reach the stage where they can no longer exercise good judgment; then, they do need the care and attention of their mentors. At the center of the cluster of characteristics that make teachers/mentors more trustworthy in students' eyes are two components that may be described as teacher's *credibility* and teacher's *authenticity*.

Teacher's credibility: Teacher's credibility refers to teacher's ability to present himself/ herself as a person with something to offer to students. When teachers have this credibility, students see them as possessing a breadth of knowledge, depth of insight, and richness of experience that far exceeds students' own. Shor and Friere [13] describe credibility as the "critical competence" that students have the right to expect of their teachers and mentors. Almost all students continually stress their desire to be in the presence of someone who is knowledgeable, skilful and an expert in his/her field, i.e., meaning that he/she can help students come to grips with the contradictions, complexities, and problems they are experiencing.

Teacher's authenticity: Authentic teachers are those that students feel they can trust [14]. They are also those whom students see as human beings with passion, frailties, and emotions. They are remembered as whole persons, not as people who hide behind a collection of learned role behaviors appropriate to college teaching. In more specific terms, students see four types of behavior as evidence of authenticity: i) teachers words and actions are congruent**;** ii) teachers admit to error, acknowledge fallibility, and do make mistakes in public view of learners**;** iii) teachers allow some aspects of their personality (outside their role as teachers or mentors) to be revealed to students; and iv) teachers do respect learners by allowing them to express their views and by being open to changing their practice as a result of students' suggestions.

Steps towards trust buildings: Trust is not something bestowed on teachers and mentors just because they are teachers or mentors, it must be earned! Undoubtedly, it takes time, effort, and willingness on the part of the teacher and the mentor to earn the trust of the students. Teachers must remember that not only can they not expect students to trust them from the outset; they most likely have to face accumulations of mistrust nurtured by actions of cynical, arrogant, and indifferent teachers in students' past. This is likely to arise when the teacher is facing the students for the first time; and face also their accumulated educational histories and their memories of the teachers they have experienced in the past. Building trust is neither quick nor easy. It may be very dispiriting to realize that one's efforts to build trust with his/her students may often bring little immediate results. With patience and persistence, however, and with the advice of those teachers and mentors with experience, it is possible to build trust where none has existed before. Undoubtedly, students will remember the time they spent with a *caring* mentor who has done his/her level best to understand and be of help to them. There are those steps and /or precautionary measures that the teacher/mentor should be aware of and attempt to follow, if and when the need arises. These measures include:

First, Denial of one's credibility: Teachers' protestations that they don't really know any more than students do, and that they are simply there to help students realize that they already possess all the knowledge and skills they need. If students conclude that teachers' experiences have left them with no greater skill, knowledge, or insight than that already possessed by them, then there is nothing useful to gain from teachers. Teachers should be careful not to undermine their credibility in the eyes of their students.

Second, Be explicit about one's organizing vision: It is quite normal to have visions that guide the practice. However, when teachers deny having any visions, plans, or educational agenda, yet through their actions do make it apparent that such visions exist and do influence classroom activities. Not to be explicit about their plans, and agenda, at the outset, confuses students & is fundamentally wrong [12]. Should be avoided.

Third, The congruence of words and actions: Few things destroy students' trust in teachers and mentors more quickly than teachers who say they will do one thing and proceed to do something very different. Or, teachers who espouse one set of plans and principles then proceed to implement something else. Teachers ought to be careful and take necessary measures to safeguard them against falling in this trap.

Fourth, Be willing to admit that you make mistake: Teachers and mentors who acknowledge that they do not have all the answers and that, like their students, they sometimes feel out of control. Such acknowledgement helps reduce the tension students feel about their own need to be seen as perfect by their peers. While declarations of fallibility from teachers who earned credibility are appreciated by the students, the same declarations from those teachers who have not earned their credibility as yet - are basically unknown quantities- may produce the opposite effect of the one intended.

Fifth, Revealing aspects of one's self unrelated to teaching: Nothing wrong when mentors refer to enthusiasms, passions, and concerns outside his/her teaching and advising role. Revealing aspects of one's personhood gives students a sense that they are in the presence of an ordinary person; thus helps in bridging the gap that may have developed between students and their teachers. Often, teachers use incidents from their own daily lives to illustrate general principles, and talk about those passions that led them to develop an interest in their fields, Also, their own enthusiasms that sustain and renew these interests [12, 15].

Sixth, Show that you take students seriously: A caring teacher should listen to any concerns, anxieties, or problems voiced by the students. If none are forthcoming, the teacher should encourage students to speak out their minds and express their concerns - no matter how misplaced or trivial it may be- without interruption, rephrasing, or interpreting their concerns. Even if the teacher is confused about what a student is saying, he/she should be patient and chances are that the same concern will be expressed by another classmate in a clearer manner. When students suggest topics, exercises, and issue they wish to explore, even if these are outside the original scope, the teacher/mentor should consider seriously how to make some compromise to include some of what has been suggested by the students [15].

Seventh, shouldn't play favorites: Almost in every class there are those students that the teacher prefers to listen to more than others, people whose work he/she looks forward to receiving, and those whom he/she would welcome as personal friends. Conversely, there are those whom the teacher may dislike personally, and whom he/she thinks are "boring", insensitive, and do not give the course the effort and attention it requires. As a human being, it is normal to warm up for some and freezes in the presence of others. But if the teacher is to be trusted by all students, it is absolutely essential that he/she does not allow himself/herself the luxury of exercising these personal dislikes, and definitely needs to avoid playing favorites. Playing favorites destroys one's credibility in students' eyes very quickly [15, 16].

***The concepts of credibility, authenticity* and the suggested steps towards building trust between students and their teacher and /or mentor** are elusive, and made the more so by the fact that they are not standardized. It is not possible to develop ways of telling people how to be credible or authentic, since contextual features affect so strongly how students and teachers define credible and authentic behaviors. The most that could be done is to offer guidelines, give examples of how teachers/mentors in different environments try to build trust, and urge those, who wish to benefit from such experience, to try to implement some of the guidelines mentioned earlier. Teaching and advising with care is not easy, and all of the potential balances a teacher is encouraged to try to attain being credible and authentic in the right proportions is a difficult task. But *caring* teachers/mentors should not be discourage or neglect the need to build credibility in students' eyes, then, chances are that students will have little confidence in what the teacher/mentor asks them to do. And if the teacher behaves inauthentically, students will regard teacher's asking them to do it as a self-serving confidence trick.

VIII. Do What You Can?

Despite all the problems that may arise and the difficulties that an advisor or a mentor may face, mentoring is, in author's opinion, intensely personal, interactive, and rewarding. Mentoring can be achieved through a variety of methods. Here's how to "do what you can" [11]:

- Identify two to three students or young professionals who could benefit from your insights and experiences. Ask them if they have questions about the scope of engineering and how they might fit in.
- Help your students evaluate employment opportunities that they might not otherwise consider. Encourage them to think about many facets within the profession, and help them secure rewarding summer break experiences, or take a semester off and join a company as a trainee.
- Encourage students to become involved with local, regional, and national professional associations. Membership and involvement in such organizations provides students with priceless leadership opportunities and helps students develop a variety of valuable workplace skills.
- Remember that a student or young engineer may have a different or even a better idea in solving a problem. The young engineer may well bring a perspective that is much more than fresh—it may well be of the "why didn't we think of that" variety.
- Seek out students where they exist. Get involved with local high schools and help them establish an engineering club. Seek involvement with community organizations such as Big Brothers and Big Sisters or Habitat for Humanity [11].

There is little if any magic in all of this. And, we won't be successful with every student we mentor. But our efforts will be one hundred percent worthwhile as we strive to help make our profession more robust and vibrant for these complex and challenging times.

IX. University's Role in Enhancing Mentoring

The university can definitely enhance the quality of advising/mentoring available to students and increase the potential of having an adviser/advisee turn into a more effective, fruitful and lasting relationship. Some suggestions, based on the experience of some forward looking universities, may be helpful. [16].

i) The university, in general, and the college in particular, should devise policies that would allow students to have the option of selecting advisors, even if not all parties want this choice. The mentoring relationship is best fostered with sound advice and in a mutually comfortable environment.

ii) The university is, by all measures, the sole organizer for improving advising in all colleges. Training programs, short courses, seminars, etc. should be established and maintained on a college basis.

iii) The university should recognize faculty participation in an advisor training program, and encourage young faculty, in particular, to participate in such programs.

iv) The college and the respective department should establish lines of communications with advisees at all levels, asking for their opinions and views on their relations with their advisors, and how may advisor/advisee relations be improved? Such feed back would help all parties involved.

v) The university should establish a reward system for exemplary mentoring, based on feedback from mentees coupled with a statement from the nominee stating his or her philosophy on mentoring.

vi) Advising with care and mentoring should become part of the tenure and promotion process. Letters should be solicited from former students/mentees soliciting their opinions on the mentoring they received during their college years.

vii) Students at all levels should be asked to complete exit surveys, to assess their views with their advisors/mentors, and the pros and cons of their experience [16].

Implementing the above noted ideas will, no doubt, improve the advising process at any university. However, we have to be realistic. If a faculty member, particularly a senior member, does not desire to help students, there is little a university can do to improve the situation. As stated by Vesilind [2] "Mentoring does not come from a guidebook, a set of rules, or even incentives. Mentoring comes from the heart." On the other hand, those who chose to become mentors, mentoring makes a difference in their lives. It's an equal opportunity relationship that is voluntary and mutually beneficial. As a mentor, you will learn just how valuable your experiences and expertise are to another. You will discover new levels of patience and commitment not previously experienced. And you will marvel at the energy, sincerity, and fresh perspectives of the next generation of professional engineers.

X. Concluding Remarks

Mentoring engineering students provides mentors the chance to make a significant difference in someone's life. For the mentor, the benefits of helping a student realize his or her professional goals and aspirations are lifelong, too. Through mentoring, we help students discover themselves and their potential, show them how to apply their skills and special aptitudes, and guide them in defining and pursuing their own career goals. In turn, mentoring helps mentors discover new things about themselves. They will learn just how valuable their knowledge, experience, and expertise are to their mentees. They will also discover new levels of patience and commitment not experienced before. And will marvel at the energy, sincerity, and fresh perspectives of the next generation of professional engineers.

The paper addresses issues of concern to future mentors highlighting the attributes of good mentors and why and how mentors should try to offer friendship to their mentees as part of their professional role. An effective mentor should try to meet students "where they are" in their educational preparation regardless of previous set backs, concerns and incompetence. When students reach out to you, take their hand and guide them. They are saying that they trust your wisdom, your experience, and your leadership. Simultaneously, as a mentor, you will enhance your expertise, communication and leadership skills, while helping the student explore a career path and prepare for the transition from college life to the workplace.

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The Effects of Teaching Material Remediation with ARCS-Strategies for Programming Education

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***Abstract*— In this paper, a method for improving the teaching materials of programming education is introduced, and the evaluation of the effects of using the strategy is presented. By using this method, the teachers of programming education will be able to assess and improve their teaching materials irrespective of their knowledge and experience of their teaching materials already used. In this method, the teaching materials were improved based on the statistical analysis of the motivation of students. Specifically, the motivation of students was measured for each lower category of ARCS motivation model with the authors' original questionnaire. The lower category in a particular lesson that showed a statistically significant decrease from the previous lesson was identified, and the improvement strategies for the lower category were selected from the list of motivation strategies in the ARCS model. The teaching materials of programming education were then improved based on the strategy. In this research, five lower categories of particular lessons in a programming course were identified, and the teaching materials were improved. The improved teaching materials were used in the following programming course, and the effects of the improvements were seen in three lower categories out of the identified five lower categories.**

Keywords—Programming education; Motivation; Motivation strategies; ARCS motivation model

I. INTRODUCTION

Many ingenious contrivances have been made in e-Learning systems especially in the next generation e-Learning systems called Massive Open Online Courses (MOOC) in order to draw better outcomes from the learners [1]. In these systems, the emphasis was put on the learning-support mechanisms which adapt to the learners' learning outcomes, but not on the feedback to the teaching materials based on the motivation of the learners. There have not been many systems based on the quantitative analysis of the relation between the motivation of the learners and the teaching materials.

In this paper, a method for systematically improving the teaching materials of programming education using the analysis of students' motivation is introduced, and the evaluation of the effects of using the method is presented. In this method, the teaching materials were improved based on the statistical analysis of the motivation of students. Specifically, the motivation of students was measured for each lower category of ARCS motivation model introduced by J. M. Keller et al. [2] with the authors' original questionnaire that used the ARCS model as the background theory. The lower category in a particular lesson that showed a statistically significant decrease from the previous lesson was identified, and the improvement strategies for the lower category were selected from the list of motivation strategies in the ARCS model. The teaching materials of programming education were then improved based on the strategy. This method of improving teaching materials of programming education has been practiced in a university of fine art, and the effects have been evaluated.

S. W. Martins et al. proposed a strategy to improve students' motivation levels in programming courses [3]. Based on two-year experience, they assessed several aspects such as motivation, self-efficacy, and satisfaction with course activities, and demonstrated an alternative model to make introductory programming courses more productive and attractive. They asked their students to make biweekly reflections on their satisfaction with their own performance, tasks, materials and class rhythm, and this was used to introduce changes when necessary. Also, they used several instruments to evaluate cognitive aspects related to motivation. The instruments include the Inventory of Attitudes and Study Behaviors (IACHE), Course Interest Survey (CIS), and the Student Motivation Problem Solving Questionnaire (SMPSQ). However, the quantitative analysis was conducted in pre and post basis and the levels have not been evaluated on a weekly basis. If the monitored qualities change gradually from the beginning of the course to the end, the evaluation in pre and post basis is meaningful. However, the duration of the course would be more than one month long, and the monitored quality might have changed on a weekly basis. If that is the case the quality is better to be monitored on a weekly basis.

J. M. Jerez et al. presented their twelve-year experience of improving their programming course for telecommunication engineering students [4]. Their aim was to increase student

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motivation by making the task of solving exercises more enjoyable, and they improved the teaching contents by analyzing the relation between telecommunication concepts and programming education concepts using concept maps. Basically, they changed the contents to be more suitable for telecommunication students, and the way of teaching from a teacher-centered perspective to a much more practical and student-centered one. Their analysis for improving the programming course was based on the opinions of teachers rather than opinions of the students. However, the opinions of the students are also considered to be important.

A. Forte and M. Guzdial also tried to improve motivation of their students in a CS course, and offered different contents for the students with different majors so that the students could learn CS in the context of their specialty [5]. They tailored their CS course by identifying discrete audiences and recognizing interests that lend themselves to learning about computation. In their approach, the high level contents of the courses were dealt with. For example, they offered different programming languages for the students with different majors. Though the improvement of high level contents are important, the improvement of low level contents such as each item in the syllabus are also considered to be important.

U. Nikula, O. Gotel, and J. Kasurinen approached the problem of rehabilitating the troubled first programming course in a more holistic manner [6]. Based on the opinion of the students who had dropped out of the course, they changed the teaching contents as a whole. For example, they changed the programming languages, virtual learning environments (VLE), teaching methods, support systems, and the assessment methods in a five-year period. After these broad scale changes, they suggest that the extrinsic motivators need to be established at the organizational level. Though they claimed that focusing on course elements rather than the course as a system has a serious risk of limiting the improvement efforts to local fitness peaks, establishing a systematic way of improving the local items in a programming course is also important.

Holistic approach is important to achieve significant improvement, but the approach is rather heuristic. For example, it is difficult to find a systematic way of changing the programming language in a programming course. The approach in this research is not holistic, but rather local in a programming course. Each item in the syllabus is the subject of improvement and the incremental improvements were supposed to be accumulated. The students' opinions are systematically collected, and the improvements have been made using motivation strategies.

II. THE PROGRAMMING COURSE

In this research, an introductory programming course in which computational figures were used as teaching materials was offered twice to the sophomore students in Osaka University of Arts. In the course, Processing language [7], which is a Java based language that facilitates the development of visual projects, was used.

The first programming course in which students' motivation was monitored was offered from June to July, 2012. There were 60 students in the course, and two classes per week

TABLE I. SYLLABUS OF THE PROGRAMMING COURSE

Week		Learning items	Details
First	**Second**		
L1-2	L1-2	1. What is Processing 2. Drawing figures 3. Variables and calculation	size, background, point, line, ellipse, rect, triangle, println, stroke, fill, smooth, strokeWeight, int, float
L3-4	L3-4	4. Repetition	**for**
L5-6	L5-6	5. Color	colorMode, RGB , HSB
L7-8	L7-8	6. Input Exam1	void draw, frameRate, mouseX, mouseY, save, mouseClicked
L9-10	L9-10	7. Conditional branch 8. Random Assignment1	**if**, random, mousePressed, rectMode, ellipseMode
L11-12	L11-12	9. Images 10. Font	Pimage, Image, image, filter, text, textSize, textAlign, Pfont, textFont
L13-14		10. Font (Cont'd) Assignment2	rotate, translate
L15-16	L13-14	11. Animation 12. Arrays	frameRate, algorithm of movement
L17-18		Assignment3 Exam2	2D animation

were conducted for 9 weeks (one class is 90 minutes). The questionnaire based on the ARCS motivation model was conducted once a week in order to assess the motivation of the students.

The second programming course was offered from October to December, 2012. There were 28 students in the course, and two classes per week were conducted for 7 weeks. The questionnaire based on the ARCS model was also conducted

TABLE II. THE QUESTION ITEMS IN THE QUESTIONNAIRE

	Attention
A1	Perceptual arousal: Did the learning content give you new and surprising incentives to learn during the programming education?
A2	Inquiry arousal: Did you feel that you wanted to learn more during the programming education?
A3	Variability: Could you study without getting bored because there were variations in the learning content?
	Relevance
R1	Familiarity: Did you feel that the learning content was familiar?
R2	Goal orientation: Did you understand the goal and the importance of the learning?
R3	Motive matching: Did you have chances to select the learning methods that were suitable to you?
	Confidence
C1	Learning requirements: Is the goal you should reach clear?
C2	Success opportunity: Did you feel that you had written your programs well?
C3	Personal control: Did you feel that you wrote your program well because of your efforts and ability?
	Satisfaction
S1	Natural consequence: Did you have occasions to use your newly acquired knowledge?
S2	Positive consequence: Were you happy when you did well?
S3	Equity: Was your accomplishment fairly evaluated with a consistent standard?

once a week. In this course too, the questionnaire was conducted once a week.

The syllabus and the teaching materials used in the courses were designed in accordance with the ARCS motivation model in order to raise the motivation of the students. The syllabus and the teaching materials used for the two courses are shown in Table I. Though the syllabuses for the two courses look the same, some modifications based on the analysis of the first class were made in the second class.

The students in the two courses studied the same contents from L1 to L10 (first 5 weeks). In the first course, the students were taught image processing in Chapter 9 in the teaching material, and font processing with “textFont” in Chapter 10 in L11-L12, and they were taught font processing with “translate” in L13-L14. These contents were taught all together in L11-L12. Also, in the first course, the students spent two weeks (from L15-16 to L17-18) to work on animation processing, arrays, and final assignments, but the students in the second course spent only one week (L13-L14).

III. THE MOTIVATION ASSESSMENT EQUIPMENT

The motivation of the students in the programming courses was analyzed using the authors’ original questionnaire based on the ARCS motivation model [2]. This model has four factors (*Attention*, *Relevance*, *Confidence*, and *Satisfaction*), and each factor has three lower categories, and therefore there are twelve lower categories in total. The lower categories and the corresponding question items of the questionnaire are shown in TABLE II. Though the question items in the table are in English, the actual questionnaire was written in Japanese.

The authors developed the questionnaire, and each question item in the questionnaire was designed to ask if each of the twelve lower categories in the ARCS model was satisfied. Each item was presented using a five-point Likert scale where answer 5 always corresponded to “agree” and answer 1 to “disagree”. The reliability of the questionnaire was verified using Cronbach’s alpha in the previous works of the authors [8][9].

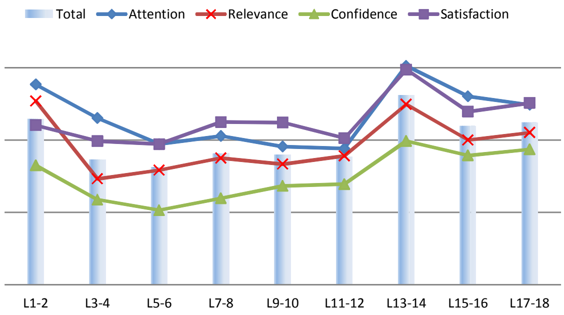

Fig. 1. Change of Motivation in the First Course

In the first course, the questionnaire was administered 9 times (once a week), and in the second course, it was administered 7 times (again, once a week).

IV. CHANGE OF MOTIVATION IN THE FIRST COURSE

The change of the average scores of the four factors is shown in Fig. 1 so that the overall trend in the first course can be understood. In this figure, the data are from the 26 students who attended more than or equal to 8 double-classes out of 9. The data of the students who were absent at most once was used for the analysis, and there were 218 effective data.

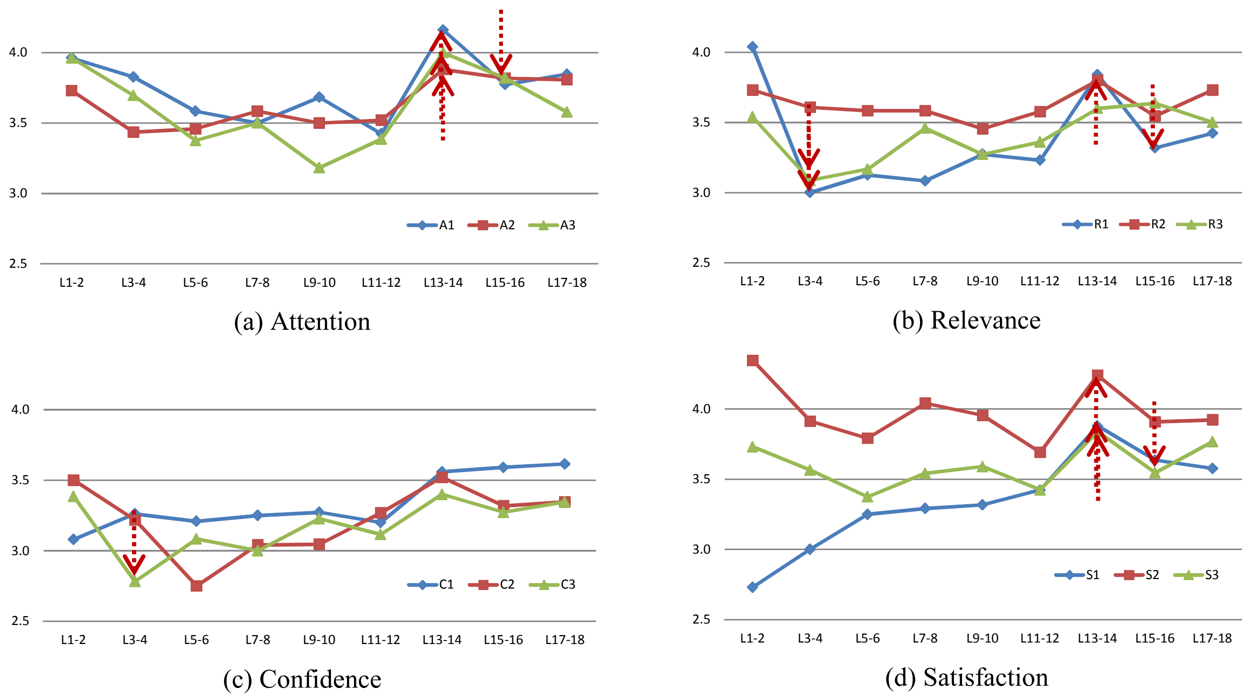

Fig. 2. The Change of Lower Category Scores

TABLE III. CHANGE OF MOTIVATION IN THE FIEST CLASS

	Attention			Relevance			Confidence			Satisfaction		
	A1	A2	A3	R1	R2	R3	C1	C2	C3	S1	S2	S3
L1-2	4.0	3.7	4.0	4.0	3.7	3.5	3.1	3.5	3.4	2.7	4.3	3.7
L3-4	3.8	3.4	3.7	*3.0	3.6	*3.1	3.3	3.2	*2.8	3.0	3.9	3.6
L5-6	3.6	3.5	3.4	3.1	3.6	3.2	3.2	2.8	3.1	3.3	3.8	3.4
L7-8	3.5	3.6	3.5	3.1	3.6	3.5	3.3	3.0	3.0	3.3	4.0	3.5
L9-10	3.7	3.5	3.2	3.3	3.5	3.3	3.3	3.0	3.2	3.3	4.0	3.6
L11-12	3.4	3.5	3.4	3.2	3.6	3.4	3.2	3.3	3.1	3.4	3.7	3.4
L13-14	*4.2	*3.9	*4.0	*3.8	3.8	3.6	3.6	3.5	3.4	*3.9	*4.2	*3.8
L15-16	*3.8	3.8	3.8	*3.3	3.5	3.6	3.6	3.3	3.3	3.6	3.9	*3.5
L17-18	3.8	3.8	3.6	3.4	3.7	3.5	3.6	3.3	3.3	3.6	3.9	3.8

It can be observed from Fig. 1 that the changes of the scores of the factors towards L3-4, L13-14, and L15-16 are significant. Decreases in Relevance factor towards L3-4 and that in Attention factor, Relevance factor, and Satisfaction factor towards L15-16 are significant comparing with other factors. On the other hand, increase in Satisfaction factor towards L13-14 is significant comparing with other factors.

The change of the score of the lower categories in the ARCS model is shown in Fig. 2. In order to find out if there is a significant change between lessons, t-test was conducted. Table III shows the scores of the lower categories with the results of the t-test (those scores that are significantly different from the previous ones are marked with asterisks). In Table III, the gray cells indicate that there is a significant difference between the score in the cell and that in the above cell with 5% significant level. Light gray cells indicate that there is a decrease in motivation levels, and dark gray cells indicate that there is an increase in motivation levels.

A decrease in motivation level is observed from L1-2 to L3-4 (Let's call it "Decrease phase 1"), and also from L13-14 to L15-16 (Let's call it "Decrease phase 2"). On the other hand, an increase in motivation level is observed from L11-12 to L13-14 (Let's call it "Increase phase 1"). Decrease phase 1, Decrease phase 2, and Increase phase 1 cover all the scores marked with asterisks. In the Decrease phase 1, the lower categories R1 (Familiarity), R3 (Motive matching), and C3 (Personal control) decreased. In L3-4, the students learned repetition with "for" statement instead of previously learned single statement of drawing figures. As a consequence, the students had to learn the new concepts such as syntaxes and algorithms, and they had problems in coping with familiarity to learning contents, selecting the learning methods, and confirmation of their own ability. These are considered to be the reasons why the scores of lower categories decreased.

In the Decrease phase 2, the lower categories A1 (Perceptual arousal), R1 (Familiarity), and S3 (Equity) decreased. In L15-16, the students learned animation programming with arrays. It is thought that the students who are familiar with high level games could not feel much new and surprising stimulus (which is the component of A1), and familiarity to the learning contents (which is the component of R1) with the simple animation and arrays. Also, for S3, while consistent evaluation standard is supposed to be applied, the instructor changed the evaluation standard from the one based on ingenuity of making still images to the one based on the movement of the animation. This can be considered to be the reason why the motivation of the students decreased.

The Increase phase 1 could be attributed to the fact that the students were allowed to work on free assignments in L14. The students could apply the knowledge and techniques they had learned to create the artwork they desired, and confirmed that what they had learned was useful. That is considered to be the reason why the motivation increased in this phase.

V. IMPROVEMENT OF THE TEACHING MATERIALS

In this chapter, the improvement strategies for R1, R3, C3 in the Decreasing phase1, and A1, R1, S3 in the Decreasing phase 2 that has been implemented are presented. These strategies are based on the Motivation strategy of ARCS motivation model [2]. Since the teaching materials and the learning items had been designed in accordance with the ARCS model so that the motivation of the students would be raised, modification of the teaching materials based on the motivation strategies would be effective. The keywords for the samplers of the strategies are shown below.

- The attention getting strategies for A1: A1.1 Audio-visual effects, A1.2 Unusual content or events, A1.3 Absence of distractions
- The relevance generating strategies for R1: R1.1 Human interest language and graphics, R1.2 Illustrations for concreteness, R1.3 Familiar examples and contexts
- The relevance generating strategies for R3: R3.1 Goal level options, R3.2 Scoring system, R3.3 Noncompetitive options, R2.4 Multiple participant opportunities
- The confidence building strategies for C3: C3.1 Exit control, C3.2 Pacing control, C3.3 Quick access, C3.4 Menu structure, C3.5 Attributional language
- The satisfaction producing strategies for S3: S3.1 Purpose and content consistency, S3.2 Exercise and test consistency

Based on these motivation strategies, some ways for improving each learning item that had shown decrease in motivation from a previous lesson were proposed. For "repetition (for sentence)" in L3-4, the improvements with regard to R1.3 Familiar examples and contexts, R3.1 Goal level

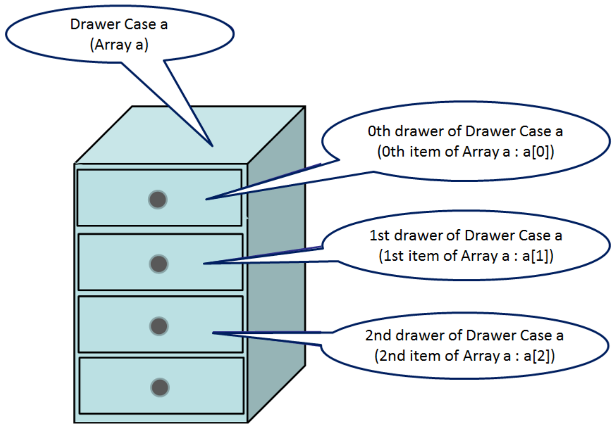

Fig. 3. Explanation of the Concept and Function of an Array

options, and C3.1 Exit control would be effective. For "movement (animation) and arrays" in L15,16, the improvements with regard to A1.1 Audio-visual effects, R1.2 Illustrations for concreteness, and S3.1 Purpose and content consistency would be effective.

Before starting the second course in October 2012, some modifications were made to the teaching materials that had shown decrease in motivation from a previous lesson. The explanation for the learning item "for repetition" in the Decrease phase 1 had been improved with the following strategies:

- An illustration that can be used to explain the concept of "for" statement had been placed in the teaching material (R1.3 Familiar examples and contexts)
- The number of the practice exercises had been increased from 2 to 6 so that the learners could chose the suitable exercises based on their understanding (R3.1 Goal level options)
- Page breaks had been inserted between explanation section and exercise section so that the teaching materials, which were PDF files, could be viewed more easily (C3.1 Exit control)

The explanation for the learning item "Animation and Arrays" in the Decrease phase 2 had been improved with the following strategies:

- Word balloons had been placed in the illustrations so that the concept of arrays could be better understood (A1.1 Audio-visual effects)
- The concepts of arrays had been explained with the illustration of a drawer case as shown in Fig. 3 (R1.2 Illustration for concreteness)
- Original code examples for arrays had been replaced with the ones with which the concept of arrays could be understood more easily (S3.1 Purpose and content consistency)

VI. CHANGE OF MOTIVATION IN THE SECOND COURSE

In the second course, the improved teaching material was used to teach programming. As in the first course, the questionnaire based on the ARCS model had been administered. In the analysis in the second course, the data are from the 10

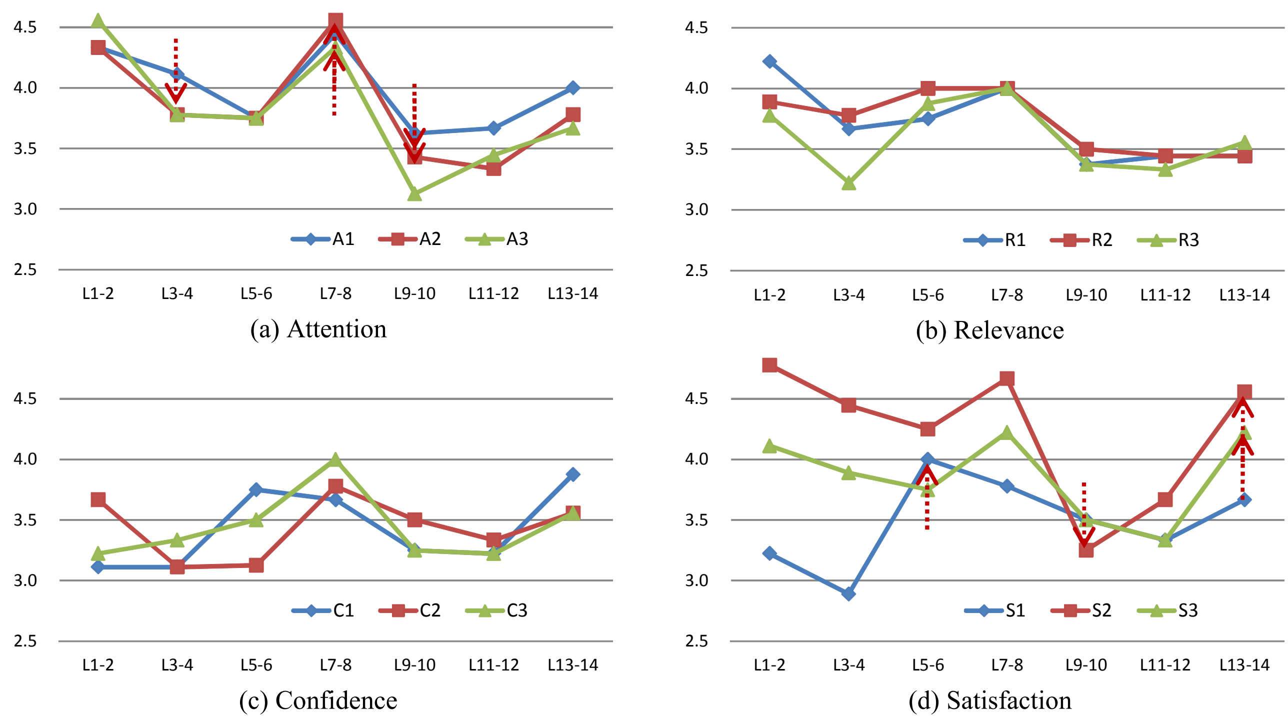

Fig. 4. The Change of Lower Category Scores in the Second Course

TABLE IV. CHANGE OF MOTIVATION IN THE SECOND CLASS

	Attention			Relevance			Confidence			Satisfaction		
	A1	**A2**	**A3**	**R1**	**R2**	**R3**	**C1**	**C2**	**C3**	**S1**	**S2**	**S3**
L1-2	4.3	4.3	4.6	4.2	3.9	3.8	3.1	3.7	3.2	3.2	4.8	4.1
L3-4	4.1	3.8	*3.8	3.7	3.8	3.2	3.1	3.1	3.3	2.9	4.4	3.9
L5-6	3.8	3.8	3.8	3.8	4.0	3.9	3.8	3.1	3.5	*4.0	4.3	3.8
L7-8	*4.4	*4.6	4.3	4.0	4.0	4.0	3.7	3.8	4.0	3.8	4.7	4.2
L9-10	3.6	*3.4	*3.1	3.4	3.5	3.4	3.3	3.5	3.3	3.5	*3.3	3.5
L11-12	3.7	3.3	3.4	3.4	3.4	3.3	3.2	3.3	3.2	3.3	3.7	3.3
L13-14	4.0	3.8	3.7	3.4	3.4	3.6	3.9	3.6	3.6	3.7	*4.6	*4.2

students who attended more than or equal to 6 double-classes out of 7. The data of the students who were absent at most once were used for the analysis, and there were 67 effective data. Since the number of lessons in the two courses was different, L11-12 and L13-14 in the first course corresponded to L11-12 in the second course, and L15-16 and L17-18 in the first course corresponded to L13-14 in the second course. In the second course, a clear increasing trend of motivation was not observed for any motivation factor.

The change of the score of the lower categories in the ARCS model is shown in Fig. 4. Table IV shows the scores of the lower categories with the results of the t-test. As before, the gray cells indicate that there is a significant difference between the score in the cell and that in the above cell with 5% significant level. Light gray cells indicate that there is a decrease in motivation levels, and dark gray cells indicate that there is an increase in motivation levels. Each arrow in the figure indicates that there is a significant increase or decrease in the level of the lower category.

In the first course, a decrease in motivation level was observed in R1, R3, and C3 from L1-2 to L3-4 (Decrease phase 1), and also in A1, R1, and S3 from L13-14 to L15-16 (Decrease phase 2).

In the second course, a significant decrease of motivation was not observed in R1: Familiarity, R3: Motive matching and C3: Personal control in Decrease Phase 1, and A1: Perceptual arousal, and R1: Familiarity in Decrease Phase 2. A significant increase in motivation was observed in S3: Equity in Decrease Phase 2. From these observations, it could be said that the improvement strategies for A1, R1, R3, and C3 had the influence on at least keeping, if not increasing, the motivation. Also, the improvement strategy for S3 was to change the program in such a way that the students could understand the value of the functions used in the programs more easily. Therefore, this modification of the teaching material is considered to be effective in increasing motivation in programming education.

For comparing R1 in L3-4 in the first course and that in the second course, a t-test was conducted, and the result showed that there was a statistically significant difference between them. The average score of R1 in L3-4 in the second course was higher. Therefore it could be said that the modification of the teaching materials using the strategy R1.3 (Familiar examples and contexts) was effective. The lower categories R1 and S3 in L15-16 in the first course had similar property as R1 in L3-4. Therefore, it could also be said that the improvement strategies R1.2 (Illustrations for concreteness) and S3.2 (Exercise and test consistency) were effective.

By comparing R3 in L3-4 in the first course and that in the second course, it can be seen that the average score in the second course was higher, though the t-test showed that there had not been a significant difference. From this, it could be said that the improvement strategy R3.1 could at least keep the motivation in the first course to the second course. The lower category A1 in L15-16 had similar property as R3 in L3-4, and therefore the improvement strategy A1.1 (Audio-visual effects) could at least keep the motivation in the first course to the second course.

Since the major goal of educational efforts in the programming courses is to make students understand better and obtain higher skills of programming, the same paper tests and skill tests were conducted in the first and second courses to see the change in the understanding and skills. Admittedly, any significant difference in the total averages of the test results was not observed.

VII. CONCLUSIONS

In this research, two programming courses with Processing programming environment was offered, and in that, the motivation of the students was monitored using the questionnaire based on the ARCS motivation model. In the first course, two decreasing phases of motivation and one increasing phase of motivation were observed. By analyzing the two decreasing phases thoroughly, the ways for improving the teaching materials were proposed. Based on the proposals, some modifications had been made on the teaching materials before the second course started. In order to verify the effect of the modification, the motivation of the students was monitored again in the second course. As a result, the effects of the modification of the teaching materials on the decreasing phases found in the first course have been confirmed. However, it was observed that there were significant decreases in scores for A2, A3, and S2 from L7-8 to L9-10. Therefore, we plan to further analyze the reason of the decrease in motivation.

ACKNOWLEDGMENT

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A Framework to Examine Fidelity of Implementation of a Hybrid Instructional Model for Computer Engineering Courses

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Abstract—This paper describes a framework adopted to examine the fidelity level of the implemented curriculum in a computer engineering course. The framework allows education researchers to analyze how an applied hybrid instructional model impacts student learning methodically. This study helps to gain insights into how instructors' pedagogical and content knowledge has shaped the curriculum implementation. Factors that influence the intended, implemented, and learned curriculum are discussed.

Keywords—hybrid instructional model; fidelity; implemented curriculum; intended curriculum; learned curriculum; pedagogical and content knowledge

I. INTRODUCTION

Engineering education plays a key role in preparing students for real-world challenges in an increasingly globalized and technology-driven society. Empowered by continued technological advances, many institutions have introduced innovative instructional models to improve the effectiveness of teaching techniques. For years, instructors struggled to deliver the mandatory amount of content at a manageable pace for students' learning until recent years when online lectures became another delivery vehicle [1] [2]. Online lectures, also known as virtual lectures, are now conveniently utilized to convey the required content without overwhelming students, allowing them to study and review course materials at their own pace [3] [4]. In-class lecture periods are used for more interactive class activities, such as group problem solving to better engage students in active learning [4] [5] [6] . Despite the evident benefit in applying these new approaches, many students still struggle to adequately use these online lectures as planned and may drop out of the online course completely [7]. Motivating students to learn computer networking concepts often experiences additional difficulties because many students find the subject rather technical, dry, and boring [8]. Disparities between teaching and actual learning have led to concerns regarding the effectiveness of new instructional models [9] [10] [11].

Our current study addresses the emerging issues that instructors experience while implementing innovative teaching models. We adopt a framework to examine the fidelity of the implementation of a hybrid instructional model applied to an undergraduate computer engineering course [12]. We analyze the data collected from in-class surveys to examine what impacts, if any, the developed instructional model has on students' learning. Other information, such as students' learning experiences from working on the team projects were analyzed as part of the learning outcome assessment.

II. BACKGROUND

A. Setting

This study was conducted in an upper-division undergraduate computer engineering course, CEE425: *Data Communications and Computer Networking* at the University of Wisconsin-Stout (UW-Stout). A hybrid instructional model was applied in this course, which included both online lecture delivery and in-class activities. Online lectures were conducted through streaming videos that delivered the majority of the course content. Online quizzes were designed and administered to assess students' comprehension of the content after they had watched the scheduled online lectures. Similar to traditional in-class course settings, periodic homework assignments were given to evaluate students' understanding of the lecture materials. The lecture material was based on theoretical concepts from the assigned textbook, examples primarily from modern internet technologies, as well as industrial experiences provided by the course instructor. However, the instructor had limited availability to be on campus for delivering in-class course materials. Due to such scheduling conflicts, the course was required to have a unique schedule arrangement, which was not necessarily desirable to all enrolled students. The class met for 4 hours every other week while the online lecture material was delivered on a weekly basis.

The online lecture content closely followed the sequence of the computer networking topics arranged in the chapters of the assigned textbook. During the in-classroom lecture, the instructor typically clarified important concepts covered in the online videos, held a question-and-answer session for students, and then proceeded with introducing new lecture material that were not previously covered by online lecture. The course plan had two purposes: (i) to keep lecture content delivery continually without overloading online videos; (ii) to elicit students' questions during in-classroom sessions. Students spent the majority of in-class time solving problems related to the theoretical concepts introduced

*The author was an adjunct faculty member with the department at the time of conducting this research study.

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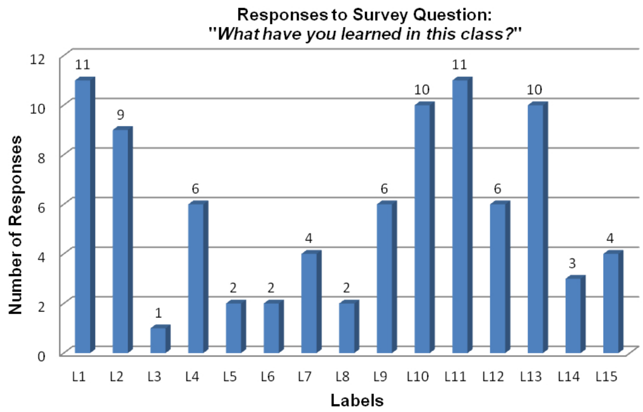

Figure 1. Self-Identified Learned Content and Skills

and performing hands- on lab exercises designed to help students become familiar with the lecture material. Furthermore, the course included an important semester-long team project assignment. For the project assignment, the class was divided into several small groups with 2 or 3 students in each group. Each team was given the flexibility to select a project topic related to computer networking upon approval of the course instructor. Initially, each team was required to submit a written project proposal for the approval. Allowing students to make their own choice of the project topic with minimum technical guidance was intended to encourage students to be creative when encountering real-world challenges. The exploratory process was expected to help students gather meaningful project information, for example, current status of the field of computer networking, the ongoing projects in the area, and issues in the field to motivate and inspire students to learn. The team project was also designed to prepare students to work effectively within a team setting that mimics real-world working environment.

B. Research Methods

Experimental design methods were used to adjust instructional techniques and advance both the goals of design and research simultaneously [13] [14]. The curriculum was developed to provide an introduction to fundamental concepts in the design and implementation of modern data communication and computer networks in terms of protocols and their applications. The instructional goals also aimed at helping students envision how data communication and computer networks are likely to evolve in the future [15]. It was important for this study to focus on designing instructional interventions that would better align teaching and learning goals throughout the semester [16]. Three surveys were conducted at the beginning, after the midterm exam, and at the end of the semester, respectively. The pre-course survey was to assess the level of student awareness of this hybrid instructional approach that combined online and in-class lecture with problem-solving lab exercises. The survey also evaluated the level of students' readiness for the hybrid teaching model, and if students understood how to make good uses of this new teaching approach, particularly

TABLE I. STATEMENTS OF SURVEY QUESTION: '"*What have you learned in this class?*"

Label	Statement
L1	Fundamental concepts in data communications and computer networks
L2	Fundamental computer algorithms and how they are applied to computer networks
L3	Math representations in computer science and computer engineering
L4	Basic data structure principles applied to computer networks
L5	Data manipulations in computers
L6	Modular design for partitioning a system into components
L7	Computer system architecture and its organization
L8	Underlying physics of signals and data communications
L9	Understanding usage of tools to diagnose network problems
L10	Computer network topology
L11	Computer networking terminology
L12	Devices used in the computer networks and their functions
L13	OSI network layers vs. Internet layers
L14	Fundamental concepts in wireless networks
L15	Fundamental concepts in network management

online videos, in-class problem-solving lab exercises, and the team project. A similar survey was conducted at the end of the semester. The post-midterm survey focused on identifying and analyzing learning challenges and progress through self- reflections of students' course experiences. Thirteen students enrolled in the computer networking course and participated in this study.

Both quantitative and qualitative methods were used in the data analyses. A modified taxonomy model was applied to assess student learning outcomes while frequency counting was utilized to quantify the survey results [17]. The course instructor and the researcher discussed the course progress regularly. The results from the pre-course and post-midterm surveys were applied to adjust the instructional approaches. The close collaborations between the instructor and the researcher prompted the design of instructional interventions to improve teaching and learning. The correspondences focusing on designs of instructional interventions were descriptive and qualitative in nature. Student learning outcomes were assessed by both quantitative and qualitative methods.

III. RESULTS

Fig. 1 summarizes student responses regarding a survey question of "*What have you learned in this course?*". Students were provided with 15 statements regarding content knowledge and skills intended by the curriculum as well as the course instructor. These statements are denoted in Table I. Five statements, labeled as **L1**, **L2**, **L10**, **L11**, and **L13** were selected by the majority of the class. Their labels are shown with **Bold** fonts in Table I. In contrast, statement *L3*, *L5*, *L6*, and *L8* were selected by only one or two students. These labels are shown with *Italic* fonts in Table I.

Derived from the results of the pre-course survey, Fig. 2 illustrates students' prior knowledge and perceptions about computer engineering and engineering learning from their previous courses. The statements listed in the pre-course survey are described in Table II.

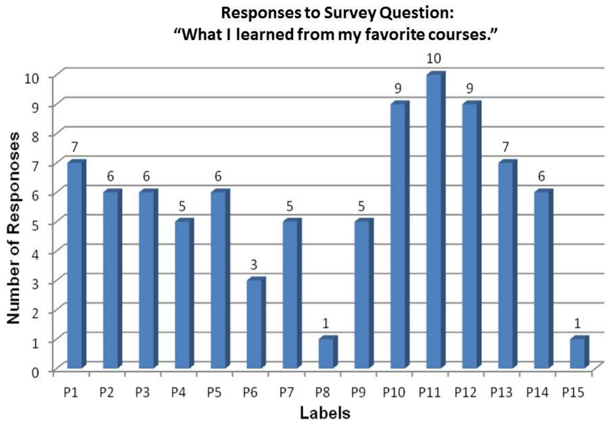

Figure 2. Pre-Course Assessments with Statements Described in Table II

TABLE II. STATEMENTS FOR PRE-COURSE ASSESSMENT

Label	Statement
P1	Fundamental computer algorithms and their analysis
P2	Math representations in computer science and computer engineering
P3	Creating and realizing abstractions/models
P4	Computer data structure principles
P5	Data manipulations in computers
P6	Modular design for partitioning a system into components
P7	Computer system architecture and its organization
P8	Data communications and computer networks
P9	Underlying physics of signals and data communications
P10	How to program accurately
P11	How to program efficiently
P12	How computer system executes programs
P13	How computer system stores information
P14	How computer systems communicate
P15	Other-FPGA board and basic signal processing

In general, students understood fundamental computer algorithms, and how a computer system executes programs and performs data stores. Students felt comfortable with programming tasks, and seemed prepared coming to the course. Labels with **Bold** fonts shown in Table II highlight student prior knowledge and skills indicated by the majority of the class. Several students indicated that hands-on learning experience was helpful. Only one learned computer networks from previous studies as indicated with the *Italic* fonts (*P8)* in Table II.

Fig. 3 shows students' responses to a group of survey questions regarding the usefulness of the semester-long team project. The survey questions are described in Table III. Overall, students reflected positively on the activity, and considered the team project as an important tool that fostered learning. The entire class made efforts and fulfilled the basic requirements by the course instructor. Yet, the quality of the final deliverables of the team project differed dramatically. One group, for example, implemented a functional network device to remotely turn on LED lights as a proof of the concept of a Smart Home function, which exceeded the instructor's expectation. Another group, on the other hand, failed to execute the plan for producing a functional deliverable that they intended to perform. Students' wide-ranging

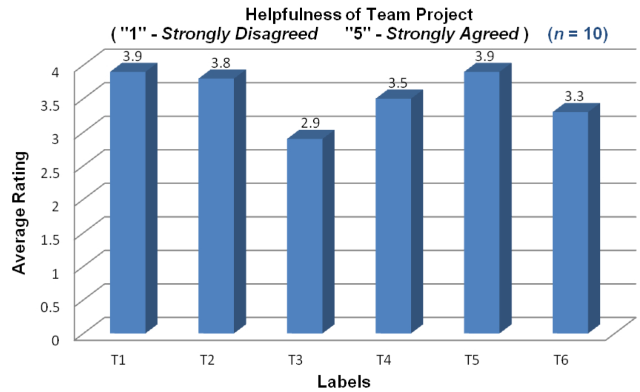

Figure 3. Average Rating of the Team Project

TABLE III. SURVEY QUESTIONS SHOWN IN FIGURE 3

Label	Statement
T1	The team project helps me improve my team work skills
T2	The team project helps me improve my communication skills
T3	The team project helps me relate what we learn in the classroom to the real world.
T4	The team project strengthened my conceptual understanding of the course content.
T5	The team project helps me improve my problem solving skills.
T6	The team project helps me appreciate group learning.

ability to master and apply several fundamental elements of computer networking concepts was obvious. Regardless of various challenges that individuals faced in the team project assignment, most students commented that they learned a lot from the activity. Students made efforts to learn and have made commendable progress in the class, as illustrated in Fig. 1.

IV. INTERPRETING RESULTS

Research results from the current study clearly show that students responded to the instructional approaches positively overall, yet quite differently in some areas. Most of students grasped the course content and developed skills intended by the curriculum and the course instructor, and a few even succeeded in every category of content knowledge and skill as reflected by completing the quality team project. However, several students did struggle in this class. This study intends to find out if and how the newly developed course and the instructional model have impacts on student learning. To interpret the results, one needs to understand why students reacted to this hybrid instructional approach similarly in some areas, but contrarily in others. For example, for the team project evaluation, the entire class indicated that they have learned a lot from the team project. However, the class was divided regarding if the team project helped relate what was learned in the classroom to the real world. Our study resorts to a conceptual framework that would allow engineering education researchers as well as engineering course instructors to examine how the level of the fidelity of the implemented curriculum influences students' learning in a systematic way [12].

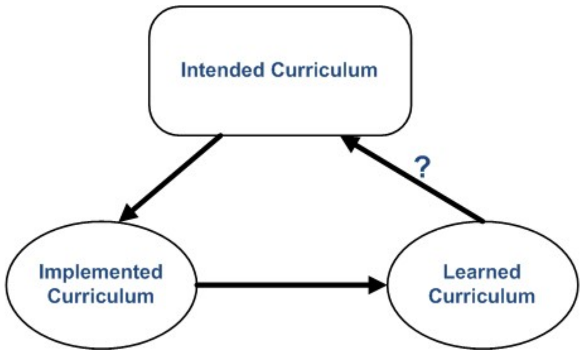

Figure 4. Framework Depicting Relationship between Various Curriculums

Fig. 4 shows the framework that sketches the relationship of three types of curriculum: (i) intended curriculum; (ii) implemented curriculum; (iii) learned curriculum. Table IV describes the adopted framework and displays main factors of each curriculum pertaining to this course.

TABLE IV. VARIOUS TYPES OF CURRICULUM

Type	Factors that influence curriculum
Intended curriculum	- Needs of society and workforce development - Advances in computer engineering - Understanding of teaching of learning technology - Values and beliefs about computer engineering
Instructor: Implemented curriculum	- Teachers pedagogical and content knowledge - Beliefs about learning engineering and learning - Perceived student needs - Constraints
Student: Learned curriculum	- Prior knowledge and skills - Motivation - Perceptions and effort support

A. Driving Forces behind the Intended Curriculum

It is very important that students are aware of rapid advances in both concepts and practices of computer data communication network. They need to be prepared for these changes and are held accountable to norms of the field. As mentioned in Section II, one of the course objectives is to help students develop the ability to anticipate how data communication networks are likely to evolve. Through learning basic concepts, protocol models, and status of computer data communication networks, students are expected to know about the internet, network tools, and applications of these tools. They need to have a deep understanding of computer system architecture and its organization, and should be able to design and configure network management systems.

B. Factors that Impact the Implemented Curriculum

Course instructors are the impelling causes behind curriculum implementation. Possible factors that affect the fidelity of the implemented curriculum are shown in Table IV. Instructors' pedagogical and content knowledge and their perceived student needs undoubtedly shape the pedagogies that have impacts on student learning. As mentioned before, the course instructor has supplemented many real-world examples based on his industrial experience, aiming to inspire students to learn actively. The instructor has made efforts to help students develop the ability to foresee how computer networking evolves based on their understanding of how the current system functions. Specifically, the team project in this course is an illustration that shows how the instructor's pedagogical and content knowledge as well as the perceived learning needs influence the design and the implementations of the curriculum. Students were given flexibility to choose the project topic, and were encouraged to explore new ideas and models. They were required to submit an outline of the project as well as an expanded proposal after getting the instructor's feedback for their initial draft. In-class problem-solving lab exercises used problems from both the textbook and real-world situations to prepare students for the team project.

Constraints influenced the implementation as well. The limited availability of the instructor affected some students even though the majority of the class adapted to the course schedule well. As a result, a few students became very critical regarding content delivery. The instructor modified the length of modules, dividing online videos into several 20-30 minute sections to take into account student attention span after receiving the feedback from students. The instructor also reinforced important concepts during the in-class lecture, and strengthened the connection of various learning activities purposefully. While the majority of the class indicated that online-videos were effective and helpful, and recognized that online lectures helped mitigate the scheduling limit in their survey responses, a couple of students never overcame the anxiety of not knowing what would be discussed during in- class lectures. Unfortunately, they failed to take advantage of online video modules and reported their frustrations in the survey.

C. Factors that Impact the Learned Curriculum

In this pilot study, the learned curriculum is defined as student learning outcomes. Fig. 1 displays knowledge and skills that students believed they learned in this course. To understand why some students mastered certain types of content and skills with an ease, but struggled to grapple with others we applied a taxonomy model that highlights the nature of content knowledge. The results are shown in Table V. The fifteen statements included in the survey question shown in Table I are re-categorized following the model by Anderson and Kratwohl [17] [18]. Individual statements are marked by four classes of knowledge: factual, conceptual, procedural, and metacognitive (knowledge of cognition in general as well as one's own and higher cognition), from concrete to abstract. A similar analysis was applied to the pre-course survey results of Fig. 2, and the results are shown in Table V.

The current study finds that almost all students have improved their learning significantly, particularly in learning concrete

TABLE V. TAXONOMY MODEL

Knowledge Type	Figure 1 Mapping	Figure 2 Mapping
Factual	L11, L12	
Conceptual	L1, L7, L10, L13, L14, L15	P8, P12, P13
Procedural	L2, L4, L9	P1, P10, P11
Metacognitive	L3, L5, L6, L18	P2, P3, P4, P5, P6 , P7, P9

knowledge such as the factual and the conceptual ones. They also did well in learning procedural knowledge. What lacks is the learning of abstract knowledge in advanced computer engineering courses. Many students seemed less comfortable in mastering meta-cognitive knowledge, such as math representations in computer science and computer engineering, underlying physics of signals and data communications, and data manipulations in computers in this course. We believe students' prior knowledge and perceptions influence their learning. Their struggles in learning abstract knowledge in up-division courses, which demands higher cognitive thinking levels, suggest interventions to help students advance cognitive thinking abilities should be reinforced. Designs of such instructional interventions need to be placed at the center of the curriculum implementation.

By applying the framework, we are able to interpret the results regarding student learning. We find that the learned curriculum is influenced by factors such as student prior knowledge, student perceptions about learning, and student effort. It was also affected by the implemented curriculum shaped by pedagogy and content knowledge of the instructor. Designs of instructional interventions are influenced by perceived student learning needs of the instruction.

V. DISCUSSIONS

The current study shows that the fidelity level of the implemented curriculum influences student learning. The team project, for example, along with the problem-solving lab exercises engaged students in active learning. The class recognized the benefits of having a semester-long team project intended and implemented to facilitate learning. Students commented that the team project, in which they learned the most, improved their problem-solving skills significantly. Similarly, they ranked the problem-solving lab exercises as one of the most helpful learning activities. Most students also appreciated the group learning opportunity. These were in line with the instructor's expectations. Complaints about lacking clear directions and topics in the team project assignment indicated that a few students were challenged by open-ended problems. Whether students lack skills or confidence, instructional interventions are needed to help students understand the necessity in developing abilities and confidence to solve open-ended problems. Students need to realize that tasks in real-world situations are often undefined and unclear. It is up to engineers (students in this case) to define what needs to be done in order to accomplish the overall project objectives. A couple of students complained that not enough time was provided for the team project even though it was assigned at the beginning of the semester. Interventions to keep students on task will be required in the future.

By applying the conceptual framework to examine the fidelity of the implemented curriculum, we find the intended and learned curriculum intersect under the team project. In other words, the instructional goals were well aligned with student learning goals. From a models and modeling perspective, we believe that both the problem-solving lab exercises and the team project activities emphasized the process of the developing knowledge and skills, instead of the process of getting a solution. Specifically, the team project has focused on representation fluencies, a crucial element in problem solving [19]. Past studies in this area have indicated that representations and the tools to produce them are among the most important artifacts that students project into and encounter in the real world [20] [21]. This is particularly important in computer engineering education where dynamic and multi-linked representations are come across almost all of the time. In the process of solving problems in this class, students need to define problems, recognize specific types of tools, and develop solutions. Students connected equations, tables, diagrams, etc. and turned these multi-linked representations into new types representations of computer topologies, both physical and logic. They then created program codes that functioned as planned. The final product of the team project was graded by several criteria including scalability and reusability. Through team work and semester long practices, the team project offered students an opportunity to encounter real-world issues, apply their knowledge, and develop skills. The holistic process includes cycles of exploring, defining, designing, testing, and revising for a specific goal [19]. The effectiveness of the team project and its pedagogical focus on enhancing representation frequencies also show that activities like this will be productive in facilitating learning of meta-cognitive knowledge, such as math representations and data manipulations. Instructional interventions for learning tasks that demand higher levels of cognitive thinking will be required all the time, however.

VI. CONCLUSION

The current research has answered the research question, and concludes that the fidelity level of the implemented curriculum influences student learning. That is, the fidelity level of the implemented curriculum minimizes the disparities between the intended and learned curriculum. The framework adopted in this study has helped us advance the goals of design, research, and practice simultaneously. We report three main findings:
(i) the framework depicting relationship of three types of curriculum provides us with a unique opportunity to gain insights into factors that influence each curriculum. It helps to ensure successful implementation of new instructional models; (ii) instructors should attend to all factors that influence the implemented curriculum, and work around constraints to balance student learning needs and constraints. Transitioning from one learning activity to another,

for example from the online-lecture to the in-classroom lecture, should be seamless and purposeful; and (iii) to maximize the potential of a hybrid instructional model, each learning activity needs to be carefully planned and designed to merge the implemented and learned curriculum into the intended curriculum that facilitates active learning. Efforts as such will have lasting impacts on student learning, particularly on learning of abstract knowledge. Furthermore, quality designs of instructional interventions will require cycles of iterations. This research could provide a foundation to additional research studies, including lower-division computer engineering and other engineering classes. Unquestionably, students from lower-division computer engineering classes would have different preparations, perceptions, and learning needs. The main findings of the current study centered on pedagogical and content knowledge of the instructor can be tested and applied in these expanded studies.

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Studying Metacognition in Natural Settings

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***Abstract*—The purpose of this paper is to provide significant evidence from the literature for the use of emerging methods to study engineering students' use of metacognitive strategies when studying. We will review current research methods used to study metacognition and provide evidence that observational methods are an appropriate methodological choice when attempting to study the actual metacognitive strategies students engage in when in naturalistic settings.**

Keywords—metacognition; methods selection; observations, naturalistic settings *(key words)*

I. Introduction

The use of metacognition has been identified as a critical aspect of learning particularly important in problem solving and conceptual change. Metacognition is defined as the knowledge and regulation of one's own learning processes [1, 2]. Much of the research in metacognition has focused on understanding how metacognition impacts learning [e.g., 3, 4] and has occurred in controlled settings. As a result, there is little research to understand *if* and *how* students engage in metacognitive practices in authentic learning environments (such as in the classroom or in peer collaborative settings) or how context affects engagement in these practices. Understanding how students engage in metacognitive practices in a *natural* setting and how students support one another in this engagement will allow for the design of interventions to support metacognitive development that take into account the influences of context.

This paper focuses on reviewing relevant literature on metacognition to develop and support the need for studying metacognition in a naturalistic setting as opposed to in a controlled environment. It also discusses the selection of appropriate methods for evaluating metacognition as many of the tools already in use have come under criticism. Choosing an appropriate setting and appropriate methods are an important first step in a larger project that examines how students engage in and support one another's metacognitive practices in a peer collaborative setting. The larger project is in the early stages of development and this paper provides support for the direction of future work particularly since choosing appropriate research methods is vitally important. The target audience for this paper includes educational researchers and practitioners interested in better understanding metacognition in a variety of fields. In this work in progress paper, we will discuss our initial argument for methods selection with a goal to gain additional insight from members of the engineering education community on moving forward with the larger study.

II. What is Metacognition?

Metacognition can be defined as a learner's knowledge about and regulation of their own cognition [1, 2]. Metacognition can be broken into two major branches: knowledge of cognition and regulation of cognition. Knowledge of cognition, or metacognitive knowledge, can be described as the knowledge that the learner has about his or her own cognitive processes [1, 2]. Regulation of cognition refers to the activities that a learner uses to regulate and oversee his learning [2].

Much of the research in metacognition focuses on the use of metacognitive strategies that are used in the regulation of cognition. These strategies include planning, monitoring, evaluating and awareness:

- Planning - activities that involve predicting the outcomes of learning, i.e. scheduling the activities used to learn [2].
- Monitoring - observation of a person's own level of knowledge as well as the act of testing and revising knowledge and activities used for learning [2].
- Evaluation - judgment of whether a person's own understanding is sufficient and the act of searching for conflicting information and connections to what is already known [5]; process of checking whether a particular learning pursuit is efficient and effective when compared to some criteria or standard [2].
- Awareness - detection of difficulties in understanding concepts and the detection of knowledge that is conflicting with expert beliefs [6].

Notice that these processes are all internal to the learner which can make measuring them challenging. We specifically address methodological challenges in the next section.

III. How is Metacognition Typically Studied

Researchers have used surveys, verbal protocols, and error detection studies to examine relationships between metacognition and learning. However, as described in this

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section, each of these methods has drawbacks. Researchers have used self-report questionnaires in an effort to study the effect of engagement in metacognitive strategies on specific learning outcomes. For example, Jacobs and Paris studied children's use of metacognition while reading using the Index of Reading Awareness and found that a classroom based program focusing on metacognitive instruction improved young children's ability to use metacognitive strategies while reading [7]. In a self-report questionnaire, participants are asked to respond to a series of statements or questions by showing their level of agreement. Examples of self-report questionnaires that measure metacognitive engagement are the Index of Reading Awareness [7], the Motivated Strategies of Learning Questionnaire [8], the Metacognitive Assessment Inventory [9] and the Learning and Study Strategies Inventory [10]. Because metacognition happens in the learner's mind and learners may not have conscious access to their metacognitive abilities, metacognitive constructs can be difficult to define in concrete ways. This lack of specificity causes issues of construct validity when using self-report questionnaires [11].

Interviews and think aloud protocols are also popular methods for the study of metacognition. Interview protocols, such as the one developed by Zimmerman and Martinez-Ponz [12], allow for gathering information on knowledge, monitoring, strategy use and regulation. In a think-aloud study, participants are given problem and asked to think-aloud while they develop a solution to this problem. Think-aloud protocols have been used to gather information about the problem solving strategies used during problem-solving by asking the student to think out loud while they attempt to solve a problem [11]. Chi, De Leeuw, Chiu and Lavancher used think aloud protocols to study the effect of self-explanations on problem-solving and found that those that used more monitoring strategies were more effective problem solvers [13]. Interviews and self-report questionnaires can be problematic because participants may not have conscious access to discuss their engagement in certain metacognitive practices [14]. And by asking participants to 'think out loud' during a think-aloud study, the researcher is potentially changing the way in which a participant may have engaged in a metacognitive practice in a natural setting.

Error detection studies, in which participants are given a problem solution or reading passage with deliberate mistakes and asked to identify the areas that make understanding difficult, have also been used in gathering data on student engagement in comprehension monitoring activities as well [14, 15]. Palincsar and Brown used an error detection method to study student's comprehension monitoring when using the Reciprocal Teaching method and found that student's that engaged in Reciprocal Teaching were able to detect mistakes in reading more accurately than students that did not engage in Reciprocal Teaching[15]. Error detection studies have been cited with issues of ecological validity due to the fact that participants do not typically encounter problem solutions or reading passages with deliberate mistakes [14].

Self-report questionnaires and interviews are used to report the perceived metacognitive practices that students engage in. Think-aloud protocols are used to study the metacognitive practices that students engage in while in a controlled setting but have the potential to change the thought process of the participants. These flaws make it difficult to use these methods to understand what metacognitive practices participants actually engage in while in naturalistic settings.

IV. USING OBSERVATIONAL METHODS TO STUDY METACOGNITION

The use of observational methods to study metacognition may be one approach to understanding how students engage in metacognitive practices in natural settings. A 2002 Special Edition of *Educational Psychologist* highlighted the importance of studying Self-Regulated Learning, of which metacognition is a critical component, in context using qualitative methodology [16]. In this issue, several researchers highlighted the use of observational methods as critical to the study of SRL in context [17, 18]. Bryce and Whitebread have used observational studies to better understand engagement and development of metacognitive skill in young children [19, 20]. These studies cited that the use of observational techniques was specifically appropriate due to concerns of lack of conscious access to what skills children engage in.

One caution is that observational methods are quite time intensive and require significant resources. Baker and Cerro suggest that this method be limited to research and not be used for practical purposes due to time and resource limitations [14]. By developing observation protocols and coding schemes, similar to that of Whitebread [21], that reduce the time intensive nature of data collection and analysis, observational methods have the potential to become a more widely used research method for studying metacognition.

V. FUTURE WORK

This literature review is part of a larger study that seeks to understand if and how engineering students are engaging in metacognitive practices while study in study groups as well as the contextual factors that impact metacognitive engagement. Observational methods, including video and audio recording, will be used as the primary method of data collection for this study.

The results of the larger study will also be used to support work in understanding how intentional factors such as motivation and learning strategies impacts conceptual change in thermodynamics. Metacognition, which is included in learning strategies for the *hot cognition* framework [22] used for this second study, has been shown to play a significant role in conceptual change [23-25].

VI. CONCLUSIONS

The use of observational methods has proven to be useful when studying metacognitive engagement in young children. Using what has been learned by Bryce and Whitebread, we can pursue using observational methods as a tool to understand how engineering students engage in metacognitive practices while learning.

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Evaluating the Effectiveness of Flipped Classrooms for Teaching CS1

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***Abstract*—An alternative to the traditional classroom structure that has seen increased use in higher education is the flipped classroom. Flipping the classroom switches when assignments (e.g. homework) and knowledge transfer (e.g. lecture) occur. Flipped classrooms are getting popular in secondary and post-secondary teaching institutions as evidenced by the marked increase in the study, use, and application of the flipped pedagogy as it applies to learning and retention. The majority of the courses that have undergone this change use applied learning strategies and include a significant "learning-by-doing" component. The research in this area is skewed towards such courses and in general there are many considerations that educators ought to account for if they were to move to this form of teaching. Introductory courses in computer programming can appear to have all the elements needed to move to a flipped environment; however, initial observations from our research identify possible pitfalls with the assumption. In this work in progress the authors discuss early results and observations of implementing a flipped classroom to teach an introductory programming course (CS1) to engineering, engineering technology, and software engineering undergraduates.**

Keywords – flipped classroom, introductory programming, learning with video, computing self-efficacy

I. Introduction

The ability to write and understand computer programs has become an essential skill for engineers to learn. The increased reliance on computer programming to address engineering needs has rapidly increased the number of programming-based courses required to receive any engineering degree. There has been a trend towards trying out newer strategies to enhance and improve how first and second year engineering students understand the principles of programming. Among the many strategies, the *flipped classroom* or *inverted classroom* [3, 4] has gained use being applied heavily at various secondary and post-secondary institutions.

The simplest form of a flipped classroom involves replacing traditional in-class lectures with video tutorials that students are expected to watch prior to class. The students are then required to come prepared for class, which is spent solving hands-on problems that are related to the video. Some variants of the flipped classroom model have students completing assignments, projects and homework in-class based on the watched video lectures. Inspiration and rapid increase of using the flipped classroom approach and many of its variants stem from the emergence of massive open online courses (MOOCs) [5], which have now been established around the world. This movement was spearheaded by the MIT OpenCourseWare [6]; aimed specifically to provide learning and knowledge to anyone who had a desire and motivation to gain new knowledge. The emergence of MOOCs as a ready-to-use learning platform and the popularity of the flipped classroom model have had a combined effect that has led to a vast migration of traditionally taught courses at many educational institutions.

This work in progress is a first attempt at a thorough evaluation regarding the effectiveness of the flipped classroom approach, specifically how CS1 or introductory computer programming is taught. Several authors have experimented with flipped classrooms in order to teach computer programming, but past assessments have focused on upper division courses. Gehringer and Peddycord [1] share their experience with using the flipped model to teach a junior level computer architecture class. Mason, Shurman and Cook [2] compare the effectiveness of a flipped classroom in an upper division engineering course that emphasizes problem solving. Both studies note that a major detractor of the flipped classroom approach is the introduction of the model in later years can be a difficult prospect for the student who has already had two or more years of learning in the traditional way. That leads to the current study, which will investigate the following research questions:

1) *Can a flipped classroom be an effective model for teaching CS1 to first and second year students?*
2) *How does the flipped classroom impact student computing self-efficacy?*
3) *What associated value do students have toward a flipped classroom approach?*
4) *What variants of the flipped classroom approach effectively help students learn?*

This paper will present our preliminary findings with the intention of shedding light on how a flipped classroom model compares to a traditional lecture-style approach in an introductory programming course.

II. Course Design

The course used in this preliminary study was taught to students enrolled in engineering, engineering technology and software engineering programs. The three sections of the course were designed to be the first foray into learning a programming environment. Two of the three sections underwent the flipped model (experimental) with the third section being taught using a traditional approach (control). The course was structured in such a manner that one experimental section used the flipped classroom model for the first half of the semester and then switched to a traditional approach after taking the midterm. The second experimental section started out traditionally and switched to the flipped approach after the midterm. The control section was traditional throughout. Students were randomly enrolled into any of these three sections.

The course content included an introduction to the Python programming language and covered sequence, selection, iteration, flow-control, branching, object creation and manipulation, as is common to most CS1 courses [8]. The hands-on activities for all the sections centered on creating game-based algorithms using Python and the PYGAME library [7]. PYGAME provided the instructors with the necessary hooks needed to make the course hands-on. This was intentionally chosen to transform the course with considerably more applied learning elements. All in-class assignments were game-based and the videos necessary for solving the in-class assignments were specifically recorded to achieve student success. A total of 22 videos were recorded; 11 were needed prior to the midterm. The final exam was given after all the videos had been watched and all assignments were completed. A total of ten assignments were given to each student; five before the midterm and five after the midterm. A student, depending on the section they were enrolled in, either did the first five or the last five assignments in-class. All students took the same midterm and final across all the three sections.

III. Courses Assessment

The common assessments across the three sections were a midterm and a final. Both were timed tests and contained a finite number of problems specific to the course. In addition to the common assessments, students were also given pre-post surveys to identify computing self-efficacy [10] and associated value toward the course.

A. Summative Assessment

The project evaluated the performance on assignments between the students who were in the flipped model classrooms with students who were in a traditional lecture-based classroom. Summative assessment included the performance on: 1) assignments before taking the midterm, 2) performance on assignments after taking the midterm, 3) the midterm, and 4) the final. Table 1 shows these represented as columns and the rows represent the instructional model that was being applied prior to taking any of the column items. The flipped row indicates the results from the experimental sections when they were flipped. The traditional row indicates the results for the experimental sections when they were traditional. The control row represents the class that used a traditional approach throughout the entire semester. Different pre and post-midterm assignments were used in this course explaining the absence of these scores in the table.

TABLE 1. Average Assignment, Midterm, and Final Scores

Model	Assignments Pre-midterm	Assignments Post-midterm	Midterm	Final
Flipped	81.4	65.5	71.4	81.7
Traditional	69.1	66.3	59.2	63.4
Control	-	-	69.4	62.3

Our summative assessments suggest that the flipped model produced higher average scores in the course. This was consistent across both experimental sections eliminating any possible group differences that may have resulted from the randomized student placement. The control section had lower scores in both the midterm and final in comparison to the flipped sections.

B. Computing Self-Efficacy & Value Toward a Flipped Classroom Approach

A pre and post computing self-efficacy survey was used to evaluate any impact the flipped classroom model had on student confidence [9]. The survey was administered to students in both the experimental and control sections. An overall analysis of students' computing self-efficacy from both classes revealed an increase from pre ($M = 53.3$) and post-scores ($M = 71.8$). A paired-samples t-test of the 39 students confirmed this difference to be significant [t (38) = -3.459, $p \leq 0.001$].

A formative evaluation of value was conducted to measure the students' associated value towards the course and also their attitude towards the flipped approach. Experimental classes were asked questions pertaining to the flipped classroom approach. Initial analysis revealed a lack of positive value toward the flipped model.

A correlation analysis between computing self-efficacy and students' perceptions of value toward the flipped classroom model was shown to be not significant. This suggests that the course improved computing self-efficacy, but that the flipped classroom pedagogical approach was not likely to have been the reasoning for this increase. There can be many factors that could be the reason for the flipped classroom approach playing a less important role in the mind of the students. The critical reasoning suggested by the students as part of the open-ended survey were:

1) Adapting to a flipped classroom approach from traditional lecture is overwhelming.
2) Viewing long static videos can be boring.
3) A time-constrained setting to complete assignments can be intimidating in the early stages of using this approach.

IV. CONCLUSIONS & FUTURE WORK

In this study we report initial findings from a mixed-methods based experimental course design aimed at evaluating the flipped classroom model for teaching CS1. Our results show that the flipped approach has promise in improving student scores, but that students found this new approach to be overwhelming and intimidating at times. We aim to formalize our experimental method over the next two iterations of the course in subsequent years. We will be performing a longitudinal study during this period and collecting data from these iterations. Our intention of this study is to completely transform our CS1 courses to flipped classrooms.

The preliminary results presented were able to show that the flipped classroom model positively impacted student scores. Student computing self-efficacy also improved, but since the flipped approach was not used for the entire duration of the class, there is a chance for improper correlation between the approach and self-efficacy. We plan to address by further testing in the classroom.

We have early insights regarding the various approaches to flipping a classroom. It is not completely clear at this juncture whether all parts of the course need to be flipped. A change is definitely required in the way the videos are recorded. The approach of video taping long lectures taught by various instructors could be negatively impacting students value toward the flipped classroom model. Additionally, an important unknown to investigate is how best to increase students engagement levels with the videos.

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Improving Student Learning Using an In-Class Material Processing Design Project

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Abstract— **At Marquette University, hybrid project-based learning has been implemented in an undergraduate mechanical engineering course on materials processing and forming using a team-based approach. The goals of the project are to 1) introduce more active and student-centered activities to improve student engagement and mastery of core concepts, 2) increase students' confidence in their ability to apply what they learned in the course to solving real-world problems, 3) enable students to gain experience using engineering software as part of the learning process and in applications contexts. While use of process modeling software in materials processing and manufacturing courses is not entirely new, the project has students actively developing a model around a realistic process, rather than passive users running "canned" models and reviewing the output. This paper presents details of the project and discusses preliminary results regarding its impact on student learning and confidence related to application of the course concepts. Recommendations for improving and expanding this in-class project are presented, along with a description of the assessment methods used to measure the impact on students.**

Keywords—project based learning; materials processing; finite element analysis; process modeling

I. Introduction

Recently there has been an increased level of interest in understanding how students learn in order to improve learning effectiveness and comprehension [1-5]. As a model is instructive for this purpose, it is useful to consider how engineering skills are acquired and to use this as a basis to implement practice-based learning activities and improve student skills. The process of formal skills acquisition, as opposed to skill gained through trial and error, can be modeled using the five stages of skill acquisition proposed by Dreyfus and Dreyfus [6-8]. This model (referred to in this paper as the Dreyfus model), which was originally based on a study of United States Air Force pilots, has also been applied to study skills development in the medical profession [9] and is also relevant to engineering. It should be noted that the Dreyfus model describes particular skill development traits rather than individual talent levels.

According to the model, a person acquiring a skill proceeds sequentially through several stages: a) novice, b) advanced beginner, c) competent, d) proficient, and e) expert stages. In applying this model to undergraduate engineering education, several implications can be discerned. A key idea is that student experiences in a traditional lecture-based engineering course are necessary to produce skills commensurate with the novice level. However, the expectation of most stakeholders is that by the time a student graduates, the engineering curriculum will enable students to develop skills that correspond to the level of an advanced beginner.

The issue of competency gaps raised by industry and the level of interest in project-based and problem-based learning provide some evidence that many graduates are not developing the expected skills [10,11]. Recognizing this, an increasing number of instructors are modifying courses in an effort to integrate more applied, hands-on content and improve student engagement. Many of these changes involve the inclusion of active, project-based, collaborative, and other forms of student-centered learning, which have been shown to improve student learning [11-13]. Active learning is an instructional method that engages students in the learning process. In active learning students conduct meaningful learning activities connected to what they are doing. While this definition could include traditional activities such as homework, in the education literature active learning most commonly refers to activities that are introduced in the classroom. The core elements of active learning are activities that engage students [14,15]. Active learning is often contrasted to the traditional lecture format where students passively receive information from an instructor.

Given the hierarchical nature of engineering education, the Dreyfus model suggests that rather than eliminating the novice steps, it is necessary to introduce experiences that allow for more open-ended learning and independence on the part of the students. In order to facilitate the transition from novice to advanced beginner stages, additional experiences such as hybrid project-based learning (PBL, a form of active learning) could be included in a way that allow for situational aspects to be introduced and tailored to the desired level within a project context. An additional consideration is that computer-based technology has transformed professional engineering practice, but this is not the case in education where it tends to be used

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more as a means to automate the existing educational process rather than as an integral tool for learning and student inquiry [16]. Although computer and virtual based technologies are routinely used in industry for engineering and manufacturing work, many students are not conversant or being trained in virtual and digital technologies which are increasingly pervasive in professional practice. However, properly structured, such technologies can be effectively utilized for student learning and skills development in hybrid PBL.

II. Project Rationale

One of the key goals of an upper level engineering course is to enable students to achieve skill traits that are more similar to those of advanced beginners than novices. When the nature of skills development is considered, it can be argued that the exclusive use of traditional lectures and textbook problem solving activities is likely to improve knowledge but keep students at a novice skills level. We hypothesize that 1) the level of student competence in a course can be increased to that of an advanced beginner in part through the use of virtual/simulation tools, and 2) this effect is measurable.

Although engineering skills encompass a diverse range of activities, ABET learning outcomes c) an ability to design a system, component, or process to meet desired needs within realistic constraints, e) an ability to identify, formulate, and solve engineering problems, and k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice [17] were most consistent with the intended project activities and scope. Thus, ABET outcomes c), e), and k) served as the framework for structuring the project activities and assessing its impact.

III. Background

Processing & Forming of Materials (MEEN 4440) is a fourth year elective offered at Marquette University in the Department of Mechanical Engineering and was used as a pilot course for the project. The emphasis in MEEN 4440 is on solidification and thermo-mechanical working and includes coverage of microstructural development in castings, melting processes, process-property relationships, and mechanics of metal forming processes. A first course in manufacturing processes is a pre-requisite for MEEN 4440 and develops skill traits that are consistent with a novice. In the past, MEEN 4440 has been offered as a lecture course. Although the course met student expectations, it was concluded that while they were able to perform analytical tasks, they struggled with using the concepts in an engineering context and demonstrated a low level of engagement/ownership in the learning process. PBL implementation in upper division courses necessitates that due to the greater technical depth that some degree of structured learning needs to be retained. Because of this, hybrid forms of PBL are well suited to engineering and were chosen for the project.

Given that a key requirement in a PBL environment is for students to produce a product/outcome, it follows that available resources at an institution will limit the type and scope of project work that students will be able to perform. In much the same way that simulation software provides practicing engineers with a powerful virtual tool that can be used for design and verification; the flexibility that such programs (particularly discrete simulation and manufacturing process modeling software) offers also make them highly effective as a learning tool in an academic environment. This is particularly true in manufacturing processes where computer-based visualization can convey concepts more effectively than text, equations, and two-dimensional images and promote student retention [18]. In comparison to a lecture-based course, PBL represents a natural environment where students can not only develop application skills using computer-based technology as part of the engineering process, but they can also use this technology as an *integral tool for self-directed learning* [19].

While materials processing provides a wide range of potential project topics, a project developed around forging process design was considered to be the most appropriate choice as it could be structured to be consistent with student skill levels and the course syllabus. Rather than using a contrived design problem, PBL philosophy indicates that an industry-based problem would provide more student motivation and connection between course content and real world problem solving. A Wisconsin company was contacted and agreed to furnish a forged gear blank geometry. Although impractical for students to actually demonstrate their process, finite element method (FEM) based process simulation enables them to build a realistic virtual model that includes the relevant materials processing physics. The ability to receive timely feedback is also an important element in PBL. By using an axisymmetric part geometry, simulation times are relatively short (on the order of 10 minutes using a laptop computer) and students are able to receive feedback regarding their design decisions and assess how well they meet the stated requirements.

To prevent skills development from being diluted and creating activities that were potentially confusing to students, it was decided that a unified, integrated approach using a single project was necessary. The project was structured so that students were provided with a set of specifications and a part print at the beginning of the semester. Students were then paired and tasked to develop a three-step prototype process that met multiple constraints. As students typically have little experience and familiarity with FEM and forging design principles, it was necessary to dedicate 2-3 class periods to cover basic concepts in these areas. Pre-project testing showed that in order to ensure that the project focused on engineering skills development rather than software usage, it was crucial to employ software that was user friendly and easy to navigate. A number of engineering software vendors have recognized that similar needs exist in industry and now offer easy to use interfaces and wizards to reduce the learning curve for beginning users. For the current project, the commercial code DEFORM (Scientific Forming Technologies Corporation, www.deform.com) was used.

In addition to using process modeling software, students also employed solid modeling to develop the necessary geometry files for the initial work piece and tool geometry. Using the post processor, students must verify that their process produces a sound forging and maintains conditions that are within workability limits for the alloy. Each team must also select an appropriate tool material and verify that stresses are within acceptable levels (i.e., below the 0.2% yield strength) based on a yield criterion. A further requirement was to demonstrate that the force profile was consistent with the kinetic envelope for a crank-slider press mechanism. To ensure that students and the instructor could monitor progress, a set of milestones and a timeline were developed with interim design documents being submitted by each team. This also provided an opportunity for the instructor to provide corrective feedback as needed and monitor the extent that key concepts were being explored by each group.

IV. Results and Discussion

The project was implemented in Fall Semester 2012 with an enrollment of 18 senior-level mechanical engineering students of which 51% had co-op experience and less than 20% had FEM experience in prior coursework or employment. Due to the low level of experience students had with FEM modeling at the start of the project, several activities were assigned as part of the interim reports that required students to investigate selected modeling concepts (e.g., mesh design) and consider the effect they had on the model performance. While there was initially some concern about students' ability to develop proficiency using the FEM software, 74% of the students were able to use the FEM software after initial training sessions with the remainder requiring minor technical advice. Most of the problems encountered were attributable to students being unsure how to approach an open-ended design problem. This was addressed through as-needed meetings between the instructor and groups to allow the instructor to provide suitable suggestions. It became apparent however, based on the interim documents submitted, that there was a need for students to improve their drawing and dimensioning abilities.

Although it is not a trivial task to assess engineering skills levels, the Dreyfus model does provide a description of attributes at each skill level that can be used to guide development of metrics. Applied to engineering practice, an advanced beginner is capable of situational discrimination and working with both context-free features and situational aspects to formulate a plan of action. This behavior is evidenced when students become less dependent on rote rule/procedure following, can independently discern which factors are important in solving the problem (i.e., situational discrimination), and are able to arrive and execute a workable solution albeit with some effort.

To determine the impact of the project on student design capability and ability to meet multiple design constraints, student success rates were determined with respect to whether or not their final design met each of the design specifications. The percentages of student teams meeting the project design criterion are shown in Table 1. While none of the teams were completely successful, 78% of the teams were able to meet 5 out of the 6 specified criteria though the low success rate in the blocker design task was unexpected. However, after using the software it was concluded that self-directed experiences alone were not sufficient to develop design skills. After reviewing the traits noted in the Dreyfus model, this suggests that it will be necessary to include additional design maxims and examples in future project assignments.

When considering how to assess the effectiveness of project oriented learning, it is necessary to consider attitudes and skills rather than simply comparing knowledge orientation as is done in traditional subject learning [18]. Students were asked a series of questions intended to conduct a self-assessment of their ability to design a process and use FEM as a modeling tool. A total of 17 students were assessed before (pre-test) and after (post-test) the project. These were intended to measure their abilities to perform a design and use a modern software tool as part of engineering practice. Pre (μ_1)/post (μ_2) evaluations were compared via a standard test of means (t-test) as well as a non-parametric test of means (Mann-Whitney U-test).

Based on their responses to questions regarding 1) understanding and confidence in designing a manufacturing process, 2) understanding thermal phenomenon in materials, and 3) understanding and applying effective stress in an applications, students were asked "How confident are you in your ability to design and model a manufacturing process?" Responses to this question were used to form a hypothesis for testing. Pre-test questions indicated that 64% of the students had low confidence in their ability to design a manufacturing process (question 1). Based on these results the hypothesis: "A student's ability to model a manufacturing process has improved" was proposed with the alternative hypothesis: "It is unknown if a student has improved his/her ability to model a manufacturing process". Results from the t-test and U-test are given in Table 2.

TABLE 1. Percentages of student groups meeting each of the six project design criteria.

Load Profile-Blocker	Load Profile-Finisher	Die Fill - Blocker	Die Fill-Finisher	Die Stress-Blocker	Die Stress-Finisher
89%	78%	11%	78%	89%	78%

TABLE 2. Assessment of student ability to design a prototype materials processing operation.

Test (μ_2>μ_1)	Calculated Probability (P-value)	Significance
t-test	$3.5x10^{-9}$	Yes
Mann-Whitney U-test	$2x10^{-8}$	Yes

Based on the results of both tests, it can be concluded that a statistically significant (small p-value) improvement was observed with respect to students' ability to design a prototype manufacturing process based on hot forging.

Responses to questions regarding 1) understanding how nodes function in FEM, 2) understanding of mesh design, 3) understanding of mesh density, and 4) understanding and ability to use information from the FEM model, resulted in students being asked "Do you understand Finite Element Analysis as it is applied to a manufacturing process?" This led to the hypothesis "A students' understanding of Finite Element Analysis as applied to a manufacturing process has improved," with the alternative hypothesis "It is unknown if students' understanding of Finite Element Analysis as applied to a manufacturing process has improved". Results from the t-test and U-test are given in Table 3.

Based on the results of both tests, it can be concluded that a statistically significant improvement was observed with respect to students' ability to understand the basics and use of FEM with respect to a manufacturing (forging) process.

An effort was also made to incorporate the modeling software as part of homework problems and exam questions in place of analytical calculations. This was done on a limited basis to ascertain if self-directed learning would increase understanding of the fundamental importance of effective stress and could be used to replace class discussions. One of the questions posed on a mid-term exam asked each student to define and discuss effective stress in his/her own words. Of the responses, 52% were deemed satisfactory and, while not conclusive, it is consistent with findings from other studies that PBL does not necessarily lead to an improved understanding of fundamental concepts.

TABLE 3. ASSESSMENT OF STUDENT ABILITY TO UNDERSTAND BASIC CONCEPTS AND USE OF A FINITE ELEMENT MODEL RELATED TO MANUFACTURING PROCESSES.

Test ($\mu_2>\mu_1$)	P-value	Significance
t-test	$4.7x10^{-10}$	Yes
Mann-Whitney U- test	$1.2x10^{-8}$	Yes

Student feedback regarding the value of the project and what was learned from it was solicited. The following is a sample of quotes from students who completed the course:

"I actually enjoyed working a lot with this software and it truly gave me a much better understanding of the whole forging process. I kind of wish we could have had more class time to fool around with the program. Other than that I think the use of this program for the mini-project was a great idea and very beneficial."

"I loved the project as it involved a real part made at a local company."

"I learned a lot about the different things that must be considered in the die forging design process including load requirements, die stress, temperature, fill, friction, etc. I have also gained a good understanding of the use of the DEFORM program and feel confident in my ability to simulate and assess forging operations."

"I learned many things such as how to use DEFORM, the relationships of temperature, stress, material flow, friction, contact time, etc. in a forging process, and I learned and understand more forging terms."

"Working with simulations allowed me to see how I could affect the outputs of a forging process by varying input parameters. Being able to see directly how I could affect results greatly facilitated my comprehension of course material."

"I gained a better overall understanding of processing as well as an appreciation for all of the time that goes into doing it correctly."

Student feedback indicated that students liked working on a real-world problem, learned about the forging process and other course material, and developed an appreciation for the many parameters involved in designing a forging process.

Due to the user friendliness of the software, minimal class time needed to be dedicated to the project from regular lecture discussions. Students were able to focus on self-directed learning using the software to study and visualize fundamental behavior while receiving more detailed feedback than would be possible in lecture, text reading, or visiting a website. While the project focused on materials processing, the experiences gained indicate that it not only provided suitable project/design experiences that can be used in a semester project, but that comparable efforts could also be applied to other courses. For example, a similar scaled-down project is being prepared for use in the pre-requisite junior-level manufacturing processes course for basic concepts related to materials forming. This would not only help to improve vertical linkage between the courses but also enable more time for coverage of necessary design maxims and examples without significantly reducing class time needed for coverage of other syllabus topics.

V. CONCLUSION

Hybrid PBL learning was implemented in an undergraduate mechanical engineering course on materials processing and forming through a team-based project. The goals of this project were to 1) introduce more active and student-centered activities to improve student engagement and mastery of core concepts, 2) increase students' confidence in their ability to apply what they learned in the course to solving real-world problems, and 3) enable students to gain experience using engineering software as part of the learning process and in applications contexts.

Based on the assessment results of the project completed in the MEEN 4440 course, we conclude that the goals of the project were met and the project experience improves students' ability to 1) design a prototype manufacturing process based on hot forging, and 2) understand the basics and use of finite element analysis with respect to a manufacturing (forging) process. While some refinement is needed, student response to the design experience and software usage was very positive and the project will become part of regular course activities.

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A PBL Approach to Process Management Applied to Software Engineering Education

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Abstract—**Given the demand in the area of Software Engineering for solutions that actually contribute to modern organizations, the search for qualified professionals who have considerable practical experience has been growing day-by-day. Set against this background is the learning process of traditional teaching, in which the Student is largely a mere recipient of information, including concepts and theoretical foundations, and is seldom given practice in problem solving. Therefore with a view to minimizing this problem, teaching and learning methods such as the Problem Based Learning (PBL) have emerged in higher education as an approach to foster changes in teaching and learning processes, which are aligned to the new requirements of the labor market and redefine the roles of those involved in educational processes. To evaluate these processes, a case study on skills training to teach Usability Testing is discussed, and important results presented that show the applicability of the proposed approach for teaching Software Engineering.**

PBL; Process Management; Software Engineering; Education.

I. Introduction

The continuous growing on the informatics market implicates in a bigger search for qualified professionals who are able to analyse and solve complex and various problems. Even though, it's easily noted how their education ends up being damaged by the use of traditional learning methods, in which the learning process enhances the theoretical learning in solving problems. It's also worth noticing that when trained in such a way, there is no relevant contribution to the development of skills to be considered in the professional condition. The lack of practical learning, where realistic practices are hold through simulated scenarios based on the current job market, hinders the Students from assuring an experience in dealing with complex situations associated to the interpersonal relationships required to this process.

Before this context, it comes to be relevant to consider the need for embracing training with different guideline approaches, intending to minimize the vantage in technology's market, as well as providing quality training to the professionals in the area. In order to attend to this need, new teaching methods, like the Problem-based learning have been introduced in higher education as an alternative in contrast with the traditional education.

Problem-based learning (PBL) [1] is compatible with the job market, once it promotes essentially a functional and practical learning by the use of problems which are similar to the ones found in the market. It's considered necessary to emphasize the alignment of the practices to the theoretical knowledge in an integrated way, what allows that non-technical abilities to be also developed.

Focusing on the Student, this concept has as inherent process the use of problems to initiate and motivate learning concepts and the promotion of necessary skills and decisions to come to a solution [2]. Even being best known in medicine, it has been applied in various areas, as in software engineering, where the results are considerably satisfying.

The benefits of the embracement and the changes in the learning process in PBL are evident. The redefinition of the roles in this process assigns Students, who are active agents, the responsibility of building their own knowledge through the collaborative learning, whereas the teacher takes the responsibility to guide the Student through the building process as a facilitator. However, many challenges have been faced in order to get effective results by its endorsement. In particular, the process management stands, because PBL is strongly directed to process [3], when considered that the term "process" is defined as being a "set of behaviours or activities performed by people or machines to achieve one or more objectives". Accordingly, the PBL process defines itself as a set of activities that aim its effectiveness by the preservation of the principles to achieve the requested objectives.

In this context, this paper proposes a PBL approach in education modeled on BPMN – Business Process Modeling Notation, but considering the method elements proposed in Santos [4] by the problems definition, practical learning environment, flexible content, human resources role, and the process of authentic evaluation.

II. The xPBL Methodology

The essence of PBL in being directed to process determines the need of a process that supports defined steps, as the planning, implementing, monitoring and continuous evaluation as a way to guarantee the theory's alignment (concepts) to the problem (practice) during the whole learning process. These steps refer to PDCA (Plan, Do, Check and Act) cycle, defined by Deming. As tool also applies to educational processes, the cycle promotes them through the management of the organization and proper execution of the activities of steps aimed at continuous improvement. The PDCA cycle was proposed as reference elements of the methodology xPBL.

In this article, emphasis will be given to the stages of planning and execution. The process, focused on the PBL approach to Software Engineering education, had as foundation the relation of the five principles of PBL elements proposed by Santos [4]:

1. *Real problems*: the problems must be real, asked by real clients, of reasonable complexity and relevant to the field and educational goals;
2. *Real environment*: the practical learning environment based on software industries promotes a better comprehension of the process by the Students, specially in its functions and responsibilities, activities and strategies to accomplish the clients satisfaction and the quality in the products;
3. *Human resources* involved: the value of each person involved contributes to the process growth in general, according to his or hers experience, education and formation, where the Students get supported by each other and also Tutors, Monitors and even the Client during the learning process;
4. *Content*: with the purpose of promoting a holistic view of the Software Engineering area, the resumes must be according to SWEBOK (Software Engineering Body of Knowledge);
5. *Assessment processes*: based on the authentic assessment strategy defined by Herrington and Herrington [5], the Students are involved in learning environments in which the activities are turned to the application of their knowledge, stimulating their ideas and critical vision and the implantation of different ways to solve them;

As a way to check these processes, the article presents the results of an experience in applying the elements of a case study proposed to Software Engineering studies, emphasizing Software tests accentuating usability.

III. Applying the xPBL Methodology in Real Cases

This section has as main objective to present some successful real cases, verifying the veracity of the PBL method. The Software Residency described in [4] was planned to form software engineers in the BADA platform for mobile devices, or by simplification "BADA Residence", used the Software Factories model as a practical learning environment, having the SIDI Samsung institute as real client of this project and CESAR as educational institution [6]. The Software Residency in Telecoms market – performed in a partnership between CESAR (www.cesar.org.br) the institution of technological innovation and Datacom Brazil (www.datacom.com.br) – had the objective of creating specialized professionals in a short period of time, so Datacom could hire, as it needed professionals with the required skills for new project [7].

In the Software Quality area, the Training in Software Tests (PCTS) was performed, aiming for offering the Students the proficiency and the dissemination of the technical knowledge on the Software tests area, using the PBL methodology [3]. It was implemented by the Software Productivity Lab (LabPS) of National Institute of Science and Technology (INES) in the Informatics Center of Federal University of Pernambuco (Cin-UFPE), with the collaboration of partners from the innovation institute C.E.S.A.R. (Recife Center of Studies and Advanced Systems) and of the software industry of Pernambuco, Brazil [8].

IV. PBL in Processes

In computer science there is a difficulty in having qualified professionals in Informational technology area, as, for example, software engineers. Some education methods try to solve this challenge, as PBL, that offers the Students a way to get the knowledge and developing skills and attitudes expected from a professional. The process based in xPBL methodology was created to assure the correct application of the PBL.

This section describes the formation structure of the Planning and execution processes based in xPBL methodology, referring to the five elements of the PBL approach in education: Real Problems, Real Environment, Human Resources, Content, and Evaluation Processes. Was seen the need to create one more element to join the elements of the methodology, the PBL Plan. The PBL Plan contains the steps of each activity, as a schedule, human resources involved and application place. It's clearly defined and aims at the entire process to be applied.

The process is composed by three splits that indicate the active people in the process, like the Client, the Coordinator and the Teacher/Tutor. In each split are the subdivisions.

A. Real Problem

The use of problems is a main tool on the PBL methodology, where it must be defined a specific problem based on real context and complexity. After defining the problem, the new learning activities start, that need to be connected to concrete facts, always searching for the reality in context. The definition process of the problem may begin from two situations, as shown in Fig. 1:

- Client defines the problem to be solved through a paper with its description and then pass it to the coordinator, when he or she will analyse the description and verify if the problem fits the PBL concepts so it can be passed to the teacher;
- The definition of the problem comes from the coordinator, so the same sends the actual problem to the Teacher through a paper with its description. The problem may have as objective to form test engineering, for example.

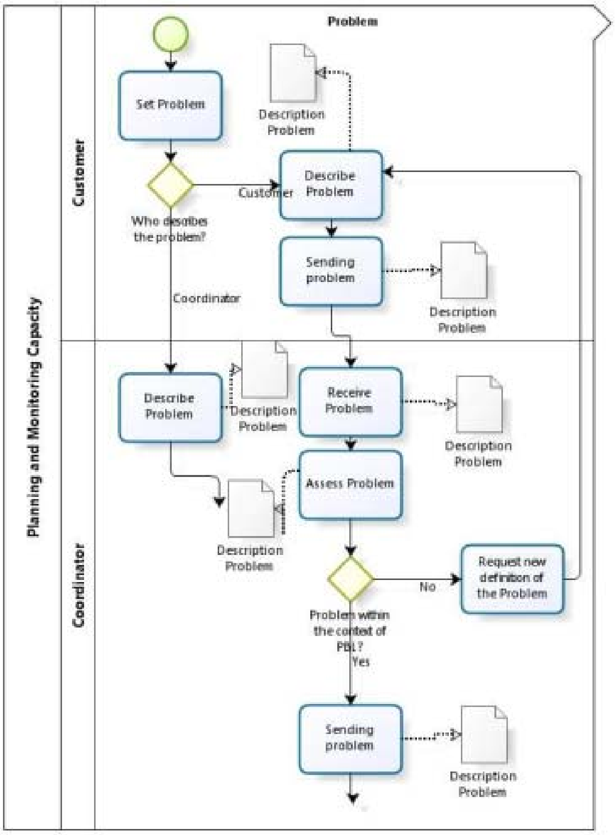

Figure 1. Processes on Real Problem perspective.

After defined the problem, the Teacher sets the educational goals, as shown in Fig. 2. Educational goals are defined objectives to determine in a most effective way which content level is wanted to achieve through a previously taught concept [7], are learning expectations over the Student.

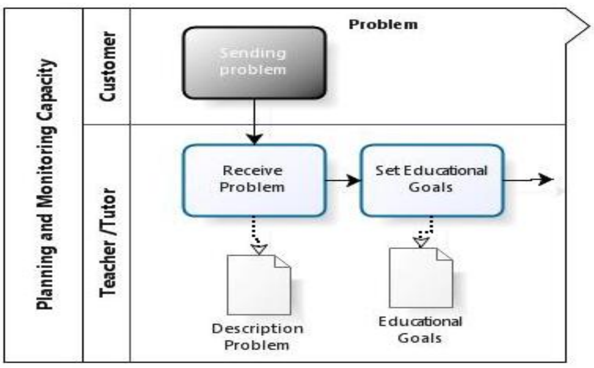

Figure 2. Setting Educational Goals.

B. Real Environment

In appropriate environment gives the Students a better structure to find the resolution of the problem (Fig. 3). This sub process is a coordinators responsibility since the definition of the local infrastructure and the necessary hardware, networks and softwares that the Students will use until the place and applications to be used are defined.

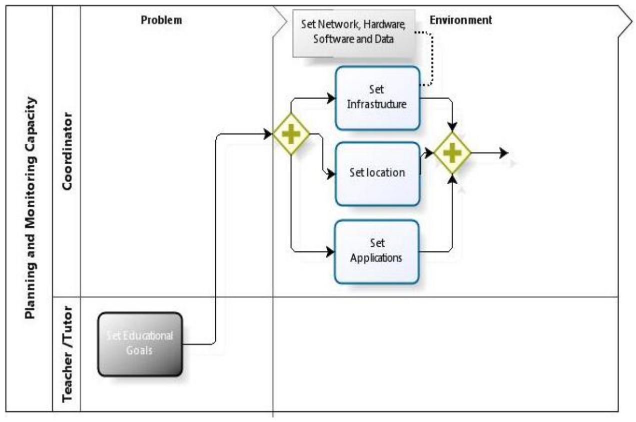

Figure 3. Processes on Environment perspective.

C. Human Resources

It's a key part of the planning process, because the value of each person involved contributes to the process growth as all, according to their experience, education and formation. The people involved are the Students, Teachers, Tutors and the Coordinator. Next, we will verify each one's role.

- *Student:* composes the team, and are responsible for performing the activities, having active role inside the PBL methodology;
- *Teacher:* responsible for teaching and preparing the subjects content, making the learning easier;
- *Tutor/Technician:* specialist on the PBL methodology and also responsible for supporting the Students, helping with the activities projections and assuring the application of the method;
- *Coordinator:* responsible for the demand of the problem, leading the methodology implementation, executing monitoring activities and validating results. and;
- *Client:* responsible for defining the actual problem.

According to the lack of professionals, Teacher and Tutor can be just one person (Teacher/Tutor) in this Process, provided they have the technical capability to both roles, as shown in Fig. 4.

Coordinator is the responsible for the definition of the teachers, tutors and the selective process itself, while the Teacher/Tutor is responsible for participating of the selection process and defining the teams, assigning roles and responsibilities for each one.

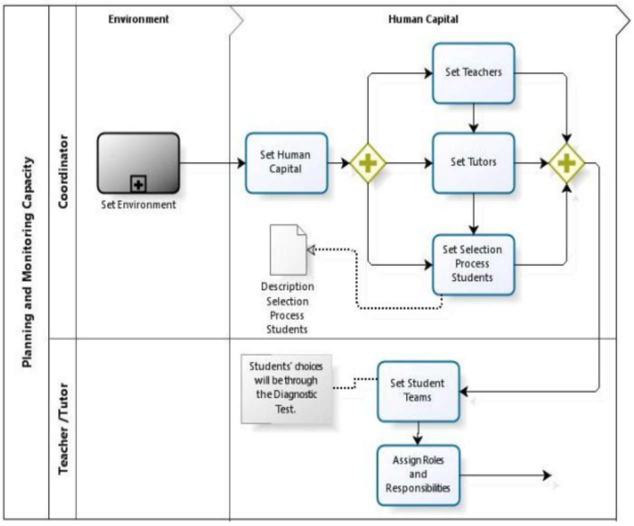

Figure 4. Processes on Human Resource perspective.

D. Content

It involves definitions of the subjects to be taught, defining their content related to the problems context and also defining the support material, like tests, exercises, etc. These definitions must be made by the responsible Teacher, according to the Students need for the problem resolution (Fig. 5).

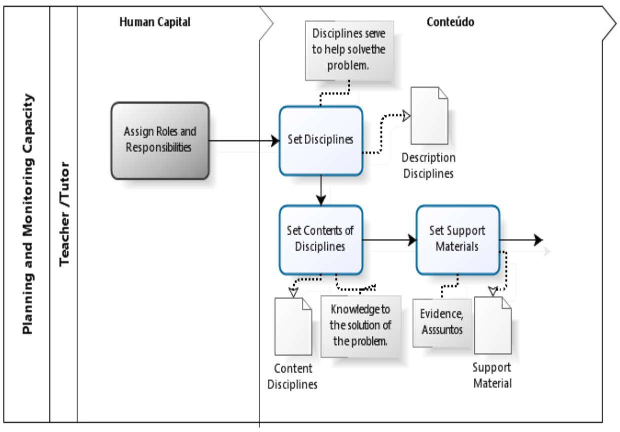

Figure 5. Processes on Real Problem perspective.

E. Assessment Processes

The evaluation must have a diagnostic function, checking the educational situation of the Students to propose improvements by the Teacher. In the proposed evaluation process, the Teacher/Tutor verifies if the educational goals were accomplished through mapping. The Coordinator defines the evaluation modalities, as well as its processes and the grading criteria (Fig. 6).

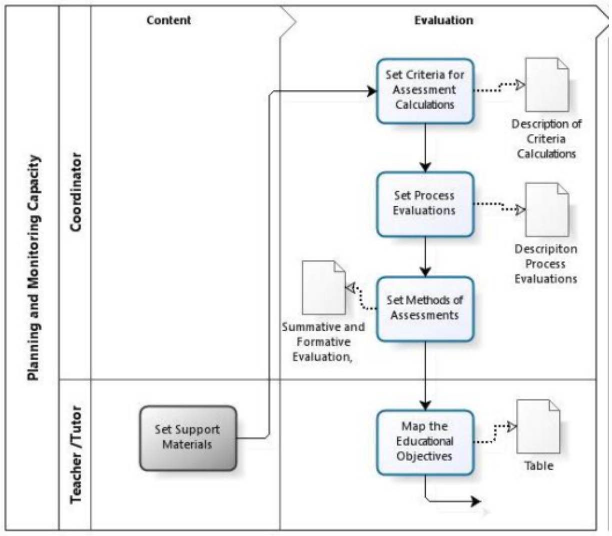

Figure 6. Processes on Assessment perspective.

F. PBL Plan

The actualization of the PBL plan is of a huge importance because a starting point is necessary so that the whole process may be applied in a clear and objective way (Fig. 7). Containing the step by step of each previously quoted element, as, for example, who will be involved inside the human resources and which are the defined contents.

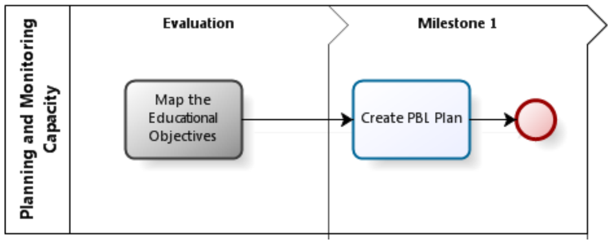

Figure 7. PBL Plan.

After accomplished the entire planning part, we move to the execution process, which is the second part of the process, where we apply what has been planned. After the Client describes the problem, the Coordinator receives the same and checks if it is necessary to divide the problem. If so, it divides and after, sent to the Teacher/Tutor.

The Teacher/Tutor is responsible for receiving the problem from the Coordinator and pass it to the Student, who analyses it and searches for solutions. If the Student finds troubles in the resolution, he or she may ask the Teacher/Tutor for help. After the questions are taken, the Student finishes the task by delivering the artefact to the Teacher/Tutor. When receiving the artefact made by the Student the Teacher/Tutor makes the following evaluations; process, performance, content and artefact. The Teacher/Tutor must also verify for fractionated problems and make the same evaluation to the remaining problems. For last but not least, the Teacher/Tutor checks if the problem which was described by the Client was solved and sends it to the Coordinator. If the problem was not solved, the Teacher/Tutor requests the Student to correct it.

When the artifact is delivered to the Coordinator, he or she passes it to the Client, who will evaluate the work. If the artifact is according to what was requested, the Client gives a positive feedback of the final product (artefact), which is passed back to the Coordinator, then Teacher/Tutor and finally, to the Student. If the artifact is not according to the requested, the Client asks the corrector for a check, who will sent it to the Teacher/Tutor, who will pass to the Student, starting a new cycle of execution until the problem is solved.

V. Applying the PBL Process

Savery & Duffy establishes eight basic PBL principles and emphasizes the need for supporting all learning activities and processes in a real problem inside a real context of an environment similar to the working place.

Before that, we chose to apply the process into a Software Test training emphasizing usability, in order to form qualified professionals inside the software quality field for the job market, in a similar environment to the working place, using the LMS Amadeus system to verify its usage, attached to the value to the system.

In many universities the term 'Software Test" is neglected, so the Students end their courses with little or none knowledge about this subject.

Software Test is the execution process of a product to determine if it has achieved its specifications and worked fine to the environment for which it was projected. The test does not depend on the development process for each stage (analysis / project / development). The objective is to expose flaws in a product, so that they can be fixed before the final delivery, achieving liability and making the software quality better [8].

The training was performed in CIN- Informatics Center in Federal University of Pernambuco in association with CiTi- Integrated Center of Informational Technology. Next, the description of the application of the process through the six elements:

A. *Real Problems*

The real Client defined the real problem "Our educational institution needs to adopt a management system of an easy use to support the learning processes of the technical courses offered. However, the communities Students rarely access the Internet, in addition to not having an ease in dealing with the computer itself. They told me about "Amadeus", but we really need to analyse this possibility! ".After validated the problem by the Coordinator, who verified that the problem was in the context and was consistent, it was sent to the Teacher, and he defined the educational goals. The educational goals were based by Blooms taxonomy, where know, understand, apply, analyse, synthesize and judge the following educational goals:

- Basic Concepts of PBL;
- TestLink tool;
- Amadeus tool;
- Basic Concepts of Usability;
- Basic Concepts of Software Test.

B. *Environment*

CIn- Informatics Center of UFPEs lab was selected, with one computer per Student with access to LMS Amadeus and TI TestLink (tool and management of test-cases simulating a software test industry.

C. *Human Resources*

The industry was structured with professionals with abilities compatible to the established objectives of the training, and interacted with the Students teams (Fig. 8). So, each Student got continuous support from the Teacher/tutor. The Client also frequently interacted with the teams, making the understanding of the problem easier to be solved. The teams division was performed in a homogeneous way, avoiding one to be weaker than other.

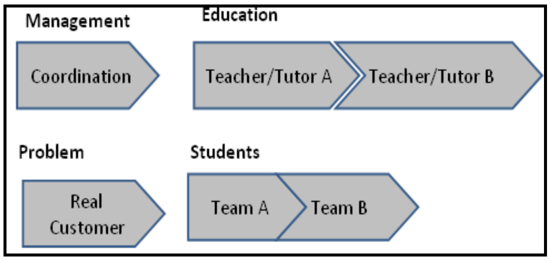

Figure 8. Human Resources in the Software Testing Training.

D. *Content:*

The following disciplines were selected according to the Students needs: Introduction to PBL, Amadeus tool presentation, Software test, TestLink tool and Usage Test.

E. *Evaluation Process*

The evaluation was based on the authentic evaluation by Herrington and Herrington [5], where the five elements the PBL approaches were evaluated based on the process xPBL.

1. *Content*: formative and summative evaluations were made to check the Students knowledge, evaluations those, made before and after each provided discipline. The table below shows the global evaluation of the Students referring to groups A and B. The result was announced at the end of the course, following the summative evaluation approach. The training used had three distinct activities of evaluation, such as:
   a. Exercise 1 was carried out for writing test cases as a whole;
   b. Exercise 2 was to write test cases for usability;
   c. The interaction was applied according to the students behaved performing the

above activities and were interacted with the rest of the group.

The criteria used for writing the test cases for both test cases in general and for the test cases for usability were the clarity, correctness and completeness. Was used at 5-point scale of values in the evaluation: "Excellent" (5) "Very good" (4) "Good" (3) "Satisfactory" (2) "Low" (1). The average content (Table I) was calculated by summing the values assigned to each question, and divided by the number of questions.

TABLE I. AVERAGE OF EVALUATIONS ON CONTENT ASSESSMENT

Team	Media
A	2,47
B	3,13

2. *Process:* The items to be analysed were projects presentation, deadlines and goals planned versus deadlines and goals accomplished, strong visions and improvement points. Due to the subjectivity of the analysis, a range of 0 to 10 points values were used, then the average taken. Notice that in the Table II, the grades were very tight, where the Students attended well in the process.

TABLE II. AVERAGE OF EVALUATIONS ON PROCESS ASSESSMENT

Team	Media
A	8,8
B	8,6

3. *Results:* The items to be analysed were understanding was applied that the teams had about Software tests, usability and PBL methodology, verification and validation of the artefacts, as well as the improvement in softwares usage. Due to the subjectivity of the analysis, a range of 0 to 10 points values were used, then the average taken. And about grades, we can see that team A was superior to team B (Table III), even though it must be considered that this group had lost two of its members.

TABLE III. AVERAGE OF EVALUATIONS ON RESULTS ASSESSMENT

Team	Media
A	9,7
B	9,2

4. *Performance:* A self-evaluation was held and also a constructive evaluation between the Students themselves [9]. It covered the self initiative, the capacity of learning, the collaboration, the communication and the focus on results. Was used at 5-point scale of values in the evaluation: "Excellent" (5) "Very good" (4) "Good" (3) "Satisfactory" (2) "Low" (1). The average content was calculated by summing the values assigned to each question, and divided by the number of questions. Notice that in the Table IV the team B has a good performance, even being in a number disadvantage.

TABLE IV. AVERAGE OF EVALUATIONS ON PERFORMANCE ASSESSMENT

Criteria	Team A	Team B
Self initiative	3,38	3,6
Learning capacity	3,62	3,49
Collaboration	3,5	3,7
Communication	3,9	3,67
Focus	3,56	3,55
Media	3,47	3,6

5. *Clients Satisfaction:* The real Client also evaluated the deadlines, the achievement of the goal, the quality of the work, if the team had a good communication during the process, the agility of the team and for last, the innovation. The average grades of both teams were very close. Team A had an average grade 7,91 and team B with 7,41.

TABLE V. AVERAGE OF EVALUATIONS ON CLIENTS SATISFACTION ASSESSMENT

Criteria	Team A	Team B
Time	10	10
Objectives	8	7,5
Quality	8,5	6,0
Communication / Transparency	4	5
Agility	9	7
Innovation	8	9
Media	7,91	7,41

F. PBL Plan

It contemplates all the training details, as local, date, hour, Teachers/Tutors, educational goals, subjects, giving a clear vision of the training performed.

Before the training we take some lessons as learned, which are:

- The lab environment was not agreeable so that the Students could reunite, when they got out of the lab to have meetings;
- The lack of time limited the interaction between them, because the training was applied in two consecutive days;

- Lack of Commitment of a Student made one of the teams unstable;
- Flexibility and unpredictability of approach favours the improvisation, and;
- The learning method motivates the Students to learn and also to contribute effectively in the learning process.

VI. Conclusions

The developed the process validated the application of PBL presented in this article, where it attempted to evaluate a training course in Software tests engineers, emphasizing the usage, based in used practices in the market, aiming at proving how effective a methodology that preserves principles, such as resolution of real problems inside real environments, with a minimum cost.

Before the authentic evaluation we had different evaluation points about the teams, providing a continuous feedback of improvement points for Students and tutors as well. It was shown that the individual and group work of the Students contributed to the development of specific improvements for each person, considering the evaluated criteria in the job market.

Finally, the case study presented successfully achieved its objectives: of the twenty subscribers, 70% of the Students attended and only 15% of those quit on the second day of training. Therewith, we formed an amount of twelve Students qualified in Software test with emphasis in usability.

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Should the first course in computational problem solving and programming be Student-Centered or Teacher-Centered?

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***Abstract*—Computational problem solving and programming are foundational skills for engineers. The first undergraduate level course that covers these topics is critical to laying these foundations. As instructors strive to incorporate the spirit of inquiry in their courses, an important question that comes forth is whether the teaching methodology should be student-centered or teacher-centered. This paper adds helpful information in the ongoing debate on this question. The paper reports on the student performance results obtained by teaching two sections (cohorts) of an introductory Computation Lab course sequence. This course sequence aims to teach new engineering students MATLAB scripting and programming in the context of technical problem-solving using mathematical models. Cohort A was taught using a traditional teacher-centered approach, while Cohort B employed an open-ended student-centered approach. Our results indicate that the teacher-centered approach has the potential of creating polarized grade distributions with relatively more A grades in the class compared to the student centered approach. On the other hand, the student-centered approach provided a smoother grade distribution, indicating that a higher number of students demonstrate noticeable progress as compared to the teacher-centered approach.**

Keywords*—*Student-Centered, Teacher-Centered, Computational Problem Solving, Programming, First Year Course

I. Introduction

Computational problem solving and programming are foundational skills for most engineers. The first undergraduate level course that covers these topics is critical to laying these foundations. As instructors strive to incorporate the spirit of inquiry in their courses, an important question that comes forth is whether the teaching methodology should be student-centered or teacher-centered.

In the past two decades, there has been an increasing interest in shifting the center of instruction from the teacher towards the students. There have been studies conducted using student-centered teaching methodologies, where the students were at the center of *learning*. Research shows that learning is triggered optimally if the course is set up correctly and is complemented with student-centered learning [1], [2]. It was also suggested that when student-centered learning technique is integrated with technologies, it provides students novel opportunities to try things and gain hands-on experience as they progress with the course [4]. On the other hand, research also shows that not every course can be taught using a student-centered approach. In [3], the authors provide insights into why students might need more than just the minimal guidance.

In this paper, we present the tradeoffs between student-centered learning and instructor-centered teaching techniques as applied to introductory computational problem solving and programming courses. We analyze two different sections (cohorts A and B) of a first-year (freshmen level) programming course, where each section was instructed using different teaching techniques. This paper is organized as follows: In Section II, we present the experimental methodology used in this research. Section III summarizes the results using numeric data collected and presents the statistics observed within the two cohorts. We then conclude this paper in Section IV.

II. Experimental Methodology

A. Course Sequence and Technical Topics

This first-year course sequence ran for 3 academic terms at Drexel University's College of Engineering. For the purpose of this study, we report on results from the

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first two terms. Technical topics that were covered in the class during the first term included MATLAB basics and plotting to illustrate fundamental software engineering and computational problem solving concepts, introductory data analytics: procuring, analyzing, and visualizing data, data visualizations - 2-D plots and animations, and string manipulation.

For the second term, technical topics that were covered in the class include MATLAB functions, mathematical modeling and simulation of physical processes (static and dynamic), 3-D visualizations, and numerical integration and differentiation.

B. Student Demographics

The two cohorts were run back-to-back and were taught by the same instructor (Abichandani) and teaching assistant (Sahin). Cohort A had 33 students and Cohort B had 34 students at the beginning of the year. The students were assigned into one of the two sections either by the college advising team or by online registration based on student schedule availability only. There were no intentional grouping of the majors of the students. Although the majority of the class (71%) was enrolled as freshmen, about 24% of the students were at sophomore level. The remaining 5% of the class population were pre-juniors (third-year students). There were no juniors or seniors enrolled in any of the sections. Out of the two sections, there was only one female student.

Both cohorts featured several engineering majors. Cohort A was dominated by Computer Science majors, where they occupied about 44% of the total enrollment. About 29% of Cohort B was comprised of Mechanical Engineering students, whereas the rest of the class was distributed relatively equally between the various engineering areas (Computer Engineering, Electrical Engineering, Civil and Architectural Engineering, Software Engineering, and Business and Engineering). Between the two sections, there were 5 *still deciding* students (who are enrolled in Engineering but did not declare a specific Engineering major yet). No race and country of origin data was collected for the purposes of this experiment.

C. Classroom and Computing Resources

The classes met for two hours every week in a computer laboratory, where the layout of the room encouraged collaboration and ideation. The students were given Macbook pro laptops at the beginning of the lab. They were asked to login with their own usernames and passwords, which enabled the students to save their work into their own workspace. All of the laptops had the exact same configuration (internet connectivity, installed programs etc.). The program used in this course was MATLAB, which is a scientific computation software. For both of the sections, the teaching materials were projected onto two different screens to ensure optimal visibility.

D. Pedagogy

In Cohort A, the problem solving techniques and programming exercises were demonstrated by the instructor in detail. The instructor introduced a problem and explained the logic behind solving the problem. Subsequent to this, the instructor demonstrated the complete solution process using MATLAB.

Cohort B was instructed using a student-centered approach that featured elements of guided discovery; specifically, the instructor introduced a technical topic very briefly, and then encouraged the students to explore the topic using problem-solving approaches and MATLAB programming with little guidance. Students were presented the basics of the topics and were asked to experiment and explore with their knowledge and to build up on them to self-learn some of the more advanced topics. Students were also shown external resources (e.g. the help file, useful websites) to encourage self-learning. Cohort B featured discussions among students, generation of ideas, and a convergence to a verifiable solution. This methodology allowed for students' independent and bold thought processes and decision-making to flourish while simultaneously honing their technical skills. The teaching assistant was asked to walk around the room throughout the whole lab session to monitor the progress of the students and to clarify any questions that might arise. The teaching assistant was directed to not give out any answers but, instead, to lead the students by asking them the right questions towards the correct answer. Students demonstrated their work and shared their solution approaches during lab sessions. No lecture notes given to the students in both cohorts.

E. Assignments

Each term consisted of 10 weeks of lectures and an additional week dedicated for final project submission. The two cohorts received the same assignments (5 in total), exams (2 in total), and project statements (1 at the end of the term) each term. Throughout the term,

TABLE I: Grading rubric for second term project

Item	Points
1. Idea and justification	Total: 15
1a. Submitted project idea	5
1b. Project idea has intellectual merit	5
1c. Project idea has broad impact	5
2. Creativity in implementing the idea	Total: 10
3. Functionality of implementation	Total: 30
3a. Submitted code works as promised	20
3b. Submitted code is efficient	10
4. Readability of the code	Total: 10
4a. Code comments explain the functionality clearly	5
4b. Code structure follows good programming practice	5
5. Design	Total: 10
5a. General GUI Appearance	5
5b. General flow of project	5
6. In-class demonstration	Total: 25
6a. Project Impact and Merit and Technical Challenges	10
6b. Solution Approaches and Overall presentation	10
6c. Q&A	5

the assignments were posted online (using the college's online course management system) within 24 hours after the lecture. They were due the morning of the next lecture. All work that needed to be graded was submitted by students using the online course management system. The instructor and the teaching assistant had full access to the course page.

The assignment questions were a mixture of closed-ended questions that were extensions of material that is covered in class and more open-ended questions. The exams were very similar to the assignments and contained two questions with extra credit opportunities. The final project statements were open ended and ranged from analyzing Twitter feed data of an account of students' choice to creating applications that featured rich physics based 3-D animations.

F. Student Work Evaluation Techniques

Grading for the course was done as fairly as possible. In order to remove any grader bias from the grades, the student work was evaluated by hiding the names. These assessment tools consisted of a combination of analytic and summative rubrics, where an example is shown in Table I. Although there were specific tasks that were being asked for, students were allowed to use their knowledge to analyze the data using any method they deemed appropriate. The grading rubrics were created in order to comprehensively cover all scenarios that a student might present during their work submission. All submitted materials were evaluated twice to ensure the order of grading didn't cause any bias.

The term projects were graded based on in-class student demonstrations and the final submission. It was noticed that there were students in both cohorts who came up with ideas worth mentioning. Some examples include train timetable lookup application, battleship game, 50 states game, and maze solver. A majority of students also included final projects with rich 2-D and 3-D visualizations.

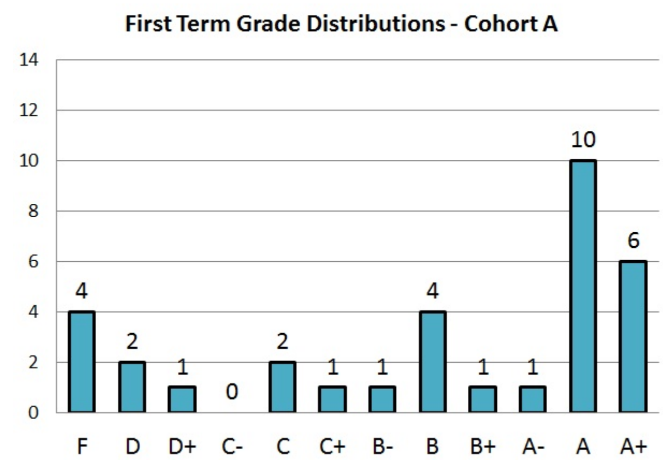
III. RESULTS

Assessment was performed using rubrics that focused on the following aspects (1) Problem-solving approach (2) Functionality and readability of the MATLAB code and (3) Final project reports. Both sections were graded using the same grading rubric for their assignments and exams.

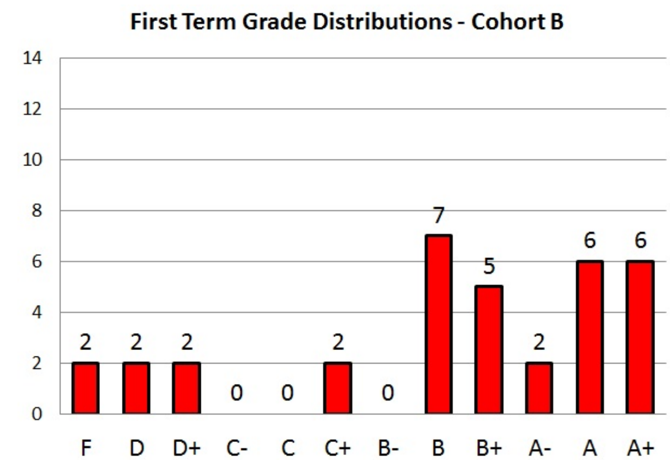
In the following discussions, we present results for both cohorts for the first two terms of the this course sequence. Table II summarizes the average grades obtained from all grading categories from each cohort for the two terms. Table III displays the p-value of Kolmogorov-Smirnov (KS) tests run on the data across the cohorts. In the first term of the course, the teacher-centered approach yielded a final grade distribution that is fairly polarized, with approximately 45.5% of class scoring an A grade, and only 33.33% of the class scoring B and C grades. Approximately, 12% of the class failed. This polarization can be corroborated from the low average grade (79.89 points) and relatively high standard deviation (22.78 points). The student-centered approach, on the other hand, had a final grade distribution that is more spread out with only 32% of the class scoring an A grade, and 47% of the class scoring B and C grades. The failure rate was approximately 6%. The smoothness of the distribution can be corroborated from the high

TABLE II: Average grades and p-values for both cohorts for the first and second terms

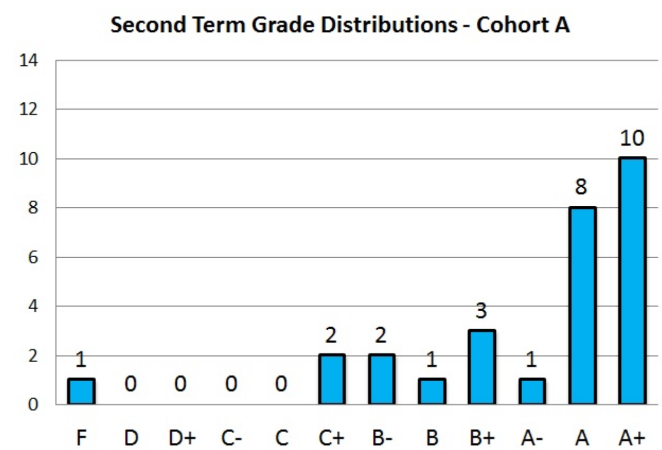
	Cohort A		Cohort B	
	Term 1	Term 2	Term 1	Term 2
Assignments	86.8%	87.8%	83.1%	95.9%
Exams	78.6%	91.4%	86.4%	90.2%
Term Project	68.6%	89.5%	73.4%	93.3%
Avg. Final Grades	79.9%	90.4%	85.0%	93.4%



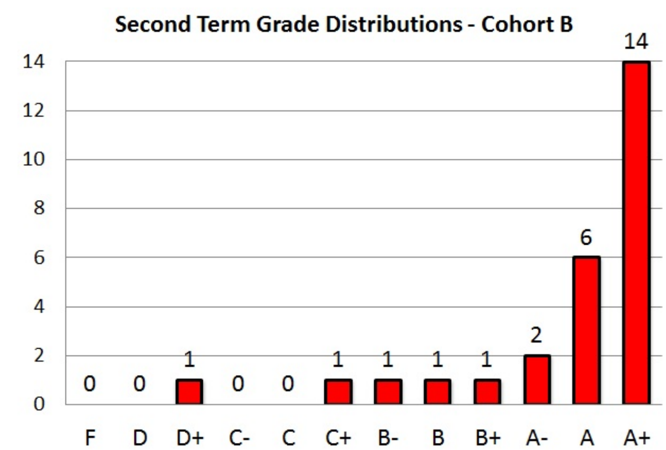
(a) First Term, Cohort A



(b) First Term, Cohort B



(c) Second Term, Cohort A



(d) Second Term, Cohort B

Fig. 1: First and second term final grade distributions for both cohorts

TABLE III: KS-test p-values

Cohort A, Term 1 vs. Cohort B, Term 1	0.3679
Cohort A, Term 2 vs. Cohort B, Term 2	0.8332

average grade (84.95 points) and relatively low standard deviation (14.66 points). These results can be seen as summarized in Fig. 1a and Fig. 1b.

A similar analysis was also performed for the second term of the course, where Cohort A (teacher-centered) presented results with approximately 68% class receiving an A grade, an increase from the first term, and about 29% of the class receiving a B or a C. Only one student failed in Cohort A. Although a relatively high number of students received an A grade, the average grade point was 90.41, where the standard deviation was 15.53, which agrees with the grade distribution observed. For the Cohort B, a very high percentage, 81%, of the students received an A grade and only about 15% received a B or a C grade. There were no failing students. The lowest grade was a D+. These grades correspond to a Cohort-wide grade average of 93.44 points, and a tighter standard deviation of 9.90 points, which focused the majority of the students above a grade of 85 points. These results are also summarized in Fig. 1c and Fig. 1d.

In order to validate the results, a student-by-student comparison was also run. Each student's first term final grade was compared against their second term final grade. In Cohort A, 10 students received the same letter

TABLE IV: Grades change across the two terms

Cohort A	1.5% increase
Cohort B	6.1% increase

TABLE V: Number of respondents and response rate

	Cohort A	**Cohort B**
First Term	12 (36.4%)	13 (38.2%)
Second Term	9 (32.1%)	8 (29.6%)

grade in both terms, whereas, for Cohort B, this number was 7. As shown in Table IV and Fig. 2, overall trend for both cohorts was an increase in average final grades. Cohort B demonstrated a higher grade increase. 67% of the students received a higher letter grade, whereas only 7% received a lower letter grade. In Cohort A, the effect was less dramatic, with 39% of the students receiving a higher letter grade and 25% getting a lower letter grade.

A. *Student Course Evaluations*

At the end of each quarter, the university asked all students to fill out a course evaluation, which collected feedback from the students regarding the effectiveness of the teaching team in reaching the course goals along with their techniques and the materials used for the course. The students are also given the opportunity to add any comments regarding the teaching team. The students are given 2 weeks to complete the surveys. Participation was voluntary and students did not receive any extra credit if they decided to submit a course evaluation. In addition to the final grades of the students, the course evaluation results provided a more comprehensive picture for the effectiveness of the course. Table V shows the response rate of the course that is of interest.

The majority of the respondents indicated that the amount of knowledge they had at the end of the course

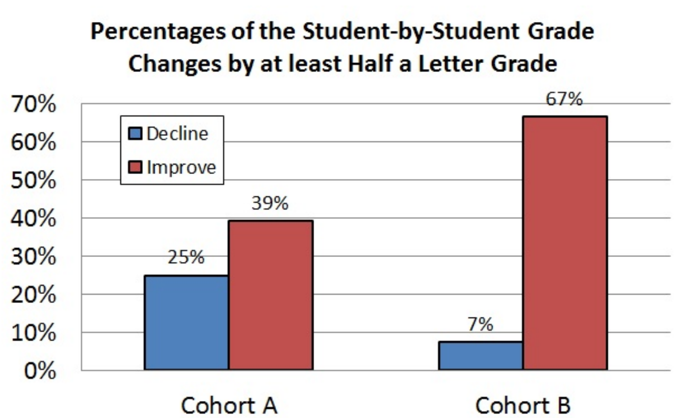


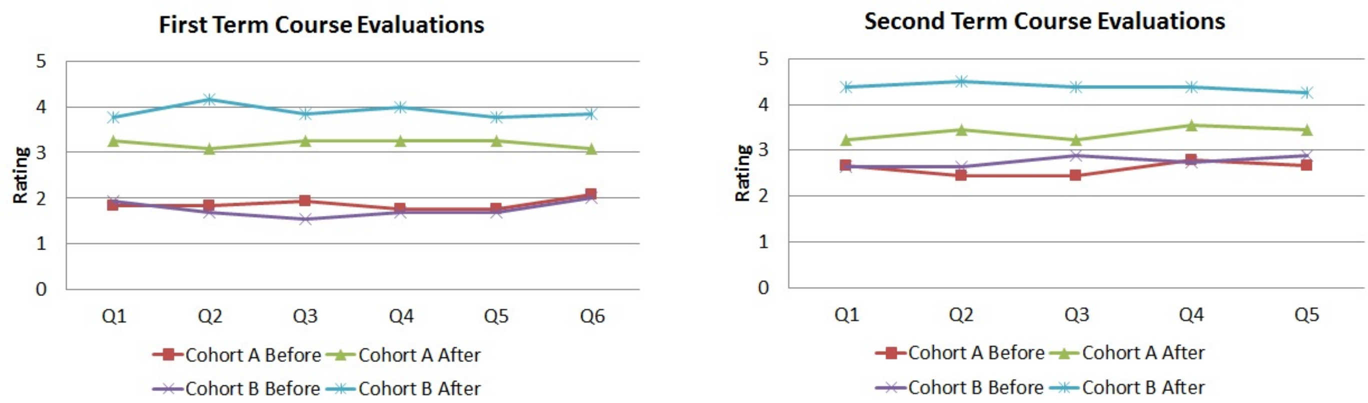
Fig. 2: Change in the final grades of individual students across the two terms

sequence is more compared to what they had before they were enrolled into the course sequence. Fig. 3a and 3b summarize the student responses. The numbers are based on the rating scale between 1 and 5, where 1 corresponds to ”do not agree at all” and 5 corresponds to ”agree completely”. In the first term, there were a total of 6 questions asked regarding the course, whereas, for the second term, the sixth question was dropped, yielding a total of five prompts. These questions below were asked in a ”before the term” and ”after the term” fashion.

The questions stemmed from the following learning objectives set for the class:
At the end of the class, students should...
- **Q1:** Be able to answer questions about practical technical situations using computation within the framework of mathematical modeling involving pre-calculus algebra.
- **Q2:** Be able to use programming constructs using numerical and symbolic computation, and scientific visualization, to automate sequences of computations of a few steps.
- **Q3:** Acquire a basic repertoire of computational actions and structures, and be able to use them to fashion solutions to simple technical problems.
- **Q4:** Acquire basic terminology of technical computation and be able to follow instructions that use it.
- **Q5:** Experience how numerical and symbolic computation, and scientific visualization, can help gain insight into problems within technical fields.
- **Q6:** Be able to utilize a technical computation tool to perform basic word processing and documentation tasks.

In addition to the numeric data collected, some of the written student feedback at the end of Term 2 included:

- *”It is a great course, but a basic understanding of programing is required”* - Cohort A
- *”we had freedom and the class involved real life scenarios”* - Cohort A
- *”I thought the creativity aspect introduced the semester was the extremely helpful in the learning process.”* - Cohort B
- *”Being taught Matlab helped me so much in*



(a) First Term

(b) Second Term

Fig. 3: First and second term student evaluation results

other classes" - Cohort B

- *"It was all good! every class i left wanting to do more programming!"* - Cohort B
- *"The course gave me knowledge of using a program completely knew to me and gave me the tools to work independently with it."* - Cohort B

As it can be seen, although the written feedback above are from within Cohort A and Cohort B, the majority of the students, who responded to the survey, thought the open-endedness/freedom, and the inter-disciplinary approach in the topics were suitable for their engineering needs. It can also be observed that Cohort B reported that they felt their knowledge at the end of the term was much more than what they started with at the beginning of the term. This observation is made by comparing the Cohort B (Fig. 3b) evaluation results to the Cohort A (Fig. 3a) evaluation results. The response rates shown in Table V should be kept in mind while analyzing the student feedback data. Although sample biasing is possible with lower response rates, studies show that surveys running for a long period of time but with low response rates provide more accurate measurements compared to those with higher participants [5].

IV. Conclusions and Take-Aways

In this paper, we presented the results of running an introductory computational problem solving and programming course using student-centered and teacher-centered methodology.

The results indicate the fact that for the class sequence discussed in this paper, the teacher-centered approach has the potential of creating polarized grade distributions, which is indicative of a pronounced divide between students whose problem-solving and programming skills improve substantially over the course of the class, and those whose skills do not improve as much. The analysis points to the fact that the teacher-centered education propels good students to better performance, but leaves the weaker students behind.

On the other hand, the student-centered approach provides a smoother grade distribution, indicating that while the relative number of students getting A grades, i.e., demonstrating superior computational problem-solving and programming skills may not be as high as compared to the teacher-centered approach, a relatively higher number of students demonstrate noticeable progress as compared to the teacher-centered approach. The better students achieve less than they would have achieved if educated in the alternative mode, but the weaker students end up with better performance. The average performance is higher but the better student paid a price for the better average. Furthermore, as students were exposed to continued student-centered pedagogy (in term 2), their individual performance increased substantially when compared to the teacher-centered approach.

As educators continue to push the boundaries of pedagogical methodologies for computational problem solving and programming courses, these results will help inform their decision making by demonstrating the tradeoffs between different methodologies.

Acknowledgments

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Developing Modules for an Inverted Classroom Project in Cost Estimating

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***Abstract*—** The need to serve increasingly diverse learning communities requires a curriculum that not only recognizes alternative modes of thinking but also helps students develop the complex thinking skills required by industry. Classroom inversion or "flipping" can provide a useful framework for this new paradigm by pre-engaging students with the material. The classroom lecture can then be replaced with collaborative problem solving exercises or model eliciting activities. While the most common methods used for pre-engagement include streamed lectures or podcasts, these techniques are subject to some of the same concerns associated with passive lectures or assigned readings. In this paper we present an approach for classroom inversion that is based on three premises: pre-engagement occurs through online interactive modules, classroom lectures are replaced with group problem solving activities, and homework assignments incorporate open ended problems or model eliciting activities. Examples of online interactive modules in accounting and cost estimating are presented. We follow with a discussion of the resultant transformation of the classroom learning environment along with some samples incorporating open-ended problem solving exercises. Preliminary assessments indicating gains in student learning along with future directions and implications for a broader approach to innovation and entrepreneurship is discussed.

Keywords-inversion; technology-enabled; problem solving skills

I. THE CHANGING PARADIGM

As a result of a global economy and the move to lean enterprises, industry has taken a stronger stance in asking for a different type of engineering graduate that has the leadership and complex thinking skills needed by today's industry. To maintain the nation's competitive advantage, the National Academy of Engineering issued a report on the changing business / industry paradigm for the 21st century. This report and a companion phase II report [2] identifies some of the ideal attributes of the engineer of 2020 as well as recommendations for curricular innovations that begin to address these attributes. The Accreditation Board for Engineering and Technology (ABET) implemented a revolutionary approach to accreditation by focusing on what is learned rather than what is taught, thereby fostering innovation [3]. Industry increasingly demands development of team skills, leadership skills, a better understanding of business processes, an ability to innovate and think outside of the box, and an ability to communicate effectively in a diverse environment (see, for example, [4]). In short, industry needs engineering graduates that can help solve and implement solutions to the complex problems industry is faced with today. Kellogg and Karlin [5] provide a holistic approach that includes technical skills, psycho-social development, cognitive development, and identity development. A conceptual framework for this approach and is reproduced in Figure 1 below.

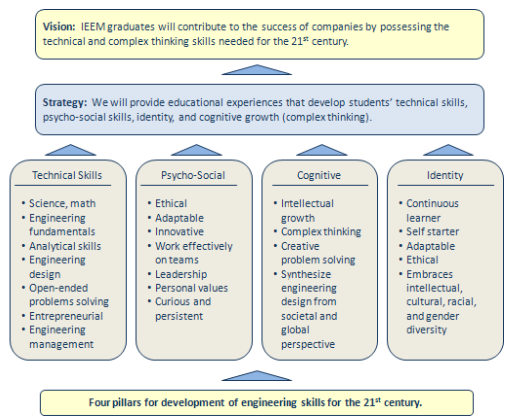

Figure 1. Four Pillars of Development of the Engineer of 2020

The Holistic Learner Development (HLD) model not only provides a useful conceptual framework, it incorporates many of the same strategies advocated by authors in the landmark 2005 edition of the Journal of Engineering Education [6-8].

The traditional engineering curriculum operates on a fundamental premise that technical skill development remains paramount and requires the bulk of instruction time. Psycho-social and identity development activities are generally relegated to minor roles and reside under the purview of student affairs and/or co-curricular activities. However, an increasing body of research indicates that this traditional approach limits student engagement and develops only a superficial understanding of engineering fundamentals. Indeed, regardless of discipline higher education seems to fall short of its promise to develop the

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complex thinking skills required for the leaders of tomorrow [9].

While Figure 1 provides a framework for the skills and attributes for the engineer of 2020, development of these skills remains a rich area of research for engineering educators. For our department, we have focused largely on activities that value intellectual diversity while simultaneously supporting improved complex thinking skills [9, 10] and promoting a better understanding of globalization and the business/management context of engineering.

II. Technology Enabled Support

According to a 2008 study, 52 percent of teenage boys and 26 percent of teenage girls spend over 42 hours per week watching TV, playing video games, computer, or internet time. Even the 73 percent of teenage girls and 48 percent of teenage boys that the researchers termed the "low screen time" group still spent 18 to 22 hours per week in front of a screen [11]. While this pre-disposition of the incoming (and already matriculated) STEM student body is generally considered detrimental to the completion of a student's homework, what if it were used instead to enhance learning and generate increased student buy-in to students' own education processes?

Over the past decade we have witnessed an enormous investment from many universities in distance education, classroom management software, technology enabled support from NSF, the National Engineering Education and Delivery and Delivery System (NEEDS), and Merlot online learning modules. Yet these efforts seem to have left a collective perception that, at least in terms of engineering and science education, these efforts fall woefully short of what is needed to dramatically improve learning gains. Faculty concerns seem pretty universal:

- Stand -alone interactive modules, either online or text based support, are seldom reviewed by students.
- Students most in need of additional support are also the students least likely to take advantage of support opportunities.
- Support modules do not adequately serve as a replacement for richer experiential learning activities.

The department has tracked student use, dwell time, and primary areas of interest for the past seven years. Data as well as faculty and student observations reflect many of the same concerns listed above. As an example, a critical area for industrial engineering graduates is statistical reasoning and the department has provided a number of online support modules in probability and statistics. Despite that effort, learning gains in that area remain elusive.

Despite these drawbacks, technology enabled support modules have a number of useful characteristics that, if incorporated well, can provide useful support for student learning. Specifically, well designed support modules can

- provide value added modules to enhance or expand learning opportunities,
- address alternative learning styles,
- aid understanding of complex ideas through a visual or animated framework.

More importantly, once developed, technology enabled support modules can ameliorate some of the instructional burden of the faculty member and allow her the opportunity to spend less time lecturing and more time engaging students in deeper learning activities. It remains our belief that technology enabled support remains a viable curricular element if it can be successfully integrated into the learning environment. The remainder of this paper is devoted to a discussion of a sample project in cost estimating which attempts to do just that.

III. The Inverted Classroom

In the traditional classroom, students are assigned a section of a textbook to read before class. Following this passive, if it occurs at all, students attend class where they are passive recipients of a lecture. For many students, the first real engagement with the course material occurs following the lecture when attempting homework.

In the *inverted* classroom, we attempt to pre-engage students with the material prior to class and move the active content engagement from post-class to in-class. The first systematic attempts at classroom inversion came from economic education [12]. These early attempts at inversion moved the passive student engagement with lecture to pre-class by using media, computers, and the internet to provide basic content information to students before class. By providing some content prior to class, the instructor is free to use appropriate active learning elements to draw the students deeper into the material.

There are a variety of techniques faculty members incorporate in an inverted class; they all share the same underlying imperative: students cannot passively receive material in class. Instead, they pre-engage with the material largely outside of class by reading, watching recorded lectures, or listening to podcasts. This pre-engagement is one of the reasons students often dislike inversion or flipping. When they are in class, students do what is typically thought to be homework, solving problems with their peers, and applying what they learn to new contexts. It seems clear that a well-designed inverted (or flipped) classroom can lead to better learning outcomes, better conceptual understanding, and increased student motivation [13]. However, inversion is not without its drawbacks [14]. Inversion is not the norm by which most students are taught. Consequently, the inverted or flipped classroom requires a paradigm shift on the part of the student and this is not always well received. A common concern of many students is why come to class if they must view the lecture, particularly a boring lecture, before coming to class. In this case, the primary focus rests with their perception of the teaching paradigm rather than on the learning that is actually accomplished. A second problem is that in the flipped classroom, students generally solve problems that are not template problems, or at least they should be. This is harder and is often met with reluctance on the part of the faculty member, the student, or both. Finally, the inverted classroom is almost always more labor intensive than the traditional lecture. It requires faculty to develop a well-organized set of materials, a cohesive set of learning objectives, and alternative learning strategies that focus on conceptual understanding rather than problem solving via the traditional pattern recognition paradigm.

IV. COST ESTIMATING PROJECT

In this project, we focus on inverting a basic skills course in Cost Estimating. We selected this course because the development time for a lower level skills class would be less and, once fully developed; the course could provide a value added component for non-majors. The course is modularized into three primary modules that consume roughly 1/3 of a semester each and are taught in sequence so that all three are covered over the span of a semester long course. The basic modules include

- Accounts, transactions, financial statements and analysis
- Business forecasting, budgets, overhead, and alternative costing methods
- Project estimating, product estimating, universal techniques, operation costs.

Modularization of the course allows us to do several things. It allows us to focus development efforts on an individual module while still allowing the course to be taught in a mixed mode that includes both inversion and traditional lecture. Because the topics are only loosely connected, modularization also seems to provide a better conceptual framework for the students. And finally, course modularization seems more palatable to non-majors who wish to complement their technical skills within a business or plant management context.

Prior experience with technology enabled support provided preliminary assessment information on different inversion techniques, different technology support designs, as well as some insight as to student perceptions regarding different support elements. Based on this preliminary data we concluded that we did not want to develop a course that relied heavily on online lectures or assigned readings in a standard text. Rather, we elected to incorporate a variety of medium intermixed with short lectures followed by group problem solving exercises. The following elements should be incorporated into the overall design.

- ***Online interactive text:*** When fully developed, each module will support an online interactive text. The text incorporates accounting and cost estimating basics but is supplemented by a wealth of reference materials for those students desiring traditional text. Interactive text incorporates reading coupled with student data entry and self-correcting exercises.
- ***Technology enabled support:*** a number of exercises similar to those covered in the text are included as stand-alone exercises on a department support web site. This allows students to review additional exercises or to review a simple method at any time during the studies. Most interactive exercises are developed in flash though a growing number are developed under alternative media. Tools include a plotter and numerical calculator.
- ***Podcasts:*** development of some materials is both labor intensive and complicated enough that students find it easier to visualize the material through a short podcast. All podcasts are accomplished via Camtasia which allows for integration of both PowerPoint and excel within one podcast. In addition, they reside on the instructor's computer so they can be easily edited for alternative applications. All podcasts are 5-10 minutes in length.
- ***Classroom Structure:*** the classroom typically involves a 10-15 minute lecture followed by a group problem solving exercise. We rarely accomplish more than two exercises in any given class period. Homework is assigned weekly with some graded in class and some open ended problems reserved for instructor grading.
- ***Model eliciting:*** we attempt to offer one model eliciting activity per module. Model eliciting activities attempt to engage students in open ended problem solving activities and understand fundamental concepts though model formulation.

Sample Online Text

The advantage of the online text is that student reading is supplemented by online data entry that is student controlled and self-correcting examples that essentially replace rudimentary homework assignments to reinforce fundamental concepts. This is accomplished by requiring students to complete online preliminary homework interactions prior to class instruction. A sample interaction is shown for financial analysis in Figure 2 below. The Try It button opens a new window and interactive exercise for students to complete before moving to the next section. In all cases, student interactions are automatically corrected after two miss-calculations.

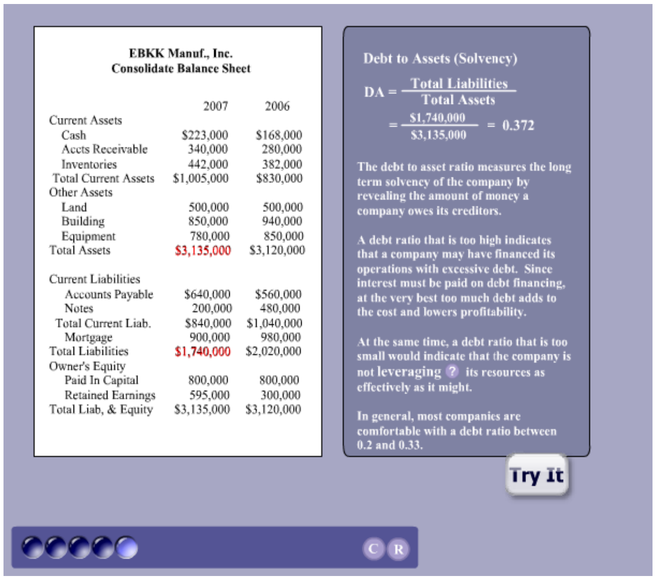

Figure 2. Sample Interactive Text with TryIt Button

For some sections a separate help dialog icon (similar to Microsoft's question mark help button) appears offering definitions of terminology or additional information. The help dialog box appears as a short window overlay on top of the main text. A sample help dialog box is shown in Figure 3 below.

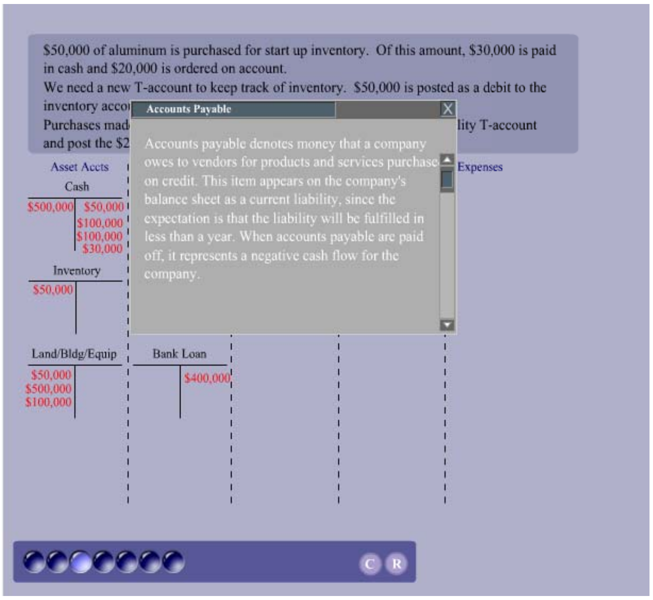

Figure 3. Sample Text with Open Help Dialog Box

A first step in the budgeting process requires a forecast typically through exponential smoothing. Figure 4 below shows a portion of the step-by-step solution for a simple exponential smoothing model. Supplemental tools include a functions page, an introduction to forecasting with moving averages, linear trends, and exponential smoothing. Short podcasts for each are provided on the course schedule page.

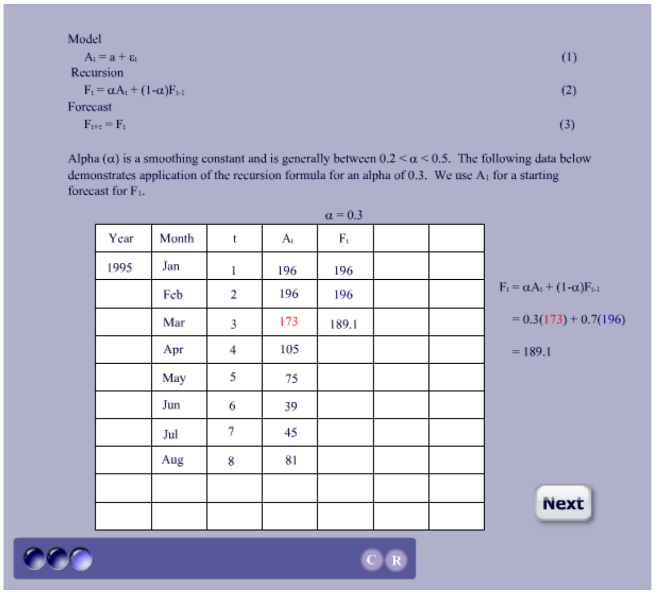

Figure 4. Online Support Module Demonstrating Exponential Smoothing

Along with the text, we provide a variety of supplemental exercises to allow students additional practice. These stand-alone interactions allow students to work through problems as they are reading through them. All interactions provide a self-correcting component which provides a hint and ultimately demonstrates how the calculation is to be made for more complex problems. A sample self-correcting exercise for a balance sheet problem is shown below in Figure 5.

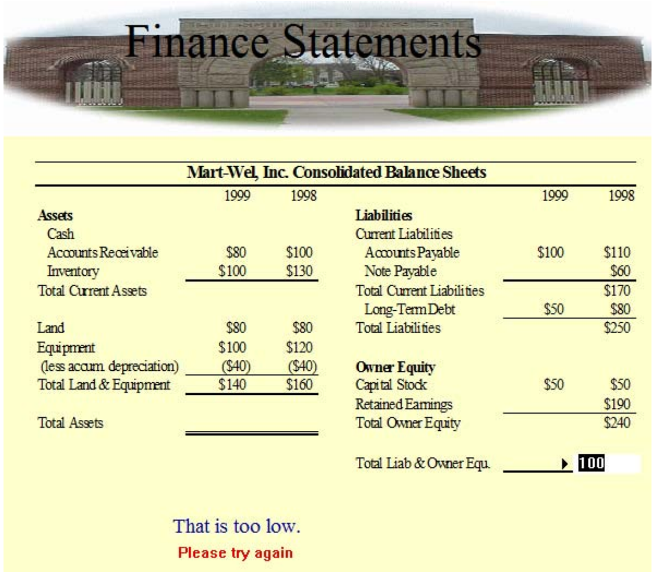

Figure 5. Self-Correcting Balance Sheet Problem

Along with sample exercises, the course includes supplementary materials that students may find useful or of interest but are not necessary for course understanding. Samples include a mortgage template, a retirement template, a loan calculator, and an interactive wealth accumulator which accounts for monthly investments, inflation, and growth rates. A sample interactive plot from the wealth accumulator program is shown below in Figure 6.

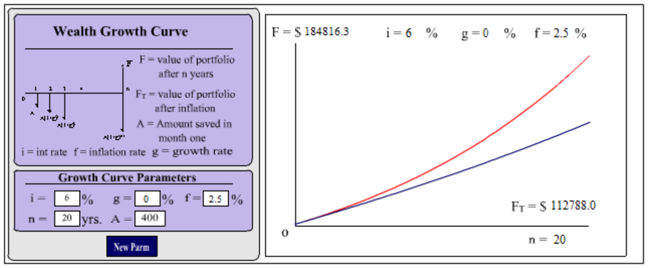

Figure 6. Sample Output from the Wealth Accumulator

V. PROJECT ASSESSMENT

While this project has required substantial development effort, ultimately less time is devoted to lecture and a greater portion of classroom time is spent on active collaborative in class problem solving. This allows for a greater variety and open ended homework assignments as well as incorporation of model eliciting activities. Assessment activities include statistical tracking of time modules used and time on task, a student satisfaction survey, and student performance on exams.

Figure 7 below shows page loads, unique visits, and returning visits for the last offering of the course. Not surprising, student usage for more developed sections. Page loads and dwell time are used as formative assessment to determine which modules are perceived to be more useful and which require additional development.

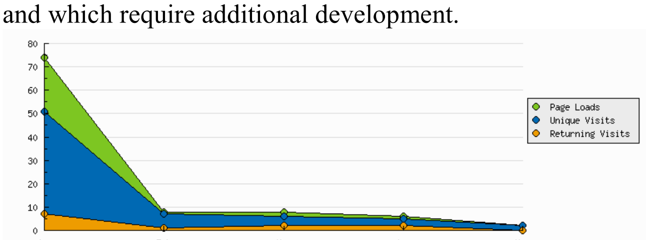

Figure 7. Student Use Tracking for Cost Estimating Modules

Student exam scores show a slight improvement from 2009 to 2012 (Figure 8 below) although it is not yet clear if real gains in conceptual understanding are realized. Department global measures include student typology using the Herrmann Brain Dominance Inventory and intellectual development through use of the Reflections of Current Issues instrument. These instruments show remarkable gains in both intellectual diversity and intellectual growth. While there is a belief that less reliance on lecture and greater reliance on active group problem solving is contributing to these gains, formal assessment correlating these gains to classroom inversion is currently under consideration. Finally, student self-reflection of learning gains indicates greater student satisfaction with the inversion approach.

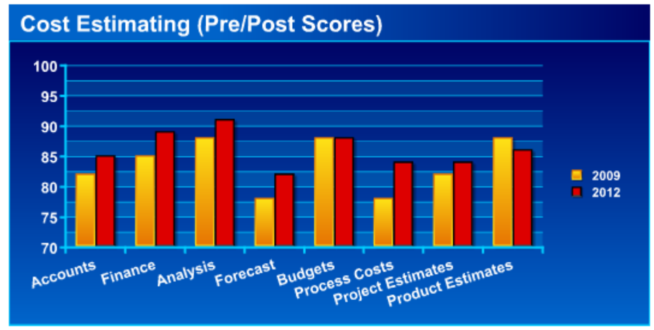

Figure 8. Pre and Post Exam Scores for Cost Estimating

VI. FUTURE DIRECTIONS

This project was established to ascertain the efficacy of classroom inversion through technology enabled support. While development efforts are significant and much still remains, it seems clear that textbooks of the future will require some incorporation of an integrated technology component. Department data, along with a substantive body of literature, indicates that students will not likely make voluntary use of supplementary materials. These materials must be integrated in the curriculum in some meaningful way. Given faculty constraints, higher learning gains are likely to be garnered at lower cost through other engaged pedagogies. Nevertheless, with the advent of new technologies, new strategies for inversion are likely to continue to be an important component of the classroom of the future.

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Why are continuous-time signals and systems courses so difficult? How can we make them more accessible?

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***Abstract*— The introductory continuous-time signals and systems (CTSS) course is widely considered one of the most difficult courses in electrical and computer engineering (ECE) curricula. This workshop will be an interactive discussion about sources of difficulty and what can be done to help improve student learning and understanding. In the first part of the workshop, discussion will be sparked and encouraged through presentation of historical data and directed questions. The goal will be to advance a continually developing understanding of the problem. In the second part of the workshop, attendees will learn about hands-on activities that are being done at Bucknell and Rose-Hulman to help address what the authors think some of the issues are. Attendees will have an opportunity to attempt one of these activities and provide feedback based on the previous discussion about learning difficulties.**

Keywords—signals and systems; continuous-time; active learning; hands-on activities

GOALS OF THE WORKSHOP

The introductory CTSS course is one of the most difficult courses that students encounter in an electrical and computer engineering (ECE) curriculum. This is evidenced at Rose-Hulman over the last 10 years by drop/failure rates that are at least two times greater than any other course except electromagnetics. We have received NSF funding to explore why students find these courses so difficult and to determine effective methods for helping students grasp the concepts. This workshop offers engineering and science faculty an engaging opportunity to explore how to improve learning in introductory continuous-time signals and systems (CTSS) courses [1]. The two primary goals of the workshop are to provide:

- an interactive discussion that will try to provide as broad a perspective as possible to the question “Why is signals and systems difficult?” and,
- a hands-on experience with laboratories that developed and used at Rose-Hulman Institute of Technology and Bucknell University over the past 4 years to improve learning in CTSS courses

CONTENT OF THE WORKSHOP

While many people are developing supplemental materials for CTSS courses, very little exploration of the sources of difficulty from the student’s perspective has been done[2][3]. There are many opinions and ideas with regards to these sources, but we would like to take a scientific approach to arrive at more definitive answers. Once more of these sources are identified, we can tailor the supplemental materials to be more effective. This work is being done in collaboration with Dr. Ruth Streveler at the Purdue School for Engineering Education, who specializes in the learning of difficult concepts. We are analyzing historical data and developing new studies to try to identify more of these issues. In addition to those studies we want to gather input from the community at large to try to get as broad an understanding of the problem as possible. The first part of the workshop will be an interactive discussion with the purpose of gathering such input. Discussion will be sparked by presenting data, current ideas, and directed questions. The results of this discussion will be used to guide the remainder of the workshop.

We have been trying to address issues that are related to lack of motivation and learning by creating application-oriented hands-on active-learning opportunities for students [4][5]. There are many examples of such opportunities described in the literature, but most of these activities make use of MATLABP®, LabVIEWP®, or DSP hardware [6]. The exercises described in this workshop are based on analog circuits and real-world applications of continuous-time signal processing and system modeling. There are certainly advantages to using software simulation tools for laboratory exercises because they are relatively inexpensive and students can perform many “experiments” relatively quickly. In fact, many of the exercises described in this workshop could be simulated entirely using such software tools. We are not advocating the elimination of these simulators, and in many cases use them for both prelab exercises and/or analysis of results. However, there is one key advantage to using hardware-based hands-on activities and real-world applications that simply cannot be obtained with software-only based activities. Practicing engineers use the theoretical and mathematical concepts from CTSS courses to model real-world physical phenomena. The overwhelming majority of students have never had an opportunity to connect those theoretical concepts with the physical phenomena that they are trying to model[2]. So it’s possible that a lack of motivation could be due to a lack of understanding of what use the concepts have. While software tools can help students visualize the concepts,

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they are in-themselves also modeling tools. An important way for students to gain an experience of the phenomena that they are trying to model is to actually experiment with them[7]. Using a real system with real-world applications creates a degree of credibility and relevance that is not possible with software simulations. When students manipulate these systems, there is an understanding that they are changing something physical rather than simply adjusting a number.

In order to facilitate application-oriented hands-on activities, we have developed a number of laboratory lesson plans and an analog printed circuit board, the signals and systems exploration platform (SSEP)[8]. The SSEP can be configured easily to sum, multiply, filter, and sample continuous-time signals. With an onboard microphone, ECG/instrumentation amplifier, and generic signal input, a wide variety of signals can be studied and manipulated. During the workshop, several stations will be set up with portable electronic instrumentation and an SSEP.

The workshop will provide a brief introduction to the SSEP and some of the lesson plans that were developed both with and without the SSEP in mind. The attendees will then have an opportunity to run through one of the lesson plans. Finally, in order to close the loop, attendees will then be able to provide feedback relating the activities to the previous discussion about sources of difficulty in CTSS courses.

Intended Audience and Number of Attendees

We expect this workshop to be primarily of interest to undergraduate electrical engineering faculty who are involved in signal processing education. The examples and materials presented would also be of interest to those teaching Fourier theory in other disciplines such as physics, mathematics, and other types of engineering. We would expect to have approximately 10-15 attendees.

Workshop Agenda

I. Introduction to the workshop **(5 minutes)**
II. Discussion of the initial question: Why is CTSS such a difficult subject for students? **(30 minutes)**
III. Introduction to hands-on activities being done at Rose-Hulman and Bucknell **(10 minutes)**
IV. Brief Introduction to the SSEP **(5 minutes)**
V. Supervised hands-on activities with the SSEP (**25 minutes)**
VI. Reviewing activities with regard to the initial question. **(10 minutes)**
VII. Assessment of the workshop **(5 minutes)**

Take Away Skills

We are expecting attendees to leave the workshop with a greater appreciation for the sources of difficulty in CTSS courses and some ideas of simple hands-on activities that can be used to help make the material more approachable to the students. They will have some experience with these activities and knowledge about how to acquire the equipment and lesson plans so that they could begin using these activities at their own institution. They will also be invited to attend a more in-depth summer workshop at Rose-Hulman during the summer of 2014 and to participate in an ongoing discussion of the issues.

Qualifications of the Presenters

Mario Simoni is an Associate Professor of Electrical and Computer Engineering at Rose-Hulman Institute of Technology. He has been teaching for 12 years including the introductory CTSS course and analog circuits. He developed an analog circuit platform that facilitates hands-on activities in the CTSS course and the activities that go with it. He has been using these activities for the past three years.

Maurice Aburdene is a Professor of Electrical Engineering at Bucknell University. He has been teaching for over 30 years, including courses on linear systems and signal processing.

Farrah Fayyaz is a doctoral student in the School of Engineering Education at Purdue University. She holds Bachelors and Masters degrees in electrical engineering from the University of Engineering and Technology, Lahore, Pakistan and taught signals and systems, digital signal processing, analog circuits and microelectronics in Pakistan for more than eight years. Her Masters research focused on identifying student difficulties in learning signal analysis. She will continue investigating students' understanding of various concepts in signals and systems for her PhD dissertation.

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True Grit: Toward a Culture of Psychological Preparedness in Engineering Education

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Abstract: **The rigors of engineering education present each student with a unique set of academic and psychological challenges. Established interventional strategies are typically focused on enhancing academic - rather than psychological - preparedness, potentially leaving many students vulnerable to various demotivating factors. Participants in this special session will collaborate to develop a nucleus of ideas to inform the future development of psychological preparedness strategies - interventions specifically designed to facilitate productive processes such as self-efficacy, self-discipline, resilience, and motivation.**

Index terms – Student preparedness, psychology, motivation, resilience, self-efficacy, retention

INTRODUCTION

"All the Sputnik-like urgency has put classrooms…under a microscope. And there are encouraging signs, with surveys showing the number of college freshmen interested in majoring in a STEM field on the rise. But, it turns out, middle and high school students are having most of the fun, building their erector sets and dropping eggs into water to test the first law of motion. The excitement quickly fades as students brush up against the reality of what David E. Goldberg, an emeritus engineering professor, calls 'the math-science death march.' Freshmen in college wade through a blizzard of calculus, physics and chemistry in lecture halls with hundreds of other students. And then many wash out."

> - From *Why Science Majors Change Their Minds (It's Just So Darn Hard)*, The New York Times, 11/04/11

Being an engineering student can be tough. Pursuing an engineering degree typically involves facing greater academic challenges compared to those in many other disciplines [1,2]. But, as the passage above demonstrates, these challenges also have psychological components. The classes are often harder, the programs are often longer, the grades are often lower, and the commitment and self-discipline required are often greater. In the interest of student success, engineering educators have implemented a variety of preparedness activities in high schools, summer institutes, and their own programs [3,4]. While often successful, most of these interventional strategies focus on academic preparedness, while few seek to prepare students mentally or psychologically. Further, "in spite of considerable research about the poor retention rate of undergraduate engineering students, we still have an inadequate understanding of the factors that affect students' decisions to remain in engineering programs and their ability to perform well enough to be retained" [1]. Common sense and educational research [5-7] indicate that an inability to cope with the psychological demands of engineering education contributes significantly to student demotivation and attrition. This session will explore potential strategies for implementing a more holistic approach to student preparedness and success – one that acknowledges both academic and psychological needs.

The importance of mental preparation prior to a challenging task or journey, as well as staying attuned to one's own psychological state throughout such an experience, has been demonstrated in many contexts, perhaps most notably in competitive athletics [8] and the military [9,10]. Effective psychological preparedness activities often lead to greater resilience and the ability to maintain motivation in the face of uncertainty or self-doubt. In theory, instilling engineering students with such capabilities could lead to increased motivation, persistence, and retention.

The facilitators will begin this session by providing an overview of common psychological challenges faced by engineering students and orient participants with brief examples of psychological awareness strategies that have been effectively applied in non-educational contexts. Through semi-structured team brainstorming and discussion sessions, participants will generate ideas for developing and implementing psychological preparedness activities in various engineering education contexts. Next, we will

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collaborate as a group to revise and synthesize our ideas into actionable concepts that can be administered independently or integrated into existing course material. Finally, the facilitators will outline plans for the development of a collaborative psychological preparedness program in the Department of Engineering at James Madison University (JMU).

SESSION GOALS

The four primary goals for this session are as follows:

1. Discuss the possibility that the following "preparation gap" exists in engineering education: *To be successful, students must be both academically and psychologically prepared for the rigors of a university engineering program, but most existing interventional efforts are focused specifically on academic preparedness, potentially leaving some students psychologically vulnerable and ultimately unable to maintain the motivation necessary to persist until graduation.*
2. Generate a nucleus of peer-developed ideas to inform the future development of psychological preparedness strategies, activities, and interventions designed to increase engineering students' self-awareness, self-efficacy, resilience, and motivation.
3. Describe the ongoing development of psychological preparedness initiatives in the Department of Engineering at James Madison University.
4. Provide session attendees and other interested individuals with resources to develop psychological awareness and preparedness activities in their own courses and programs.

SESSION AGENDA

The session will be highly interactive with much of the time spent in group work and discussion. Two short presentations will help guide the group discussions. The agenda is as follows:

1. Welcome, introductions, and a brief presentation on the "preparation gap" that may exist between efforts to improve the academic and psychological strength of engineering students, and how students might benefit from being better prepared to meet the characteristic psychological challenges of an engineering education. [10 min]
2. Brief introduction to literature supporting the value of psychological preparedness [5 min]
3. Focused, large group brainstorming session to generate a list of common psychological challenges and preparedness needs of engineering students. [15 min]
4. Brief presentation on psychological preparedness strategies/interventions that have been effectively applied in domains such as athletics, business, and the military to increase motivation, grit, and resilience. [10 min]
5. Team activity (5-8 people per team, including one session facilitator) during which groups generate potential psychological preparedness strategies/activities/interventions that address common challenges faced by engineering students. The spokesperson / note taker for each team will present team findings to the large group. [30 min]
6. Large group synthesis of implications and potential future directions in the study of psychological awareness and preparedness in STEM education. [10 min]
7. Short introduction to a collaborative psychological preparedness initiative in development at JMU. [5 min]
8. Wrap-up summary and Q&A. [5 min]

DESCRIPTION OF ANTICIPATED AUDIENCE

We expect this session to be attractive to a diverse group of engineering educators who are interested in student preparedness and well-being and/or in increasing retention rates across engineering disciplines. A major goal of this session is to provide participants with potential strategies to help their students sustain the psychological challenges of engineering education and become productive professionals.

EXPECTED OUTCOMES AND FUTURE WORK

The primary expected outcome of this session is a nucleus of innovative work on the emerging domain of psychological preparedness for engineering students, which will be disseminated to participants and other interested colleagues. In addition, participants are expected to gain insight into the psychological challenges faced by their students, potentially leading to more effective teaching and advising strategies. If this session does impact the future work of engineering educators, it may have transformative implications for students' well-being and perseverance. Further, this work will inform on-going research and publications emerging from James Madison University.

DISSEMINATION OF RESULTS

Since we do not anticipate having time to fully discuss and share the results of the group work during the special session, we plan to collect the results of the group work, organize them, and send them to session attendees and other interested colleagues after the conference. Please contact Jesse Pappas (pappasjb@jmu.edu) if you do not attend the session but would like to receive a written summary of our results.

ACKNOWLEDGEMENTS

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Monitoring the Video Use for Learning Support

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Abstract - **The video consumption tends to grow in coming years and it will be increasingly imperative to know the validity and effectiveness of using this type of media especially in teach and learn activities. It is very important to be able to assess how much knowledge a particular didactic video content was effective in building students knowledge. In this paper we present a tool we developed and an experiment we realized with two classes of computer engineering course related to network computer subjects, totalizing 140 students. In our experiment we divided our students in two groups: half of them attended a video explanation and half of them had the same explanation but only in a traditional classroom format. Our experiments show that video can be a great ally in the teaching and learning processes. Nevertheless, our investigation must continue in order to understand all video potential in this purpose.**

Keywords - video, viewer engagement, learning processes.

I. INTRODUCTION

The video consumption tends to grow in coming years and it will be increasingly important for institutions that produce and use videos in their core activities, to have metrics and parameters with which to scale the physical infrastructure and human resources needed for such use. At the same time, it becomes increasingly imperative to know the validity and effectiveness of using this type of media. Especially in teaching and learning activities, it is very important to be able to assess how much knowledge a particular didactic content in video format was effective in building students knowledge, considering a student or group of students.

Many systems are designed to provide educational materials in video format for distance learning environments, as well as support learning material. The production of these videos requires a sophisticated infrastructure and a team to manage the entire process: the recording of videos, their edition, and the delivery process.

We wish to evaluate the degree of absorption of knowledge through this media consumption, as well as engagement with the subject. The concept of "viewer engagement" can be used in many ways, considering aspects such as usage scenario, age, or user´s cognitive characteristics, or by verifying the degree of involvement, using interactive tools and social networks to disseminate information or feelings about watching the video. In our case, we are more focused on education scenarios, with computer engineering students. Considering this, one possibility is to compare students' opinion about a video explanation, for instance, and their results in formal evaluation.

In this paper we present a tool we developed to monitor the video consumer behavior and, from polls, posting of opinion and multiple choice tests, infer about user interest about the video and the absorption of the content. We present also an experiment we have realized of video usage in learning processes with two classes of computer engineering course related to network computer subjects.

This paper is organized as follows. Section 2 presents related work. The monitor system is described in Section 3. Usage Scenario is showed in Section 4. Finally, results and analyses and conclusions and future work are presents in Sections 5 and 6, respectively.

II. RELATED WORK

Projections indicate that by 2012, video use will represent half the consumption of network in the world, already surpassing the P2P traffic, currently the most responsible for network traffic. By the end of the decade, projections indicate that this percentage will fit about 90% of the network bandwidth [1].

With this expectation is extremely important to monitor this consumption. Several monitoring tools have been released in recent years mainly for the purpose of checking the consumption of network resources.

For instance, Video Streaming Monitoring from Dotcom-monitor [2] that clam that the service monitor 3-5 seconds the media server, and in this period it verify the connection time, buffering time, received packages rate, frame rate and average bytes per second. Other example of commercial tool is Media Streaming Monitor by SciVisum [3]. Nevertheless, these kinds of tools focuses only in network consumption, and don´t make any monitoring related to video engagement.

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So far, few academic papers in monitoring and evaluating video consumption field have been published. Studies found, which will be discussed below, can be classified into user engagement with the consumption of Web videos, and videos using the method of teaching / learning.

Dobrian [4] evaluated the impact of video quality on user engagement, concluding that live content is most impacted when there is quality lost. This study concludes also the context of the user is very important for the analyses. Milliken [5] studies the potential of UGOV (User-Generated Online Video) tool, which allows video generation. These videos are posted on YouTube to check the contribution of regional identity in their consumption, level of involvement and engagement of Internet users. Engagement, in this case, is measured using a questionnaire that includes, for example, questions about frequency of application use, how much a user learned, how a particular video changed user´s opinion on a particular subject, and how many comments posted on social networks were related to the concerned video.

In another study, conducted by Bardzell [6], physiological measures, such as heart rate and respiration per minute, were used to measure the emotions caused by the most popular videos. They also used strategies such as emotional **tag** (user indicates their emotional state by choosing emoticons), space for adding a text review and logging the user actions with respect to the video (pause, stop, browse the timeline of video (seek), etc.). The work uses triangulation to analyze results obtained, crossing information, relating them to perception and emotional experience, preferably video, as well as contextual factors.

Another work that deserves attention, as it deals with an educational context, is the article written by a group at Microsoft Research. The article´s aim is to test the effectiveness of a video annotation tool, which provides video and synchronized slides, and space to include participation textual support [7]. The tool was tested for learning purposes in-group work, and also with individuals, showing that there was excellent absorption of educational content with its use. Another study presents a tool that defines the best place to put ads in a video [8]. The evaluation was done subjectively; using as parameters the relevance of the site, comfort ability and user satisfaction.

III. SYSTEM ARCHITECTURE

Four modules compose the monitoring system we had designed, as showed in figure 1.

- Server module: monitors the metrics related to server;
- Application Module: responsible for metrics related to user interaction with application;
- QoE and Content Absorption Module: records the QoE and content absorption´s assessment score;
- Report Module: responsible for the use of the data obtained, crossing it to allow proper result analysis.

As the purpose of this system is to monitor the learning actions and check the student's engagement to consume video element, we chose to integrate the monitoring module to a system of teaching/learning, as LMS (Learning Manager System). Thus, we can join quickly and easily the video element to a course material, and monitor the student interactions.

Although monitoring modules are independent from any system, we choose Tidia-Ae LMS [9] to integrate QoE and Content Absorption Module, in order to build a learning context.

The diagram in figure 1 show the system overview and its modules, focusing on the communication flow, where solid lines indicate the request between user desktop/LMS and LMS/Video Server; the dashed line indicates the video streaming from video server to user desktop or device and the dotted line represents monitoring of data persistence in database.

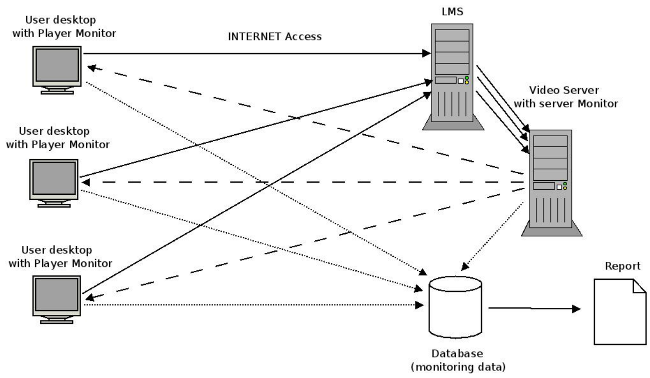

Figure 1: System overview with communication between modules indicated

Using the monitoring system it is possible to get many metrics of video consumption that can be classified by:

Video Player Parameters – monitored based on user interaction with video player:

- Mouse actions;
- Windows focus;
- Pause, fast forward, rewind
- Use of Comments tool;
- Interaction with social network tools (Facebook, twitter).

QoE – check the level of user satisfaction proposing a poll;

- Related to video content quality;
- Related to video quality;
- Related to transmission quality.

Content Absorption – check how much user has learned watching video content:

- Evaluation based on test learning validation;
- Other activities to check content absorption (debates, work groups, etc).

Figure 2 shows the interface of the LMS integrated with the monitoring modules. In this screen it is possible to see the video player, the text box for comments, social networks Facebook and Twitter icons, the stars that allow classification of video quality (and consequently transmission quality), and finally, next to the video player, the tests to assess content absorption.

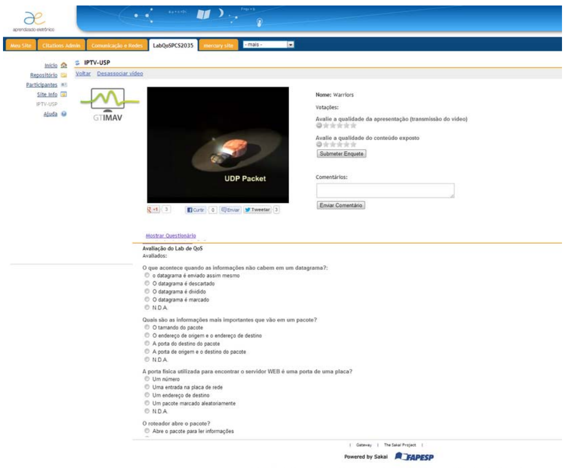

Figure 2: Shot screen video player in LMS integrated to monitoring modules

Please, refer to [10] for more information about system implementation.

IV. USAGE SCENARIO

When an user accesses a video, he/she can interact with it in different ways: evaluating it using tools provided in the application interface (chat, forum), commenting on it (by blogging, writing in a wiki or publishing comments in a public site), as well as sharing it in social networks. In addition, the user can be asked to answer several types of polls and tests about the watched video.

The use of video application to support the learning process is being considered as a baseline to guide the project development. We understand the potential of using video in this type of scenario and see that the goal is to design a monitoring service to assess the benefits of using video in this context.

Besides trying to measure how much the videos help in the learning process, we aim to enable the service to extract various other important informations, such as quality of content, level of effectiveness of a particular video on learning a specific concept, and the level of student interest in the subject.

In order to evaluate the service being developed, first we must create the following test scenario:

- Use of two groups of students. For the first group, class material will be available on video as supporting content. For the second group, this video material is not available, thus serving as a control group for testing.
- For the team using the video material, the assessment of student awareness and engagement with regard to the material will be made through a set of subjective questions, for example:
  - Evaluating the perception:
    -- Overall: excellent, good, indifferent, bad, very bad;
    -- Understanding of content: it helped a lot, helped, indifferent / did not help, made me confused.
  - Evaluating the engagement:
    -- Through comments made about the video;
    -- Through the sharing / recommendation of the video.

Figure 3 illustrates the usage scenario.

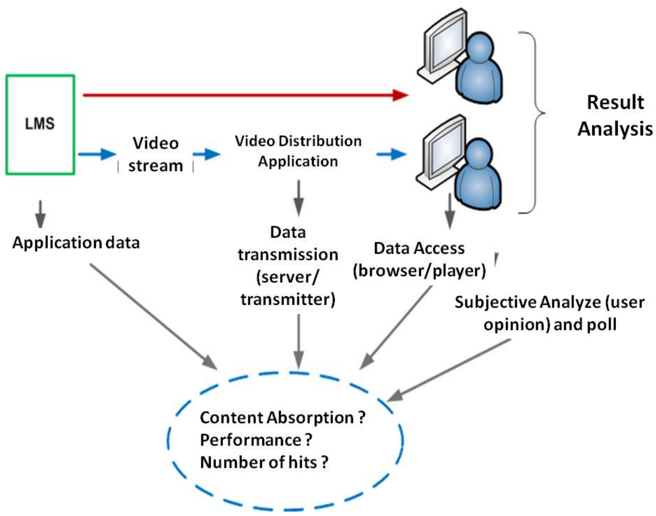

Figure 3: Learning scenario of system use

After the tests, based on the average score of each team and within the group that received the video as learning support, the variation of the grades will depend on the level of subjective evaluation, combined with evaluation of technical parameters collected (if the student had trouble watching the video due to a long buffering time or transmitter overload, for example, if he or she has watched all the content or not, interacted with the content by making a comment or engaging in video sharing/recommending)

Then, the final score of each group will be compared and analyzed, and within the group which received the video material, specific parameters will be created for the evaluations, such as the variation of grades depending on the subjective evaluation questionnaire that each student has answered. Adding to this, the technical data collected (directly related to the reception quality of the user), will also be considered. For example: difficulty in watching the video due to problems arising from the user's network infrastructure, the video application, network video transmitters, as well as analyzing whether the user has watched the video in its entirety or only partially, written comments or recommended the content in any way. Thus we have a complete analysis of the user experience quality and how these factors affect student performance.

From this scenario it will be possible not only to assess the potential of the service, but also to allow extraction of information that may be useful to improve the attractiveness of the videos and content, or make it possible to adapt the content (for example, videos should not last longer than a certain time, or the absorption level drops). These are just some examples of analysis that could be made from the data collected.

V. Results and Analyses

According to the procedures described in item VI we applied, during the last academic semester, an experiment as described above to a group of students at the beginning of the second year of engineer, and/or computer present courses. Actually these students are from any science or technology course offered by UFABC University, as it is an obligatory discipline. To this experiment we considered that it would be easier to accompanist students and listening to their opinions during present the classes so we took this experiment not in virtual classes but only in face-to-face classes. As the discipline was Communications and Networks we choose a movie with an explanation of how Internet works, focused on how packets move through the Net, and how routers and switches treat these packets. It is possible to see in Figure 2 a shot screen of the video we used in this experiment.

Our students were divided in two groups, one with 78 students and the other with 74 students. Each group belonged to a classroom and the professor, which was the same for the two groups, in both classes explained the same concepts but, in one of these classrooms, students were asked to watch a movie with the same explanation done in the classroom.

As students were not obliged to watch the video explanation only 41 from 78 students did this activity. To both groups were applied in their traditional evaluation two questions that were explained in classroom and that appeared also in the video explanation. We also did a Quiz questionnaire in the video page with the same two questions we did to both groups in their formal evaluation. In Figures 5 it is possible to observe the video quiz results.

Figure 4 shows the distribution of students that answered correctly equivalent question at video quiz for exam´s questions 2 (Q2) and 3 (Q3), and for that ones that answered wrongly equivalent question at video quiz for exam´s question 3 (Q3). The intervals considered are: Interval 1 is from 0,82 to 1, interval 2 is from 0,62 to 0,8, interval 3 is from 0,42 to 0,6, interval 4 is from 0,22 to 0,4 and Interval 5 is to 0 to 0,2. These show that, for instance for Q2, 88% of students got maximum score on this question at the final exam after doing video quiz; and considering Q3, 64% of students got maximum score at this question at the final exam after doing video quiz. In the other hand, 29% of students that answered wrongly Q3 at video quiz got worse score at this question at final exam.

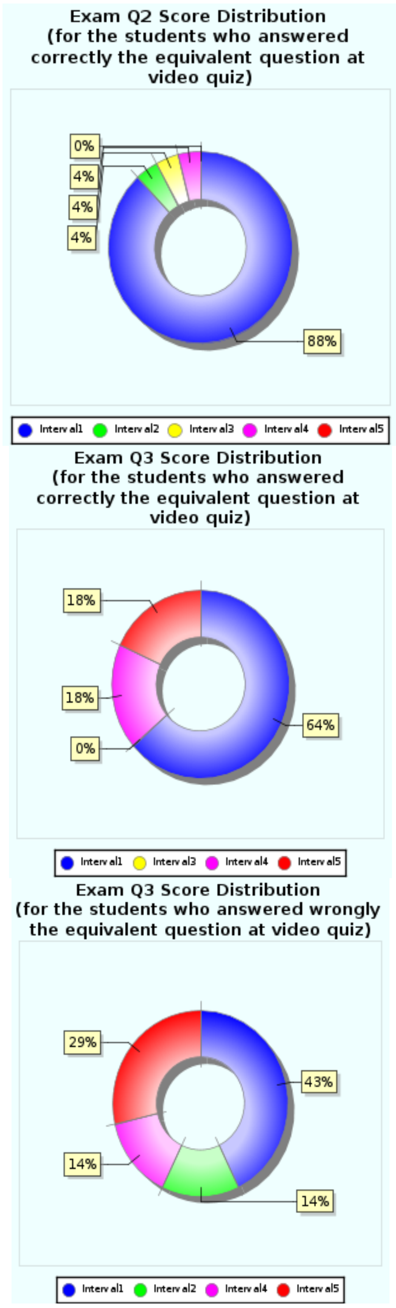

Figure 4: Video quizzes results*Normalized scores: interval5 = [0, 0.2], interval4 =]0.2,0.4], interval3 =]0.4,0.6], interval2 =]0.6,0.8], interval1 =]0.8,1]

We also applied to both groups the same questions in their formal evaluation, which means, both classes did an evaluation in a written format. We repeated the same questions to the group that watched and that had already done the same questions in the video quiz questionnaire and the results are shown in Figure 5.

From the results shown in Figure 5, one can observe that the students who watched the video performed better than students who did not watch the video. From these results, we conclude that the video content helped students better understand the educational content they were learning. In this case, the video content was used as a support material, since the same teacher in the subject that was requested during the evaluation taught both groups.

Comparison between classes

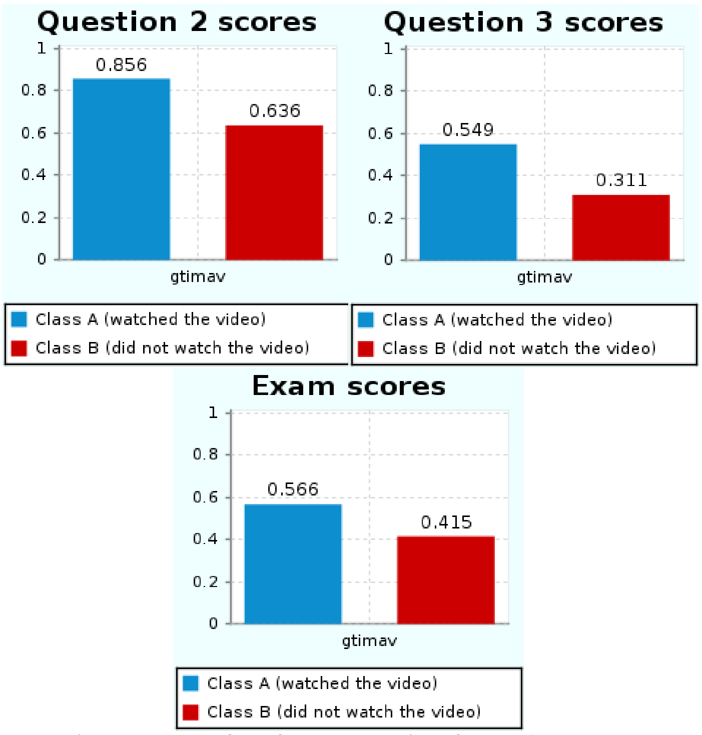

Figure 5: Results from formal evaluation of group A and B

Simultaneously we were observing how students were learning from the video contents; we observed how was their perception of video transmission quality and how was student's perception of video content, shown respectively in Figure 6 (a) and (b).

Another question we would like to answer in this project is: is there a relationship between student's learning profile and his/her behavior when exposed to a didactic content presented in a video format?

At the beginning of this experiment we imagined that it would be important to know our student's profiles to try to answer to question presented. It is not an easy task to determine and obtain this information but we applied a profile test based on Multiple Intelligences, proposed by Gardner [11] and tried to verify if there is any relationship between student's behavior in our video tests and their learning profiles. We can see some relations and some results in Figure 7.

Figures 6a and 6b: Students evaluating of video transmission quality and perception of video content

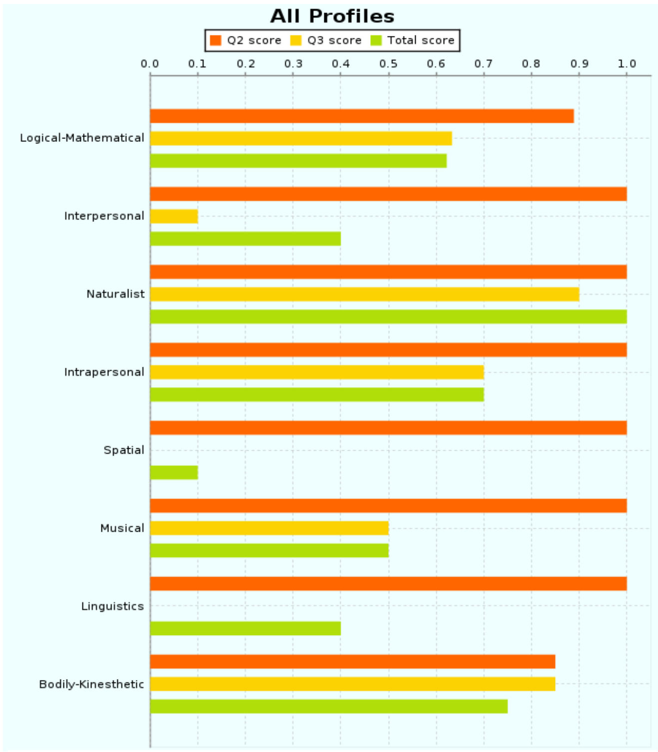

Figure 7: Relationship between student's profile and their performance in the test

VI. CONCLUSIONS AND FUTURE WORK

As presented in this paper, video consumption tends to grow in coming years and it will be increasingly important for institutions that produce and use videos in their core activities, to have metrics and parameters with which to scale the physical infrastructure and human resources needed for such use. At the same time, it becomes increasingly imperative to know the validity and effectiveness of using this type of media. Especially in teaching and learning activities, it is very important to be able to assess how much knowledge a particular material in video format was effective in building, considering a student or group of students. The results that we see from this experience seem to be like that the offer of educational content in video formats tend to achieve better results in our intent to teach a specified content.

But, although we developed our experience with groups formed by a significant number of students, it is not easy to observe the relationships between the data collected. So these data are not yet sufficient to say that actually students learned more based on didactic content offered in video format. So to be able to say with certainty that a didactic content in video format is effective in the learning process we need to develop more experiments like this so that we can cattegorically state that it worth it produce educational video content once this format not only entails a higher cost of production but also distribution, since resource-intensive network infrastructure are needed.

Another important conclusion we obtained is that to prepare an experiment like this it is necessary to produce in advance all videos will be used, to define in what moment during the discipline period they will be offered and what questions will be done to be possible to infer what and how much students have learned. To do this it is important to have a group to setup the experiment because it demands a lot of work to a teacher develop alone.

Finally, as nowadays there are a lot equipments to produce 3D video, we want to produce some didactic material in this new format, to try to understand if the conclusions we obtained by observing the 2D didactic content can be applied to 3D format as well.

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Programming Tutors, Practiced Concepts, and Demographics

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***Abstract*— A study was conducted to find out who needed online problem-solving tutors and who benefited from using them. In particular, the study focused on whether there were any significant differences between male and female students and between traditionally represented and under-represented racial groups. Data collected by two Computer Science tutors over multiple semesters was analyzed. The only significant differences found between sexes and racial groups were when female students practiced significantly more concepts because they had solved significantly fewer problems during pre-test, or when they demonstrated greater pre-post increase in score because they had scored significantly less on the pre-test. In both the cases, the tutors helped female students overcome differences in prior preparation vis-a-vis male students. No difference was found between the sexes or racial groups on the number of practice problems solved per practiced concept. Finally, students needed and benefited from the tutors in the same proportion, regardless of sex or racial group.**

Keywords- problem-solving; online learning; demographics; software tutor; computer programming

I. INTRODUCTION

Solving problems is an integral part of learning STEM (Science, Technology, Engineering and Mathematics). Traditionally, problems have been included at the end of each chapter in STEM text books. Instructors have given out problem-solving assignments, and used problems for assessment during tests.

Problem-solving activity is increasingly going online. The benefits of online problem-solving are several: students get their answers graded instantly; they can receive feedback on how to solve problems correctly; and they can solve problems as often as they please, at their own pace, and on their own time.

Some online problem-solving systems that are available for computer programming include CodeLab (turingscraft.com), myprogramminglab (myprogramminglab.com), codingbat (codingbat.com), CodeMate (pearsonhighered.com/mycodemate/), and CloudCoder (cloudcoder.org) - they provide practice writing code snippets focused on specific programming constructs. In contrast, we have been developing software tutors to help students learn programming concepts by solving code-tracing problems, called problets (problets.org)

Most of the studies of the effectiveness of learning Computer Science concepts from online tutors originate from research on Intelligent Tutoring Systems (ITS). For example, in one of the early studies, ITS researchers documented one standard deviation improvement in learning LISP using a problem-solving tutor [1]. However, many of the studies in Intelligent Tutoring Systems have been conducted *in-vitro* rather than *in-vivo*. More *in-vivo* evaluations of online tutors in Computer Science would better justify the wide-spread use of such tutors in Computer Science and the concomitant costs associated with developing the tutors. In one of our early *in-vivo* studies, we found that online tutors indeed helped students learn [2] and students who used the tutor for practice learned better than those who used a printed workbook [3].

Women and minorities are significantly under-represented in Computer Science, e.g., in 2011-2012, the latest year for which Taulbee survey figures are available (cra.org), women represented only 12.9% of Bachelor's degree graduates; Caucasians represented 64%, Asians 16.3%, and non-Asian minorities accounted for less than 20% of the graduates. Given the rising popularity of online tutors in Computer Science, it is appropriate and timely to study the differential effects, if any, of using online Computer Science tutors on women and minorities. In one of our earlier studies, we found that female students did learn using problets, and that there was no statistically significant difference between the improvement in the learning of female and male students using problets [4]. In another study, we found that using problets improved the self-confidence of female students to be on par with that of male students when female students started with lower prior self-confidence than male students [5]. We also found that female students assessed problets more positively than male students [6], and whenever there was a statistically significant difference between racial groups, under-represented racial groups assessed problets more favorably than positively stereotyped racial groups [7].

Two interesting questions about the differential effects of using online problem-solving tutors in Computer Science are: who *needs* to use them, and who *benefits* from using them. In particular, whether there is any significant difference between male and female students, and between traditionally

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represented and under-represented racial groups. In order to answer these questions, we conducted a study using problets, spanning multiple semesters. In this paper, we will present our findings, after first discussing the research methodology, and data analysis.

In the study, participants were asked to identify their sex (biological notion of male/female) rather than their gender (social/cultural notion of man/woman) [8]. Therefore, the analysis will be presented in terms of sex rather than gender. When comparing racial groups, two groups were considered: traditionally represented racial groups versus under-represented racial groups. Asians are positively stereotyped in quantitative domains such as Computer Science (e.g., [9]). Therefore, Asians were combined with Caucasians to form the traditionally represented racial group (referred to as "majority" in another study [10]). The other racial groups, viz., Black/African American, Hispanic/Latino, Native American, Native Hawaiian/Pacific Islander and Other designations were combined to form the under-represented racial group.

Given the significant under-representation of women and minorities in Computer Science, the results of this study will be of interest to educators who use problem-solving software tutors in their Computer Science courses. If women and/or minorities are found to need and/or benefit from using problem-solving tutors, the results would provide justification for greater development and use of such tutors in Computer Science.

The online problem-solving software used for this study, called problets, deals with introductory computer programming concepts. Each problet presents problems on a specific programming construct and has the student solve them. When the student submits the answer, the problet grades it, and provides feedback, including step-by-step explanation of the correct answer, which has been shown to help students learn [2].

Each problet is configured to administer pre-test-practice-post-test protocol as follows:

- **Pretest** – During the pretest, the problet presents one problem per concept. If a student solves a problem correctly, the student is given credit for the corresponding concept. No feedback is provided to the student, and no more problems on the concept are presented to the student. On the other hand, if the student solves a problem incorrectly, feedback is presented to the student immediately after the student submits his/her solution to the problem. Additional problems are presented on the concept during the subsequent stages.
- **Adaptive practice** – During this stage, additional problems are presented to the student on only the concepts on which the student made mistakes when solving problems during the pre-test. For each such concept, the student is presented multiple problems until the student masters the concept, i.e., solves at least 60% of the problems correctly. On each problem, the student receives feedback explaining the correct answer step by step.
- **Post-test** - During this stage, the student is presented test problems on the concepts that the student mastered during adaptive practice.
- **Demographics** - Students are provided the option to identify their demographic information, including sex and race. Demographic information is solicited after the pre-test-practice-post-test protocol to avoid the effects of stereotype threat [11,12,13].

The pre-test-practice-post-test protocol was limited to 30 minutes and was administered back-to-back, entirely over the web.

Given this set up, the following were the types of experiences students had using the problet:

- The student solved all the pre-test problems correctly. So, the student was presented no practice or post-test problems.
- The student solved at least one of the pre-test problems incorrectly. However, the student ran out of time solving practice problems and never solved any post-test problems.
- The student solved at least one pre-test problem incorrectly, solved sufficient practice problems to demonstrate mastery of at least one concept and solved a post-test problem on each such concept. For these students, **the number of practiced concepts** was the number of concepts on which the student solved pre-test problems incorrectly, solved sufficient practice problems to demonstrate mastery and solved the post-test problem.

For analysis purposes, we grouped students into four categories, and used the following measures to compare them:

- **Students who did not need to use the tutor** – these were the students who scored 100% on the pre-test. So, the tutors did not present any practice or post-test problems to these students. For these students, the time spent per pre-test problem was compared - those who solved problems faster had greater self-efficacy [14] when they started using the tutor.
- **Students who needed the tutor, but did not get to practice with it** – these students scored less than 100% on the pre-test. But, they spent all 30 minutes solving pre-test problems. So, they ran out of time and did not get to solve any practice or post-test problems. For these students, the score per pre-test problem was compared - those who scored more per problem were better prepared when they started using the tutor.
- **Students who solved practice problems, but not enough to practice any concept** – these students scored less than 100% on the pre-test, so they needed to use the tutor. They solved practice problems, but not in sufficient numbers to demonstrate mastery, i.e., score 60% or more on any one concept. So, the tutor did not present any post-test problems to these students. For these students, the number of practice problems was compared - the more practice problems a student solved without mastering any concept, the less the tutor helped the student learn.

- **Students who practiced one or more concepts** – these students solved less than 100% on the pre-test, solved sufficient number of problems during practice to score at least 60% on one or more concepts, and went on to solve post-test problems on those concepts. For these students, the number of concepts practiced and the pre-post change in score on the practiced concepts were compared – the more the number of practiced concepts and the more the increase in score from pre-test to post-test, the greater the learning. The number of practice problems solved per practiced concept was also compared – the more the problems solved, the more the effort needed by the student to learn with the tutor.

For this study, two tutors were used, both on introductory concepts:

- Arithmetic expressions tutor, designed to help students learn to evaluate arithmetic expressions as used in computer programming. Each problem contains an arithmetic expression that includes one or more operators. The student is asked to evaluate the expression one operator at a time, according to the rules of precedence and associativity.
- Selection tutor, designed to help students learn to trace programs containing if and if-else statements. Each problem contains a computer program that includes selection statements. The student is asked to predict all the outputs of the program, one output at a time, along with the line number of the code that generates the output.

These two tutors were selected because they promised large sample sizes – they are both typically used early in the semester and are used by larger numbers of students than tutors on more advanced topics such as functions and arrays. At the same time, the two tutors were not duplicative – they have different user interfaces and require different problem-solving skills.

The tutors were used by students enrolled in introductory programming courses. Students from multiple institutions used the tutors each semester – an average of 12 institutions for arithmetic tutor and 15 institutions for selection tutor. All the students used the tutors over the web. The entire protocol was administered back-to-back – any student considered in this study went through all the stages of the protocol within 30 minutes, with no breaks in between. So, any change in score from pre-test to post-test is attributable to the use of the tutor and not any extraneous factors.

II. Arithmetic Expression Tutor Results

During pre-test, arithmetic expressions tutor presents 16 problems. For analysis purposes, only those students who had solved at least 10 problems during the pre-test were considered. When a student had used the tutor multiple times, data from only the first time the student had solved at least 10 pre-test problems was considered.

Data was collected over five semesters – fall 2010 through fall 2012. All the students used the same version of the tutor during these five semesters. After eliminating duplicates and students who had not solved sufficient problems during the pre-test, 1236 students remained in the study:

- 242 students "did not need to use the tutor";
- 206 students "needed the tutor, but did not get to practice with it";
- 273 students "solved practice problems, but not enough to practice any concept"; and
- 515 students who "practiced one or more concepts".

Since providing sex and race information was optional, the value of N may vary in the following analyses.

A. *Students who did not need to use the tutor*

Univariate analysis of the time per pre-test problem yielded a significant main effect for sex [F(1,185) = 6.717, p = 0.01]: Female students spent statistically significantly more time to solve each pre-test problem than male students, as shown in Table I (In the table, means are listed with confidence intervals at 95% confidence level). Since both male and female students scored 100% on the pre-test, perceived self-efficacy [14] may be one possible explanation for why female students took more time – female self-efficacy is significantly lower than male self-efficacy [15]. Similar analysis did not yield a significant main effect for race [F(1,185) = 2.082, p = 0.151], i.e., the difference between the racial groups was not statistically significant.

TABLE I. Time per pre-test problem on arithmetic expressions tutor for the group that did not need to use the tutor

	Male	**Female**
N	142	44
Mean	45.48 ± 3.66	56.83 ± 7.83
	Caucasians+Asians	**Under-represented**
N	135	51
Mean	47.99 ± 3.90	54.31 ± 7.71

B. *Students who needed the tutor*

Among the students who needed the tutor, but did not get to practice with it, there was no significant difference in the pre-test score per problem between the two sexes [F(1,145) = 0.115, p = 0.735] or racial groups [F(1,145) = 0.959, p = 0.329]. In other words, both the groups in each comparison were equally prepared before using the tutor.

Among the students who solved practice problems, but not enough to practice any concept, no significant difference was found in the number of practice problems between the sexes [F(1,213) = 0.3, p = 0.584] or racial groups [F(1,213) = 0.128, p = 0.72].

C. *Students who practiced one or more concepts*

Analysis of the number of concepts practiced yielded significant difference between the sexes [F(1,392) = 5.52, p = 0.019], but not between the racial groups [F(1,392) = 0.357, p = 0.551], as shown in Table II. Female students practiced significantly more concepts than male students, possibly because they solved statistically significantly fewer problems on the pre-test than male students [F(1,392) = 5.931, p =

0.015], and therefore, demonstrated proficiency on fewer concepts during pre-test.

TABLE II. CONCEPTS PRACTICED ON ARITHMETIC EXPRESSIONS TUTOR

	Male	Female
N	300	93
Mean	1.588 ± .14	1.933 ± .253
	Caucasians+Asians	**Under-represented**
N	289	104
Mean	1.716 ± .147	1.804 ± .249

No statistically significant difference was found on the pre-post change in score on practiced concepts, whether between the sexes [F(1,392) = 0.45, p = 0.503] or racial groups [F(1,392) = 0.031, p = 0.861]. Similarly, on the number of practice problems solved per practiced concept, no significant difference was found between the sexes [F(1,392) = 1.865, p = 0.173] or racial groups [F(1,392) = 0.101, p = 0.751].

In summary, among the students who did not need to use the tutor, female students may have exhibited lower self-efficacy. Among the students who practiced one or more concepts, female students practiced significantly more concepts than male students, possibly because they were less prepared than male students when they started using the tutor. No other difference was found between the sexes or racial groups on the number of practice problems solved per practiced concept, or the pre-post change in score on the practiced concepts.

III. SELECTION TUTOR RESULTS

During pre-test, selection tutor presents 12 problems in C++ and 9 problems in Java/C#. For analysis purposes, only those students who had solved at least 8 problems during the pre-test were considered. When a student had used the tutor multiple times, data from only the first time the student had solved at least 8 pre-test problems was considered.

Data was collected over four semesters – fall 2010 through spring 2012. All the students used the same version of the tutor during these four semesters. After eliminating duplicates and students who had not solved sufficient problems during the pre-test, 893 students remained in the study:

- 370 students “did not need to use the tutor”;
- 91 students “needed the tutor, but did not get to practice with it” or “solved practice problems, but not enough to practice any concept”. No analysis was done on these groups because of their small sample size.
- 432 students “practiced one or more concepts”.

Since providing sex and race information was optional, the value of N may vary in the following analyses.

A. *Students who did not need to use the tutor*

Univariate analysis of the time per pre-test problem did not yield a significant main effect for sex [F(1,251) = 0.474, p = 0.492], but did so for racial groups [F(1,251) = 6.908, p = 0.009], as shown in Table III. Under-represented students spent statistically significantly more time to solve each pre-test problem than Caucasians+Asians. Again, since both racial groups scored 100% on the pre-test, perceived self-efficacy [14] may be one possible explanation for why under-represented students took more time – under-represented racial groups were found to have significantly lower prior self-confidence in another study [7].

TABLE III. TIME PER PRE-TEST PROBLEM ON SELECTION TUTOR FOR THE GROUP THAT DID NOT NEED TO USE THE TUTOR

	Male	Female
N	194	58
Mean	52.85 ± 4.60	56.03 ± 7.83
	Caucasians+Asians	**Under-represented**
N	203	49
Mean	48.38 ± 4.20	60.50 ± 8.05

B. *Students who practiced one or more concepts*

There was no significant difference in the number of concepts practiced by the two sexes [F(1,323) = 1.608, p = 0.206] or racial groups [F(1,323) = 1.321, p = 0.251], as shown in Table IV.

TABLE IV. CONCEPTS PRACTICED ON SELECTION TUTOR

	Male	Female
N	253	71
Mean	1.686 ± .152	1.896 ± .289
	Caucasians+Asians	**Under-represented**
N	240	84
Mean	1.696 ± .165	1.886 ± .281

The pre-post change in learning was significantly different between the sexes [F(1,323) = 4.661, p = 0.032], but not the racial groups [F(1,323) = 0.002, p = 0.962]. Female students had a greater improvement from pre-test to post-test on the practiced concepts as shown in Table V, likely because they scored statistically significantly less on the pre-test than male students [F(1,323) = 4.252, p = 0.04]. The post-test scores were not significantly different. The interaction between the sexes and racial groups was also significant [F(1,323) = 5.223, p = 0.023] as shown in Table V, i.e., pre-post change was less for under-represented males and more for under-represented females than Caucasians+Asians.

TABLE V. PRE-POST IMPROVEMENT ON PRACTICED CONCEPTS ON SELECTION TUTOR

	Caucasians+Asians	Under-represented	Total
Male	.887 ± .033 (N=187)	.809 ± .054 (N=66)	.848 ± .032
Female	.882 ± ..060 (N=53)	.963 ± .104 (N=18)	.923 ± .061
Total	.884 ± .034	.886 ± .059	

On the number of practice problems solved per practiced concept, no significant difference was found between the sexes

[F(1,323) = 0.328, p = 0.567] or the racial groups [F(1,323) = 2.744, p = 0.099].

In summary, among the students who did not need to use the tutor, students in under-represented racial groups may have exhibited lower self-efficacy. Among the students who practiced one or more concepts, the change in score from pre-test to post-test was significantly more for female students than male students, and this made up for the fact that female students scored significantly less on the pre-test. No other difference was found between the sexes or racial groups in the number of concepts practiced, or the number of practice problems solved per practiced concept.

IV. DISTRIBUTION OF STUDENTS AMONG CATEGORIES

As mentioned earlier, students were grouped into four categories:

1. Students who did not need to use the tutor
2. Students who needed the tutor, but did not get to practice with it
3. Students who solved practice problems, but not enough to practice any concept
4. Students who practiced one or more concepts using the tutor.

We analyzed the distribution of students among these four categories by sex and race. Univariate analysis of the category by sex and racial group for arithmetic expressions tutor yielded no significant main effect for sex [F(1,938) = 0.185, p = 0.667] (Figure 1) or racial group [F(1,938) = 0.28, p = 0.597] (Figure 2). In other words, no statistical difference was observed between male and female students and between traditional and under-represented racial groups in their distribution among the four categories, including the proportions that needed the tutor and that benefited from the tutor, i.e., practiced one or more concepts using the tutor.

Similar analysis of the data collected by selection tutor again yielded no significant main effect for sex [F(1,630) = 0.373, p = 0.542] (Figure 3) or racial group [F(1,630) = 1.956, p = 0.162] (Figure 4). *So, students needed and benefited from the tutors in the same proportion, regardless of sex or racial group.*

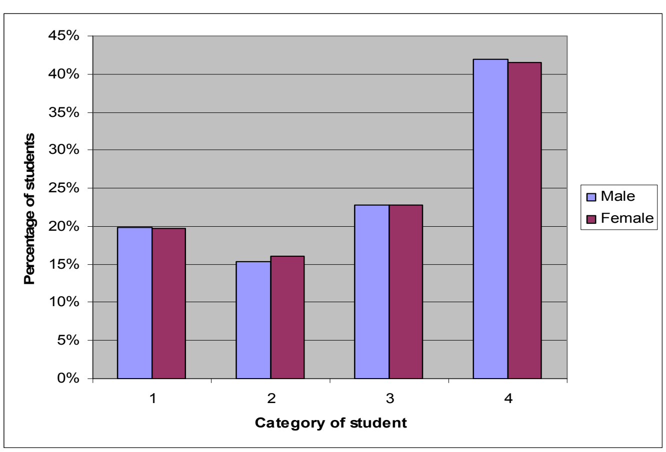

Figure 1. Arithmetic Expressions Tutor: Percentages of male and female students distributed among the four categories

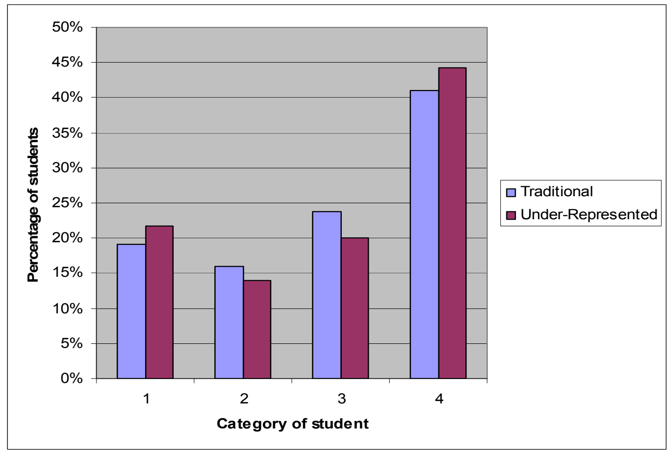

Figure 2. Arithmetic Expressions Tutor: Percentages of traditional and under-represented racial groups distributed among the four categories

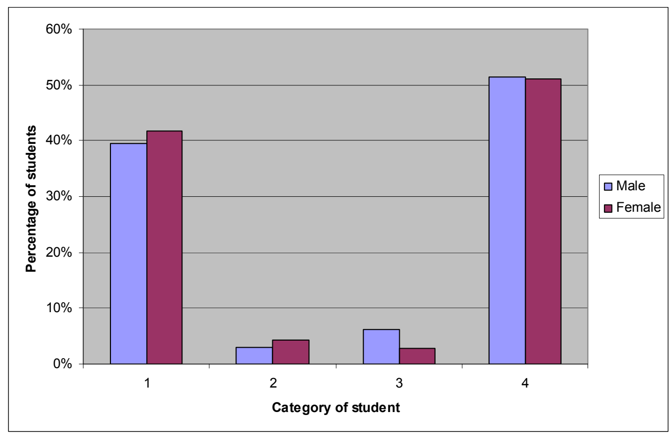

Figure 3. Selection Tutor: Percentages of male and female students distributed among the four categories

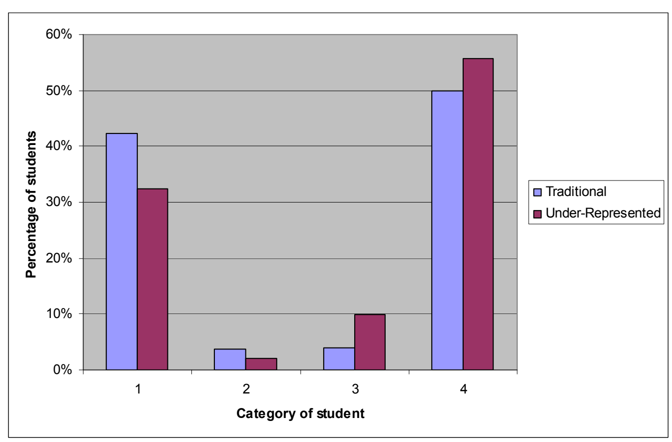

Figure 4. Selection Tutor: Percentages of traditional and under-represented racial groups distributed among the four categories

V. DISCUSSION

Two tutors were used in this study. The following summarizes the analysis of the data collected by these two tutors:

- Students who did not need to use the tutor – Among these students, whenever any difference was found, either female students or students in under-represented racial groups spent longer solving problems, possibly because of lower perceived self-efficacy [14].
- Students who practiced one or more concepts – Among these students, whenever any difference was found, it was female students who either practiced significantly more concepts when they had solved significantly fewer problems during pre-test, or demonstrated greater pre-post increase in score when they had scored significantly less on the pre-test. These results bode well – one study found that the most significant cognitive factor predicting attrition in Science was low grades earned in introductory courses [16]. Attrition of female students is of particular concern in Computer Science, a phenomenon popularly referred to as the shrinking pipeline [17]. Given that the tutors help female students improve their scores from pre-test to post-test, they might help reduce the attrition of female students in introductory Computer Science courses.

No other differences were found between the sexes or racial groups. In particular:

- No difference was found on the number of practice problems solved by the sexes and racial groups per practiced concept. So, the effort needed to practice with problets was the same regardless of sex- or racial group.
- Students needed and benefited from the tutors in the same proportion, regardless of sex or racial group.

Both these results are reassuring for the use of problem-solving tutors in Computer Science, given the significant under-representation of women and minorities in Computer Science and the push to broaden participation in the discipline.

Socially relevant themes, and teamwork and collaboration, are increasingly being emphasized along with hands-on learning as effective pedagogical approaches for engaging women in computing.. [18]. That female students learned just as well as male students by using problets seems to suggest that hands-on learning is effective on its own, even without the incorporation of socially relevant themes or teamwork and collaboration, neither of which is part of problets.

The tutors used in this study dealt with basic topics in programming. We plan to conduct additional studies with tutors on more advanced programming topics to see whether these results can be replicated or different patterns will emerge.

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An instructional practice based on handwritten answer sheets with a course management system

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***Abstract*—Since the start of the 21st century, information technology (IT) was introduced in many universities to support effective instruction. One solution intended to support STEM classes took the form of a *classroom* management system, such as DyKnow Vision™, which was different from a *course* management system (CMS), such as Moodle™. This may be because HTML editors on web-based CMSs do not easily allow both instructors and students to produce freehand scientific information such as equations, charts, and illustrations. However, *classroom* management systems require special devices such as Tablet PCs and force instructors to perform complex system operations. Moreover, in some cases these systems are not necessarily designed to accumulate learning activities for ABET or e-Portfolio. To support both writing by hand and the accumulation of learning activities in a class, the system proposed here, developed on the basis of the key concept of "No special devices in a class," makes use of sheets of paper and digitizes the papers after the class so that they can be stored in a CMS. A multifunctional peripheral with a digital watermark enables this educational setting. Our demonstration experiment for three classes functioned well. This paper presents a system overview and the preliminary results.**

Keywords—writing by hand; OCR; watermark; e-Portfolio; course management system; collaboration and learning environment

I. INTRODUCTION

To achieve more effective learning outcomes, many universities developed IT infrastructures in the 2000s. Tablet PC-based learning technologies with classroom management systems are favorable for this purpose in that they support active learning for all students in a classroom [1]. With the trend of "bring your own device" (BYOD), which became popular beginning in the 2010s, institutionally selected or recommended PCs might no longer be the best solution for institutions, in addition to their being a financial burden. If the main reason to employ Tablet PCs is to support text written by hand, a paper-based instructional method should be reconsidered that can be integrated with a CMS. Educators seem to prefer classroom management systems such as DyKnow Vision™ over CMSs such as Moodle™ because HTML editors on web-based CMSs do not easily allow both instructors and students to produce freehand scientific information such as equations, charts, and illustrations. However, classroom management systems require Tablet PCs and force instructors to perform complex system operations. Moreover, they might not be designed to accumulate learning activities for ABET or e-Portfolio. To support both writing by hand in a class and the accumulation of learning activities, the system proposed here was developed on the basis of the key concept of "No special devices in a class." Regarding the scientific and instructional feasibilities of the project, students in a STEM class can produce every form of scientific information by using this paper-based instructional method. Instructors can use a paper size larger than the display size of Tablet PCs. This system has significance for the education community because it can be applied in a broader scope, as it is applicable to STEM education as well as the humanities and social sciences.

II. TECHNOLOGY AND SYSTEM OVERVIEW

A core technology of this system is a multifunctional peripheral (MFP) that operates as a scanner and printer. This MFP also provides the technologies of a digital watermark and an optical character reader (OCR). In general, a digital watermark has been used for digital rights management or copyright protection [2]. In this study, the role of the digital watermark is to integrate with the CMS. As shown in Fig. 1, microscopic dots are printed on the background of the paper to embed 16 bytes of unique code.

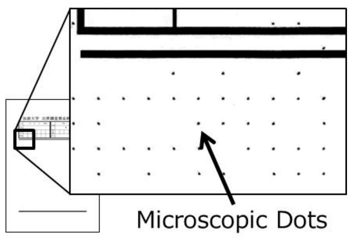

Fig. 1. Sample of a digital watermark.

The system proposed here is composed of an MFP and a CMS. The MFP employed is a network-compatible system made by Fuji Xerox Co., Ltd., Japan, featuring an OCR function and a large operation panel. At the MFP front end, a control PC is added to run developed modules with the database. The CMS is a Sakai® CLE 2.7.1 on CentOS 6.2.

III. Design To Apply The Technology to a Use Case

One of the use cases of this system is an "answer sheet," as shown in Fig. 2. This figure illustrates the process of this use case according to the steps involved. The process begins in the upper-right position in Fig. 2. To set the course code and the number on the operation panel of the MFP, an instructor prints an equal number of answer sheets as the number of students before the class commences. Then, the MFP prints the answer sheets with the unique ID embedded in a digital watermark across the surface of the sheet. At the same time, the class code is stored in the database with the unique ID as a key. In the class, the instructor instructs the students to write their answers by hand on the sheets. After the class, the instructor writes the grade and comments by hand on the answer sheet for each student, and finally scans all of them with the MFP. The MFP reads the digital watermark to obtain the unique ID and creates PDF files. Through the OCR function, the MFP simultaneously recognizes the handwritten student IDs and the scores written by the instructor. When all the data are ready, the MFP uploads the PDF files to the CMS and generates the summary data for the instructor. The students log in to the CMS and can see their scores and comments on the attached PDF. The instructor can also obtain a set of answer sheets that are sorted according to the students' IDs in a PDF and a spreadsheet file that lists the students' scores.

IV. Project Status and Results

Before we developed the system, we conducted a feasibility study to confirm the recognition capability of the OCR in June 2012 at the time of regular final examinations during the first half of the 2012 Japanese academic year. In October 2012, the preliminary system to support the use case described above was developed and became available at Hosei University in Japan. Using this system, we conducted the demonstration experiment for three classes until the end of 2012, and we confirmed that the system functioned well.

A. *OCR Recognition Rate*

Eighty-three third-year students in the Faculty of Science and Engineering wrote their answers with pens in the traditional way for a paper-based final examination. The instructor also handwrote the scores on the examination papers. The MFP scanned all the papers and recognized both the

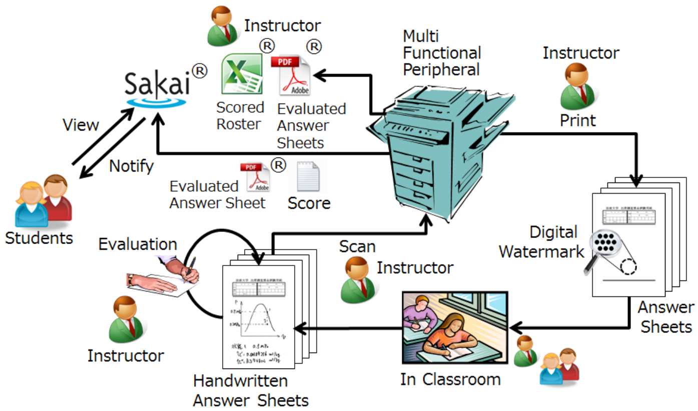

Fig. 2. System overview of the technology being applied.

student IDs written by the students and the scores written by the instructor. The results of the recognition rate are shown in Table 1. The characters "6", "0", and "5" are incorrectly recognized as "8", "6", and "3", respectively. The recognition rates are 99.4% and 99.8% for the instructor and the students, respectively.

TABLE I. Results of Recognition Rate of OCR

	Number of character images	Number of true recognition	Number of false recognition	Recognition rate (%)
Instructor (n = 1)	510	507	3	99.4
Students (n = 83)	581	580	1	99.8

However, a recognition rate of 99.96% might be achieved if this system were applied to a class of 200 students spared from the impact of a false recognition. The student ID consists of seven characters. So the MFP tries to scan a total of 1,400 characters for 200 students. If the MFP can recognize more than 1,399.5 characters, a false recognition will not possibly occur for 200 students. In that case, a desired recognition rate is expressed as

$$1399.5/1400 = 99.96\%.$$

To improve the recognition rate, the following approach will be applied in future.

- The student ID will consist of numerical and alphabetical characters. In the case of student IDs of our university, the third character from the left is an alphabetical character and the rest are numerical. So the candidate characters are reduced to match the character type when the MFP recognizes the student IDs.
- Examples of fonts that the MFP can easily recognize will be additionally provided at the bottom of the answer sheets.

B. *Task Analysis*

The total required time—from pre-processing such as obtaining answer sheets to post-processing such as returning scored sheets to the students—was analyzed by a task base. Suppose there are 100 students in a class. Comparing our method to the traditional way of returning the scored answer sheets by hand in a class, our method saves a time of approximately 10 min. If the instructor used a CMS to return the scored answer sheets as a PDF file to the students, the total required time that would be saved with this system is approximately 1 h. This is because in the traditional method, one would use the scanner to individually scan all the sheets collectively and obtain one PDF file that includes all the sheets, with a file name based on a date, such as "201303150722.pdf." Therefore, time would mainly be required to separate the files of each student, rename the files with the same name as the student ID, and upload the files to a designated place in the CMS using a Web browser.

V. Future Plans

The preliminary system has been evaluated in practicable and efficient manner, enough to be applied to a real-world scenario. We plan to deploy this system at our university step by step. First, we are certain that this system can be applied to other teaching methods such as reports and tests, mainly on the basis of the results obtained from this study. Looking toward the possibility of campus-wide implementation in the near future, we intend to develop an interface module that enables the MFP to obtain course attributes from the CMS, such as course title, instructor name, and timetable. This is possible because the operation panel on the MFP currently can display three courses given for this study. We are developing this system particularly for face-to-face STEM classes. However, writing by hand using pen and paper is still prevalent in the education field. Therefore, this system will be applied to all educational settings in which the courses are not completely online.

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Rethinking Remote Laboratories: Widgets and Smart Devices

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***Abstract*— Until the last decades, students of distance learning universities had to go to traditional and physical laboratories to acquire practical knowledge and skills. Currently, thanks to the advances in communication and computer networks and the evolution of programming languages, new eLearning tools have emerged that enable the usage of learning methodologies such as blended learning and distance learning. One of them is the remote Web laboratory. A remote Web laboratory is an application which allows students to work with real hardware or instruments. To do this, students only need a computer with an Internet connection. However, emerging technologies and other hardware such as mobile devices, cloud computing and the Internet of Things, require the design of different models to support innovative learning experiences. For this reason, remote labs are being reconsidered to smart device paradigm. Physically, the considered smart device is made of the junction of a controller (computer server) connected to physical equipment on the one hand, and to the Internet on the other hand. This paper describes the process to translate a "traditional" remote Web lab into a set of smart devices which are able to work together in the cloud and the Internet of Things.**

Keywords—remote laboratories; eLearning; distance learning; eLearning services

I. INTRODUCTION

Astronomy, biology, chemistry, electricity, electronics, mathematics, physics … any science domain of knowledge can be studied with experiments where the empirical predictions derived from the theoretical model are compared with the actual phenomena. However, interacting with real systems through computer-based devices such as workstations, laptops or mobile phones requires a proper infrastructure. Instant response to the learners' actions and an intuitive way of manipulating the remote components (i.e. modifying their parameters to view the results) are two key features. These environments try to convey creativity and ease of use. In one side, students perform different activities from any location at any time. On the other hand, instructors keep track of their progress with collected data from their sessions.

When remote laboratories were originally launched within the eLearning community, such capabilities could not be included due to the limitations imposed from programming languages and learning systems for the World Wide Web, either specific institutional applications or learning management systems (LMS).

The previously described scenario has dramatically changed, but monolithic systems with a reduced set of functionality are still the prevailing choice. Aside from slight integration at the LMS level of dynamic elements, the experiments rely on a very inflexible framework. In the following sections we will analyze these solutions tailored to online experimentation. Based on this analysis, the smart device concept is introduced as a way to extend these laboratories. Its benefits and possible flaws in comparison to other operative installations will be also addressed. As a final section, some relevant examples of such conversion will be described to support this hypothesis and future efforts.

II. DESIGNS OF REMOTE LABS FOR ELEARNING

Although many classifications of online laboratories have been proposed in the course of time, the focus of attention here is on remote labs. In this particular setting, students are able to control the actual device (i.e. it is not a simulation) or system from a long distance. Generally, a camera is installed in the physical lab room, so any variations applied to the initial and subsequent states are immediately viewed by students.

Two main types of data transmission belong into this group: interactive and non-interactive operation. The parameters of the experiment can be changed in the first group whenever a student wishes to do so, whereas the learner must wait a certain lapse of time to data being processed by the system in the other case, also called batched experiment. Viewing sensor data through a chart might be considered a third class, but it is restricted to a posteriori analysis of the visualization output.

Every single remote lab depends on its fundamental building blocks to establish the communication. The basic configuration consists of a local server connected from one side to the experiment (usually bridged with a data acquisition card) and on the opposite side to the local network or Internet, and, the client computer. A typical remote lab is completely encompassed with these basic components and some slight mutations [1].

The user interface (UI) comes next as an element of interest. Students and teachers usually identify themselves in

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the portal of their affiliated institution. From there they can go to their course and start the experiments. Most platforms facilitate access to the experiments through a simple form-based interface [2]. Recent efforts resemble to such a degree the manual controls that is pretty difficult to tell the difference between real and virtual images [3]. An special category of labs is worthy to mention in the graphical aspect. That is the hybrid lab, where visual elements are overlapped with the original components of the view in an augmented reality [4]. If learners activate its “virtual view”, the user interface displays additional information about the experiment that would be otherwise unavailable without further calculations.

After this general review of current existing developments, it is safe to assert that remote laboratories present a common number of issues related to both user side and developer side. Among the items that should be addressed, these are the most significant points of conflict:

- Laboratory hardware and software implementations tied to specific vendors. Monolithic designs, from the user interface to the fundamental building blocks, are mostly programmed with proprietary languages and external plug-ins: Adobe Flash, Java and LabView.
- Navigation, search and discovery of single experiments, their resources –documentation, exercises, assessments, etc.– or even their associated laboratory according to some criteria such as domain, institution, difficulty or student’s age demands a fair amount of time from those people interested.
- Sharing data of the lab between different machines is not feasible because sources to get them are scarce, unstructured or even non-existent. Until recent specifications, Internet protocols were neither designed to keep a fast and stable channel of communication (or be absolutely sure that the values had been sent).
- Scheduling/reserving a lab session involves a process of authentication and authorization that it is not transparent to other devices. Many different systems (queues, slots, tokens), custom implementations and databases (administration, LMS, portal) uncover security threats that need to be carefully tackled.

Nevertheless, open standards [5] have emerged as the cornerstone to build an ever-growing network of interconnected devices that overcome these recurrent issues. Web services and widgets help in that regard.

Service oriented architecture (SOA) enables developers to abstract complex languages in local computers with different services that expose the application data [6]. A service can be defined as a process which consumes a particular set of inputs and produces outputs. W3C widgets [7] or OpenSocial gadgets [8] can be linked to those services, therefore simplifying the creation of modular apps to be deployed on different appliances. Instructors can build mashups with collections of these objects that fulfill a common goal simply by arranging them in their Web space. Reusability of the whole lab is improved substantially separating the user interface of the Web application from program logic; a critical obstacle for device to device communication is removed here.

Conversion of traditional laboratories to conform to the aforementioned specifications will be dealt with in the next sections. As a matter of fact, smart devices are going to stand out as the new paradigm with which remote experiments will verify the cited premises.

III. FROM HCI TO DEVICE-TO-DEVICE COMMUNICATION

Human computer interaction (HCI) has greatly improved in the last decade. Tactile input or voice feedback are mainstream features accessible through many handheld instruments. Although these enhancements have become very familiar in commercial technology, its implementation in remote laboratories has not yet reached that level of prevalence [9]. A pending task of remote labs is interacting less obtrusively with humans through personal learning environments or PLE (i.e. hiding the fact that humans interact with computers).

As it was pointed out before, online laboratory platforms do not allow a standard method to access and reorganize their built-in components on the screen. Neither are capable of communicating with other systems in the network to improve their global performance and robustness. As a consequence, workarounds must be put in place that help students and instructors to customize the final experience, as well as offering the best interaction achievable. Here the smart device paradigm enters the scene with its advanced capabilities, effectively acting like a nexus to interconnect remote experiments. Small dynamic blocks of content known as widgets are responsible of handling the desired flexibility and high interactivity from a graphical user interface. These couple of specifications need to be studied with more detail. From here onwards, the reference schematic that will be considered is depicted below (Fig. 1).

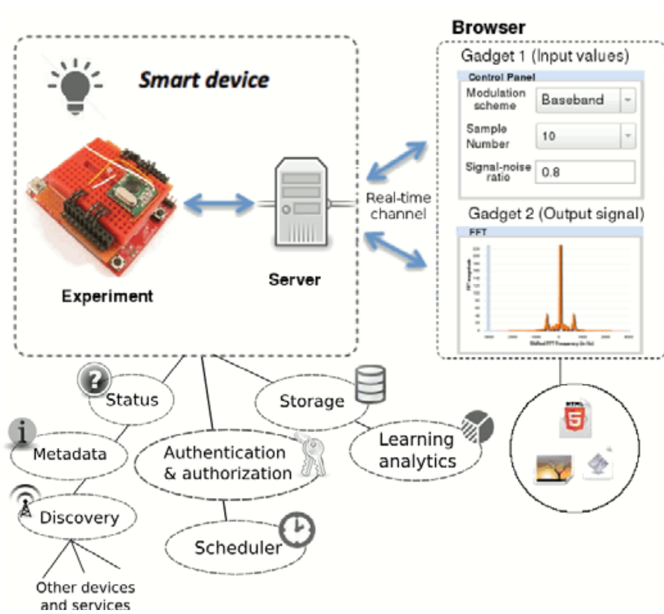

Fig. 1. Smart device structure, widgets and services of a remote experiment.

The smart device concept [10] has a tight relationship with ubiquitous computing (UbiCom). The last term refers to Information and Communication Technology (ICT) systems that enable information and tasks to be made available everywhere, and to support intuitive human usage, appearing invisible to the user. In fact, with smart environments and smart interaction, smart devices close the set of basic architectural designs for UbiCom. In this context, the vision of automatic device to device and device to service communication are summed up in a concept known as the Internet of Things [11].

Another requirement to support collaboration in the same experiment is the widget specification. Widgets consist in a combination of four very popular Web technologies: HTML, XML, Javascript and CSS. An engine, generally installed in the server-side, renders the page resulting of data extracted from external services. OpenSocial gadgets are another variant of this specification but centered in social network interactions. In the eLearning ecosystem, these blocks are not only environment agnostic, they are independent of the webapps or content publication system (e.g. blogs, content management systems, social networks, wikis). LMS can also make good use of them in learning objects through server plug-ins; gadgets are flawlessly embedded within content packages such as SCORM or IMS LTI remote tools [12]. However, PLEs stand for the preferred solutions as their user-centered philosophy is more suitable for team work in the same concurrent time space.

To build a remote lab capable of covering the conditions formerly outlined, a last element is crucial: the protocols of communication. The arrival of Web technologies oriented to real-time transmission of data, such as videoconference or online workgroups (e.g. concurrently editing documents, sharing a teacher's whiteboard with many viewers…), sending and retrieving data through a well-established protocol has become another task at hand. This efficient way of transmitting digitally codified information can be applied to the values of variables from laboratory experiments. In addition to that, compression algorithms allow members of educational networks with low speeds and limited bandwidth to achieve a satisfactory experience. Although WebSocket has become the de-facto standard for fast communications across different browsers, smart devices must support a wide array of protocols (Fig. 2).

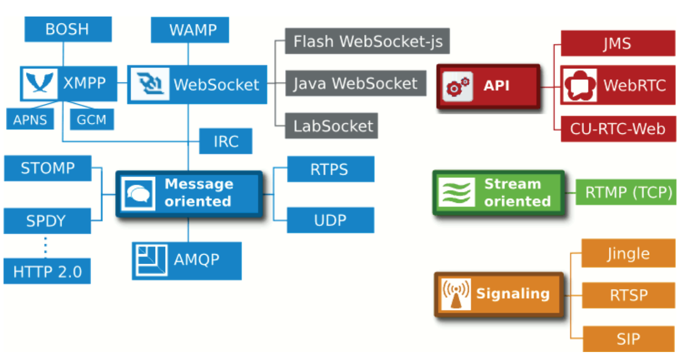

Fig. 2. Classification of real-time protocols for remote labs by data transmission method and APIs.

Finally, with all fundamental elements at hand, the general structure surrounding a smart device for remote labs is clearly defined. When the smart device is in operating mode, a set of inputs/outputs are active while learners interact with the experiment (Table 1).

TABLE I. INPUTS AND OUTPUTS OF EXPERIMENTS

	Format	**Encoding**	**Typical application**
Inputs (commands, values, user info, component selection)	Unstructured text	iso-8859-1, unicode, other codification	form-based dialogs
	Structured text		csv tables, xml metadata, json, app-associated
Outputs (measurements, results)	Structured text	iso-8859-1, unicode, other codification	csv tables, xml metadata, json, app-associated
	Static image	bmp, png, jpeg, tiff	diagrams, charts, screenshots
	Audio stream	g.711, gsm, mpeg3, ogg, opus, speex, silk	podcasts
	Video stream	divx, mpeg2/4, h.263, h.264, vp8, theora, xvid,	monitoring, conference

IV. SERVICES IN THE SMART DEVICE NETWORK

Given the relevance that services acquire in the whole infrastructure, such event gives an idea of how existing platforms will be decomposed in the new paradigm. In relation to Web services in the cloud, these external sources of data have been distributed into seven main categories with their corresponding functions:

1) *Authentication and authorization,*
2) *Discover,*
3) *Learning analytics,*
4) *Metadata,*
5) *Scheduler,*
6) *Storage,*
7) *Status.*

A more exhaustive comparison of these services with existing platforms will mark the main differences. Therefore, an analysis of how each one of the services are assembled together comes next to illustrate the architecture.

A. Authentication and authorization

Controlling which users shall access an experiment turns into a prerequisite of any remote laboratory. Statistics from usage need a unique identification of the learners that visited the lab. Generally each institution implements its own authentication and authorization system with a federated system [13]. That way administrators give access exclusively to the members stored in a personal database. Furthermore, security is guaranteed verifying their identity. Data confidentiality relies on cryptographic protocols (e.g. HTTPS). Anonymous and open access is also allowed in some environments.

The login system consists in a Web formulary. Students must type their assigned user and password values that they obtained, either by registering in the remote lab page or, if possible, retrieved from the institutional portal through a single sign on facility. This last type of authentication alleviates the tiresome task of creating a profile for every tool in an eLearning ecosystem. Other option that is spreading only requires the e-mail address to start all the process. If users have more than one address, they get an intuitive method to keep their contact info in sorted categories according to its place (home, work, university, etc.).

In the smart device network, all requests first go through the authentication service. This requirement is justified by the recompilation of learners' statistics. If every user does not have a unique id, all related data could not be correctly organized for future queries in the instructor's page. The separation of UI (widgets) and the server logic ease the place where the login form must be located. In fact, there is absolute freedom to transmit that info between other devices or services. Different types of authentication can coexist in the same *widget container* (this tool is described in the examples) while staying transparent to the user, so it is open to further experimentation. Moreover, as hiding the HCI from users has been settled as the aimed objective, form-based layouts must become a fallback option with respect to other instruments (Fig. 3). Biometric systems with a low-intrusive approach would upgrade a relatively outdated component of laboratories. Graphical password schemes also offer protection against spyware or dictionary attacks through an attractive input [14].

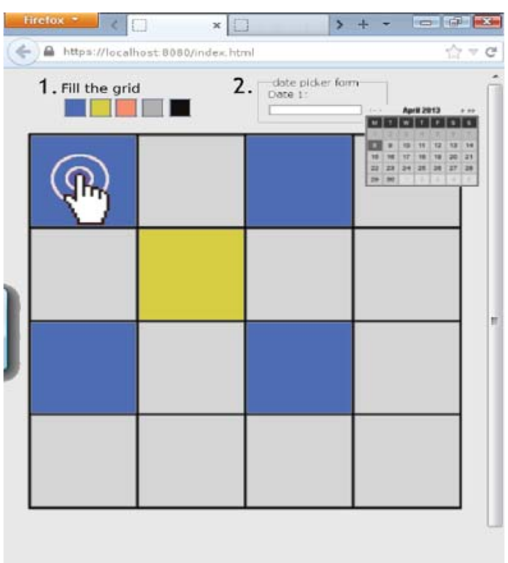

Fig. 3. Prototype of a typical graphical password system.

B. Discovery

Used by a smart device connected to a network to announce itself and to discover other devices or services, this service has not any equivalent in remote laboratories. As for the computer world and industry, that exact statement would be absolutely incorrect. The Universal Plug and Play management, discovery and control system, HAVi, JINI and the OSGi alliance [15] are initiatives that have developed interoperability guidelines for home devices. As for a SOA industrial scenario, there are currently two alternatives to be deployed at device level: Devices Profile for Web Services (DPWS), and OPC Unified Architecture (OPC UA) framework [16][17]. The SOCRADES project combines these specifications with other standards in order to promote mutual interoperability [18].

Consumer electronics such as domestic appliances include a selection of features to ease their use. For instance, TV sets are designed to automatically detect and communicate with external media players or wireless hard drives when they are located in its proximity without any action coming from the user. All these devices have an internal code (also called firmware) programmed in their hardware that is responsible of assigning a unique identifier to each object.

Smart devices are able to find other compliant device or service and share data between them. LinkSmart is an application of that technology [19]. In this context, showing different experiments through the same user interface becomes a reality with a collection of services. If the physical system broadcasts its presence, third parties receive a tool to build their custom lab explorers suited to their needs. This open network possesses a great potential for improvements, so including this feature in the smart device for experiments is necessary. An schema to identify every single device and their properties in a consistent way across contexts (e.g. terms with a well-defined meaning) is the Web Ontology Language (OWL-S) [20]. The IEEE1451 is currently working in a unique identifier for these devices.

C. Metadata

The description of laboratories and experiments exhibits an irregular implementation among eLearning environments. Nonetheless, most developments include some information about the resources in the Web portal or the LMS. Learning object metadata (LOM) and profiles based on this standard format represent the best examples [21]. As a result, some projects have assumed an important role introducing metadata formats to describe and search labs and other resources linked to them. Repositories of experiments reduce the effort in finding and exploring lab installations [22][23][24][25].

In order to other devices or services to "chat" with a smart device or some of its components, they have to know some properties about the structure: inputs, outputs, protocol, technical specifications (maximum speed, data format, compression…) and relationship with elements of the network (it is part of, depends on). Educational characteristics such as the scientific domain, age of students, difficulty and related documentation fall into this service. Taking the main classification as a reference, structural metadata and descriptive metadata are the types associated to smart devices [26].

The level of aggregation hinders the extensibility of laboratories. This service combined with widgets is a good start to increase the modularity of the complete network. It must be noted that widgets possess a specific section dedicated to their description, so sharing metadata between them and external services is viable.

There is not an universal schema to handle several descriptors and domains –it might be even counter-productive for parsing and generating high amounts of metadata interoperable with other systems. Therefore, all these characteristics may be extracted from one device in a variety of structured formats when external sources demand them, such as IEEE's Automatic Test Markup Language (ATML) [27], Dublin Core [28], Contextualized Attention Metadata (CAM) [29], Javascript Object Notation for Linking Data (JSON-LD) [30], State Chart XML (SCXML) [31] or the Resource Description Framework schema (RDF) [32].

D. Learning analytics

If one functionality stands out from the full set of modules integrated into eLearning systems, that is the tracking and assessment of learners. Instructors have constantly struggled with the high difficulty of building an attractive and simple statistics registry to gather and export results since their origins. In most cases the task was extremely complicated, as the sequencing procedure in SCORM for LMS, or practically unusable. Remote labs are not the exception. Once again, developers either use the limited internal capabilities of their LMS, or create specialized analysis tools without any connection to the outside network [33]. Other typical method of fetching information about users, but restricted only to the number of visits or their geographical origin, is the Google Analytics service.

Nevertheless, where do statistics come from? If we distinguish between client and server, there are two sources: user interactions and logs, respectively. The first kind refers to the tasks a student makes in the interface: elements clicked (e.g. buttons, slide bars, knobs), gestures used in the environment to finish a learning phase, opened pages, hyperlinks visited, etc. In the second group stands all data stored from visitors into the server drive, such as user identifiers, timestamp of sessions, or their sequence of actions. These groups are similar to the extent that both are complementary. In spite of that fact, server logs have become the main option to avoid privacy issues. On the other side, paradata or metadata of usage is acquiring importance. With widgets and an application programmable interface (API) tailored to that purpose [34][35], any mashup can register the users' actions and draw their workflow (e.g. heat maps).

This service registers a specific array of variables of the experiment. The selection of some elements of that array springs forth from the fact that instructors must filter which signals are more than enough to evaluate the progress in experiments. Other variables derived from measurements could be calculated instantly through the same service. In fact, a mashup can show graphs, bar charts and scores in a consistent user interface from a list of learners in the instructor's Web page. Generating reports exportable in popular formats (doc, pdf, csv) from a wide selection of places is a powerful feature provided by this service.

E. Schedule and reservation

A maximum number of concurrent students is the known restriction of remote labs. If that limit is exceeded, the experiment does not behave in a useful way (e.g. long delays between actions of the learner, lost packets or unexpected disconnections from the lab could happen frequently). The bottleneck comes from the network bandwidth and the physical experiment. Consequently, such undesired situation must be circumvented at all cost.

Schedulers and reservation systems take charge of limiting the number of users connected at the same time. Interactive experiments are the most restrictive, in contrast with experiments operated in batch. The latter group admits queue system where slots can be filled immediately after the task has been completed (if each task is not time-consuming). There are a fair amount of methods of scheduling an experiment depending on its interactivity: booking, queues or hybrid algorithms, among them. In fact, it has reached the status of a critical cross-lab requirement [36]. If two or more experiments from different locations are going to be watched through the portal, a widget handles the specified timeframe transparently.

F. Storage

Participants of laboratory sessions work with a remarkable quantity of digital content during the learning process. Attending to interactivity, content is divided between static and dynamic. In the first kind there are tutorials, slideshows, spec sheets or reports. On the other hand, conceptual maps, a list of hypotheses and the personal journal would be perfect examples of instances included in dynamic content. This documentation is widely distributed across the LMS and Web portal servers. However, the cost and low integration of editing tools makes dynamic resources a secondary in proportion to the former.

The storage service provides space for data. Any content that shall be saved permanently goes to this component. Validation of the supported formats, file size limits, quotas, integrity of received documents etc. are critical characteristics that must be guaranteed in the communication with the experiment.

V. Migration of Remote Laboratories to the Smart Device Paradigm

In a boundless software ecosystem, developers would presume that every single laboratory up to the current date can be decomposed in a limited set of smart devices. Unfortunately, that is not the landscape yet. For that reason, not all experiments admit a full conversion without rewriting the code, that neither is accessible to third parties in most cases. Keeping that in mind, we will explore typical situations and then propose the best approach to manage the transformation of the remote laboratory.

At this point, it is clear that there are two blocks to confront: the server-side and the client-side. Depending on the conditions owners stipulate to access the laboratory, four cases will show up. To understand the scope of upgrading remote laboratories to conform with the smart device paradigm, any changes that affect the components of the whole eLearning ecosystem will be listed. Advantages and aspects to watch after the improvements have been applied are the aspects summed up in this analysis.

A. No changes to the experiment structure

Administrators of the laboratory do not allow (or cannot provide) any sort of tinkering with the server. Neither the code of the client is available for introducing some modifications. This is the worst case that could be faced in any circumstances. *Embedding the Flash animation or Java applet in an iframe* is the only possible workaround. Students need to go through the remote lab login system and scheduler every time they load the object.

As far as the original laboratory is concerned, user id is the only new data that the widget container retrieves. Learners and instructors do not obtain benefits whatsoever. Nonetheless, once the object has been included in the container, other widgets are at the owner disposal (from the LMS or PLE). For instance, an assessment tool could be configured to support the experience if that feature was not programmed in the original experiment.

B. Client access only

In this case, developers have enough permissions to add an *alternative user interface*. This fact implies that the authentication system can also be upgraded to match the portal. Although the server is off-limits, learning analytics, scheduling and data storage are also accessible.

Single sign-on is the immediate enhancement to avoid users the inconvenience imposed by a double login (e.g. sharing security tokens across widgets of the same experiment). As for scheduling, additional adjustments to the booking system are recommended as well: one time reserves. Other temporary variables or data might be stored in the widget container.

As another result of accessing the client-side, learning analytics become available (i.e. learners can be tracked) through user interactions. Recording statistics of lab sessions securely through a Representational State Transfer (REST) service requires the installation of such functionality in an external server. The Learning record store [37] could manage this function, or an installation explicitly designed for saving such data. Building a customizable mashup for reports and charts to monitor the educational progress of students from the instructor's page is still pending further study.

C. Client access and limited server adjustments

For this particular situation, the existing server connected to the experiment admits modifications from its previous behavior. Client-side is also open to developers inspection. On the other hand, owners wish to leave an unaltered LMS as their learning environment.

At the current stage of integration of LMS and remote labs, a methodology to consistently incorporate these apps has not been successful. Specific plug-ins for each LMS represent one approach, like the Moodle version for OpenSocial apps [38]. The first steps towards an unified solution of this issue are underway. Adding the required middleware that wraps remote laboratories as services is the proposed link. This smart gateway consists of a Javascript library that translates all requests from the lab to those functions supported in any LMS. Any benefits will be restricted to the level of compliance reached between the two aforementioned software elements. Learning analytics and data storage must be processed following exactly the same procedure described before.

D. Full access to all components

If teachers want to take advantage of the flexibility that widgets and smart devices hold for eLearning experiences, this is the best path to follow. Any required services will be deployed around the experiment.

VI. Conclusions

Experimentation is essential for a material, scientific, rigorous and critical comprehension of the existing reality. The creation of attractive and engaging experiments requires high-end developers that work in a tight but conflictive relationship with teachers. Remote laboratories also demand a methodological and theoretical reflection about "how", "why", and for "whom" an idea is taught, but without being independent of "what" is taught. As a consequence, only a small number of experiments with very strict limitations is currently available.

Smart devices provide guidelines and resources that help to overcome this situation. Communication protocols and formats for exchanging and sharing data are key elements in this aspect. The described service-oriented (SOA) infrastructure makes a clear separation in roles, where the teacher and developer have their respective technical and instructional tasks clearly defined.

A compelling challenge for SOA developers and instructors is to find adequate services for solving a specific task. Future work is oriented to build the network of services that connects experiments in a simple fashion. The combination of these services with collections of attractive widgets or mashups will promote their use. Aggregating such webapps for eLearning can simplify the authoring process and customization of personal learning experiences.

Personal learning environments and remote labs also breach the barrier between university and high school, acting in the practice as a link for lifelong learning. Learners assume an active role in all the process. This space of collaboration based on services and widgets will provide a richer experience for teachers and students.

Remote labs based on the smart device paradigm is a work towards the common goal of securing and encouraging a better assimilation of science, technology and mathematics knowledge through a variety of exercises. Obtaining analytics from activities will ensure a better understanding of the students' progress (common pitfalls, ways of remediation), but also adapt the experience to different learning styles or levels of difficulty.

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Packing and Reusing Virtual Web Laboratories as Sharable Content Object in wide range of educational Fields

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***Abstract*— One of the key issues in the education field is the acquisition of skills. This practical knowledge was usually acquired through traditional labs or standalone simulation programs. The World Wide Web and the advance in web programming language have allowed teachers to create online learning applications, such as virtual web laboratories which can be displayed by Web browser, at any time and everywhere. Currently, a large amount of virtual Web labs can be found in the World Wide Web, and these are able to cover a wide range of educational fields such as physic, chemistry, electronic, medicine, mathematics and languages. This paper describes the process of searching of these laboratories and their packing in Sharable Content Object, following the e-learning standard called SCORM.**

Keywords—Sharable Content Object; Learning Objects; Learning Management systems; Virtual Web Laboratories.

I. INTRODUCTION

Currently, it is very common to see students working with learning tools which are run for PCs, tablets or mobiles. But, until 80s, students acquired knowledge and skills through traditional resources and activities such as books, cassettes, videocassettes, face to face classrooms and traditional laboratories.

These learning resources and activities are being replaces or complemented with e-learning resources and applications, for instance:

- Books are being replaced by electronic files (Webpages, PDFs or epubs).
- Cassettes or videocassettes have been replaced by podcasts and electronic video.
- Face to face classrooms are not replaced fully, but they are being complemented with learning applications, such as learning management systems, which allow teacher to create learning scenarios. According Klebl [1] a learning scenario is a social setting dedicated to learning, education or training. It is a process of interaction between people in a specific learning situation using resources for learning within a designed environment.
- As the Face to face classrooms, Traditional Laboratories are being complemented or replace by learning application called virtual and remote Labs.
    - Virtual Labs are simulation programs which allow student to carry out experiment at anytime and anyplace.
    - Remote Labs are programs which allow student to carry out experiment with real instrumentation at anytime and anyplace.

Both electronic files, learning management systems, virtual and remote Labs be uploaded to Internet and displayed, depending on the format, over different devices, such as PC, electronic readers, tablets, or mobiles. Therefore, currently it is possible to find a great number of learning resources and applications. Each one are developed in different formats and programming languages. In the case of e-learning resources, many groups are working in the developments of e-learning standards which allow teachers to search and reuse these learning resources, such as:

- IEEE Learning Object Metadata (IEEE LOM) [2], which enables learners or instructors to search, evaluate, acquire, and use learning resources or objects across any technology supported learning systems. To do this, LOM defines the structure of a metadata instance for a learning object. This conceptual schema specifies the data elements. In the schema, data elements are grouped into nine categories: General, Cycle-Life, Meta-Metadata, Technical, Educational, Rights, Relation, Annotation and Classification category.
- IMS Content Packaging (IMS-CP) specification describes data structures that can be used to exchange data between systems that wish to import, export, aggregate, and disaggregate packages of content [3]. This structure is called package interchange file (PIF)

and it stores a set of items (images, texts, etc.), and references to items from other PIFs in an organized way.

- Sharable Content Object Reference Model (SCORM) is a collection and harmonization of specifications and standards that defines the interrelationship of content objects, data models and protocols, such that objects are sharable across systems that conform to the same model [4][5].

- The IMS Question & Test Interoperability (IMS-QTI) specification describes a data model for the representation of question (assessmentItem) and test (assessment) data and their corresponding results reports. Therefore, the specification enables the exchange of this item, assessment and results data, between authoring tools, item banks, learning systems and assessment delivery systems [6].

These and other e-learning standards have been developed to make easier the searching and reusing in learning environments, such as learning management system (LMS) or Courseware.

This paper describes the process of collecting different virtual Labs which are over Internet, packing them in Shareable Learning Object (following the e-learning standard called SCORM) and their integration with learning management system. These steps make easier the creation of learning scenarios in different LMSs without having to do many changes.

II. SCORM

As it was mentioned, SCORM is a collection and harmonization of specifications and standards that defines the interrelationship of content objects, data models and protocols. It is divided into three main sections:

1. Content Aggregation model.
2. Run-Time Environment.
3. Sequencing and Navigation.

A. *Content Aggregation Model*

It describes the components used in a learning experience, how to package those components for exchange from system to system, how to describe those components to enable search and discovery and how to define sequencing information for the components (Fig. 1). These components are:

- Assets are an electronic representation of media, such as text, images, sound, assessment objects or any other piece of data that can be rendered by a Web client and presented to a learner.

- A SCO is a collection of one or more assets. The only difference between a SCO and an asset is that the SCO communicates with an LMS using the Institute for Electrical and Electronics Engineers (IEEE) ECMAScript.

- A learning activity may provide a learning resource (SCO or asset) to the learner or it may be composed of several sub-activities.

- A content organization is a representation or map that defines the intended use of the content through structured units of instruction (activities).

- Content aggregation can be used to describe the action or process of composing a set of functionally related content objects so that the set can be applied in a learning experience.

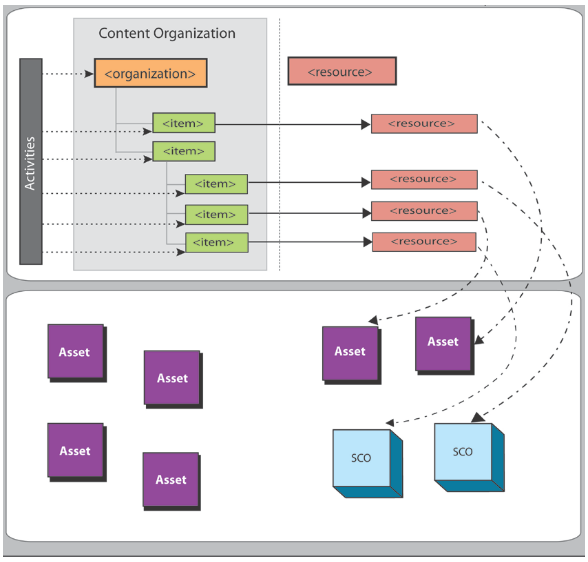

Fig. 1. Content aggregation model [4].

B. *Run-Time Environment*

It describes the learning management system (LMS) requirements in managing the run-time environment (i.e., content launch process, standardized communication between content and LMSs and standardized data model elements used for passing information relevant to the learner's experience with the content). In the figure 2 is shown how the data model exchange information with the LMS.

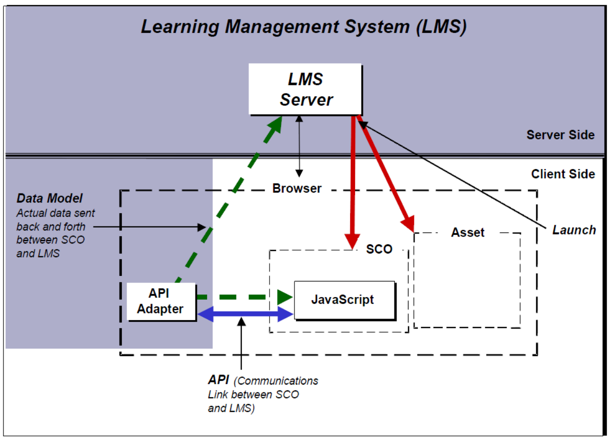

Fig. 2. Run-Time enviroment [4].

C. *Sequencing and Navigation*

It covers the essential learning management system (LMS) responsibilities for sequencing content objects (Sharable Content Objects [SCOs] or assets) during run-time and allowing those SCOs to indicate navigation requests. Therefore, it describes in detail how sequencing behaviors are applied to track learner progress.

III. Packing Virtual Labs in Shareable Content Objects With SCORM

Before describing this process, is important to describe in more detail what a Virtual Web Lab is. As it was mentioned a virtual Lab are simulation programs which allow carrying out experiment at any time and any place. The programs which are developed for the World Wide Web and displayed by a Web browser are called Virtual Web Labs (Fig 3).

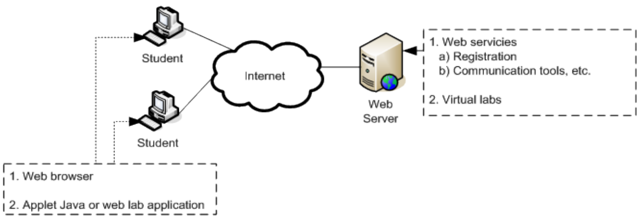

Fig. 3. Virtual Web Lab.

Therefore, Virtual Web Labs are developed in different technologies such as Java Script, Java Applets, Flash Applets or Active X and can be embedded in a HTML page and included as an asset of SCORM package.

This section describes the process of searching and packing of virtual web Labs in a SCORM package.

A. *Searching Virtual Web Labs*

Currently it is possible to find a great number of then over Internet and they cover a wide range of educational fields, such as: chemistry, mathematic, biology and physic. Therefore, many virtual web Labs are searched by internet. The results of this searching were 28 virtual web Labs, divided into:

- Six Web Labs of physic:

  1. http://www.enciga.org/taylor/lv.htm
  2. http://www.phy.ntnu.edu.tw/java/index.html
  3. http://www.sc.ehu.es/sbweb/fisica_/
  4. http://www.walter-fendt.de/ph14s/
  5. http://perso.wanadoo.es/cpalacio/30lecciones.htm
  6. http://www.pidlab.com/en/home

  These Labs allow students to carry out online experiment about electromagnetic, light-optic, mechanics and waves.

- Five Web Labs of Chemistry

  7. http://www.chemcollective.org/applets/vlab.php
  8. http://www.chem.ox.ac.uk/vrchemistry/labintro/newdefault.html
  9. http://chemistry.dortikum.net/
  10. http://www.dartmouth.edu/~chemlab/ (Dartmouth College)
  11. http://www.chm.davidson.edu/vce/Equilibria/index.html

  These Labs allow students to carry out online experiment about complex ions in aqueous solution, Interactive Organic Mechanism, Named Organic Mechanism and Organo-transition metal chemistry.

- Seven Web Labs of Biology

  12. http://www.hhmi.org/biointeractive/vlabs
  13. http://biomodel.uah.es/lab/inicio.htm
  14. http://web.mit.edu/star/genetics/
  15. http://www2.edc.org/weblabs/WebLabDirectory1.html
  16. http://phet.colorado.edu/en/simulations/category/biology
  17. http://www.edu365.cat/aulanet/comsoc/Lab_bio/bio_simula.htm
  18. http://virtualurchin.stanford.edu/index.html

  These Labs allow students to carry out online experiment about cardiology, immunology, bacterial identification and genetic.

- Six Web Labs of Mathematic

  19. http://www.walter-fendt.de
  20. http://palmera.pntic.mec.es/~jcuadr2/laboratoriosd/
  21. http://onlinestatbook.com/rvls.html
  22. http://www.math.uah.edu/stat/
  23. http://virtuallab.in/blog/
  24. http://ccl.northwestern.edu/netlogo/models/index.cgi

  These Labs allow students to carry out online experiment about Geometric Models, Bernoulli Trials, Finite Sampling Models, Games of Chance and Markov Chains.

- Two Web Labs of Electronic to understand basic concepts about electronic.

  25. http://tec.upc.es/el/moreno/index2.html
  26. http://meteo.ieec.uned.es/www_Usumeteog/

- Two Web Labs of idioms to learn a foreign language

  27. http://lvi.educarex.es/
  28. http://www.englishlab.ucn.cl/

B. Packing Virtual Web Labs in Shareable Content Objects

Once these Virtual Web Labs are found, the step of packing them in a Shareable Content Objects (SCOs) is carried out. To do this, there are several SCORM editors which make easier the creation of SCOs. The most well known is Reload [7].

To describe this section deeper, an example of one of the listed virtual web Lab is going to be explained:

1. Once the reload editor is downloaded in the PC, teachers can open it, doing double click in the executable file. A graphic interface is displayed with a menu of options.

2. Teacher select the option edit→new→ Adl SCORM package (Fig 4).

3. Once it created the empty SCORM package, the editor ask for a directory where the files or learning resources, which are going to be added to the package (Lab, manuals, etc.), are stored and shows the structure of package SCORM (Fig. 1 and 5). The files and resources are added and organized through drag and drop. The Virtual Web Lab is embedded in a HTML page. In the figure 5 the HTML page Laboratorio.html contains the web Labs (adding the URL as a reference or embedding the applet of active X)

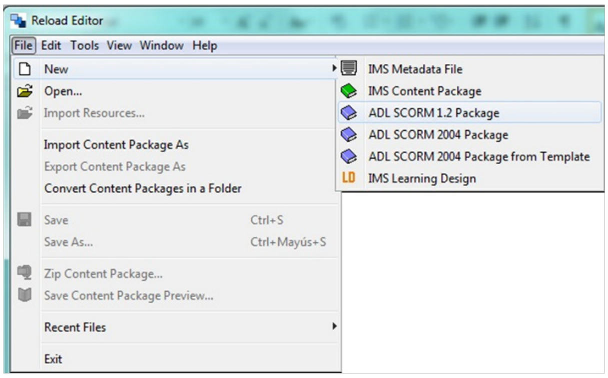

Fig. 4. Creating a empty SCORM package.

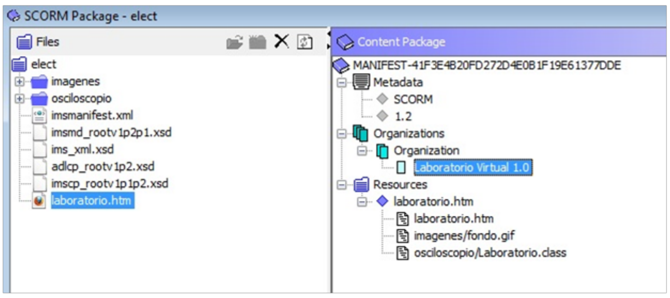

Fig. 5. Creating a SCORM package with several HTML pages.

4. Once all the resources have been included, Teachers save the package in a zip file and see a preview of the package (Fig. 6), using the editor.

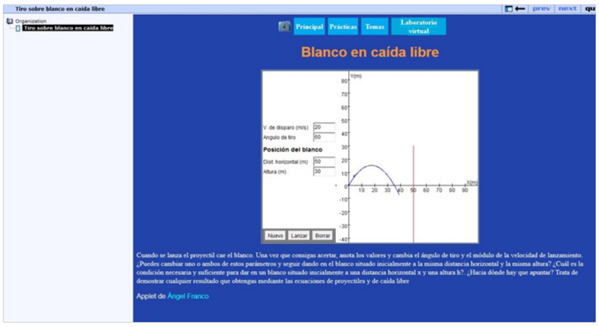

Fig. 6. Preview of packed virtual Web Lab in a SCORM Package.

IV. Adding the SCORM Package in a Learning Management System

An LMS is a framework that delivers and manages instructional content, identifies and assesses individual and organizational learning or training goals, tracks the progress towards meeting those goals and collects and presents data for supervising the learning process of an organization as a whole [8-10]. These can be classified as:

- Proprietary LMS, such as Blackboard [11].
- Open Source LMS, such as Moodle [12], dotLRN [13] or Sakai [14].

While, the proprietary LMSs only allow determined programmers to know its source code, the open LMSs allow some programmers can know its source code, modify and adapt it to the needs of the university or institution for their work.

The vast majority of LMSs provide educational tools, such as:

- Administration. It must be able to manage user registrations, roles, assign tutors, user payments, etc
- Synchronous and asynchronous Communication Tools. It must allow collaborative work. So that they can share information, opinions and experiences.
- Evaluation. The tutors and teachers must be able to evaluate the student's progress. Also the students can do test where they can see their progress. To do it, The LMS provide a set of assessments tools and in some cases these tools fulfill with e-learning standards as IMS QTI (Question and Test Interoperability).
- Tracking user. A set of tools which provide information about user activity and the results of these activities.
- Content packing. It organizes the content in a hierarchical structure and sets up a mechanism to swap content between different learning management systems. To do it, it's usually used the specification IMS content packaging or the specification SCORM (Shareable Courseware Object Reference Model).

Therefore, The SCORM package which has been created in the previous section can be added along with assessments, chats, forums, etc. without having to program anything (Fig. 7).

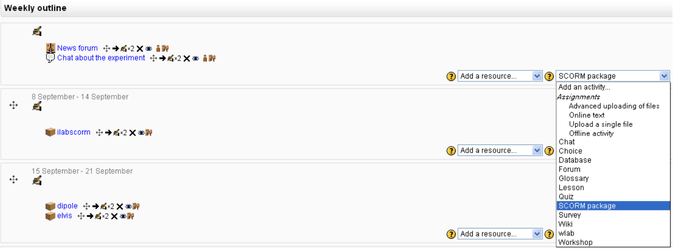

Fig. 7. Adding a SCORM package in a Moodle course and wrapping it with e-learning Tools, such as Forum, Chat.

V. Discussion

This article is focused on the idea of using Learning objects and a well-known e-learning standard called SCORM to reuse Virtual Web Laboratories. The adaptations of Web pages, which contain virtual Web Labs, to SCOs provide a set of advantages.

- The Virtual Web Labs are in a SCORM structure and around it, other web pages, videos, audio, applets are packed to provide a whole learning pack. Also it is organized following a sequence of navigation.
- Each SCORM package is described by a set of metadata which make easier the searching of Labs. For instance, it can be stored in a content management system and deployed in a LMS.
- The SCORM package can be modified with editors and it is not necessary to know about programming.
- The SCORM package can be added in a different LMS course (independently if it is Sakai, Moodle or Blackboard) and can be "wrapped" with e-learning tools such as authentication, forums, chats, assessments and file storage without programming anything.

But, this process also has a set of disadvantages, such as:

- Version problems. Not only, there is a version of one standard, For instance SCORM have several versions, such as v1.2 or v2004. These provide different features and API. So, if a teacher is working in packing a set of statics resources, then he should check the e-learning system where the content package is going to be installed.
- Standards, such as SCORM or IMS-CC, pack text, images, or even applets. Therefore, they are packing static resources. But, new e-learning resources, such as remote Labs are dynamic application which cannot pack in a zip file. To solve this, several new initiatives are emerging, such as:
  1. SCORM next generation. This project adds to SCORM a Web Service Runtime Communication Profile Standard (based on a Web Service binding of the IEEE 1484.11.2 functionality and on IEEE 1484.11.3) to exchange data between SCORM package and LMS [15].
  2. Common Cartridge & Learning Tools Interoperability Alliance. It is the merging of two e-learning Standards:
     a. IMS Common Cartridge defines a new package interchange format for learning content, able to run on any compliant LMS platform.
     b. IMS Learning Tools Interoperability (LTI) v1.0 provides a single framework or standard way of integrating rich learning applications (in LTI called Tools) with platforms like learning management systems, portals, or other systems from which applications can be launched, called Tool Consumers [16].
  3. Widgets. According to W3C World Wide Web Consortium (W3C), widgets are client-side applications that are authored using Web standards such as HTML and packaged for distribution. They are typically downloaded and installed on a client machine or device where they run as stand-alone applications, but they can also be embedded into Web pages and run in a Web browser. These can create complex applications that pull data from multiple sources to be "mashed-up" and presented to a user in some interesting and useful way (http://www.w3.org/TR/widgets/). These widgets can be combined to create online learning scenarios and activities which can be displayed in different devices, such as smart phones, tables, web browser and PCs.

To sum up, new initiatives, focused on reusing e-learning resources over Internet, are emerging. But, until these can be used, e-learning standards, such as SCORM, are good solutions to create learning scenarios in learning management systems

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AREA: A Social Curation Platform for Open Educational Resources and Lesson Plans

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***Abstract*— Content curation has emerged as a topic of interest in the last few years in the Internet. It aims at discovering and ordering interesting resources from the web, and sharing them with others. From the profile and past behaviour of users, new resources that may be of interest can be recommended to them. This paper discusses AREA, a content curation platform targeted at teachers, where they can aggregate into shareboards the resources that they find in the web. Those resources can be used in educational activities, which are the building blocks for composing sequences of activities, that are in turn the cornerstones of guides (lesson plans). The educational experiences that result from the use of guides are also contemplated in the platform. The key original feature of AREA is that it extends the concept of content curation, so that, not only contents, but also activities, sequences, guides, and experiences, in addition to other resources such as persons, events and tools, are first-class curable elements in the platform. Therefore, shareboards of teachers can include any of those elements; and all of them can be shared, commented, rated, and also recommended to other teachers.**

Keywords—content curation; lesson plan; learning resource; referatory; paradata

I. Introduction

Nowadays, technological developments and innovations are producing continuous changes in our society. These changes can be seen at all levels, from children at the school to workers in companies. Technology provides many solutions to problems, but it also creates new difficulties and challenges. A specific issue is that education needs have moved the focus from knowledge acquisition to 21st century skills. In addition, children are digital natives and they seem to have a different view of the world. In this situation, teachers are required to change their teaching approaches to take advantage of the new technologies in order to engage learners and promote a more effective learning.

In this context, several initiatives have been initiated focused on supporting teachers in the acquisition of new pedagogical approaches and the development of ICT competences. In Europe, the iTEC project [1] is trying to support the adoption of technologies in schools at a large scale and in a sustainable way. The idea is not simply to get teachers used to new technologies, but also to introduce changes in the pedagogies that allow teachers to take full advantage of the affordances provided by the new devices (e.g. tablets, interactive whiteboards) and applications (e.g. social Web, smartphone apps). To this end, the iTEC project has developed a set of guidelines for innovative teaching and learning activities [2] that can be taken by teachers as a reference. In addition, it also provides tools to facilitate the application of the guidelines to particular contexts, such as authoring tools and recommenders.

In this paper, we present an initiative called AREA to support teachers in the creation of lesson plans. Following some ideas from iTEC, the purpose of AREA is to facilitate the adoption of new technologies while promoting a change in the pedagogies. This is done through the guidelines included in proposed activities, but also through a curation facility that empowers teachers as authors and reviewers of new learning resources and proposals. The key idea is not just to provide guidelines and resources, but to support teachers developing their own guidelines, taking them into practice, and sharing the ideas, resources and results with their colleagues.

The rest of the paper is organized as follows. Section II shows the features of AREA as a referatory of learning resources and arrangements. Next, section III provides an overview of AREA as an authoring application where teachers can create learning guides (lesson plans) and document learning experiences. Then, section IV introduces the functionality of AREA as a curation service. The paper finishes with a review of related initiatives and some conclusions.

II. AREA as a Referatory

A key AREA feature is that it doesn't include a repository of learning contents. Instead, it provides the functionality of a referatory [3]. This means that contents (e.g. pictures, videos, podcasts, animations, questionnaires) are not stored in the AREA database, but just the descriptive information of such contents (namely: metadata).

The decision to provide a referatory functionality and not a real repository was taken in accordance to the following reflections. Firstly, during the last years many projects and initiatives related to the promotion of new technologies in education have been focused on developing learning contents and maintaining them in repositories. A clear example of this

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approach is the European Union eContentPlus programme [4] in which more than 50 projects were funded to produce learning contents for different fields and, in many cases the corresponding repositories. These initiatives have succeeded to a certain extent, but some problems remain to be solved, such as the poor use of the contents provided to final users. Indeed, the past year, the ODS project [5] was initiated to provide a solution through the development of a common access point to the contents and repositories of several projects. Secondly, learning contents can be found and maintained everywhere in the current Web. A key feature of the Web 2.0 and the Social Web is that anybody, either an expert or a novice, can easily create a new video, picture, slide presentation or podcast, and then to upload it and share it using online services such as YouTube, Flickr or Slideshare.

Taking into account the repository experiences and the fact that learning resources are available everywhere, we decided to provide in AREA a referatory functionality. The information in the referatory is taken from existing repositories and from the Web in general (see section II.C). In this way, AREA maintains information about learning contents (e.g. name, description, picture, type, rating, educational level, difficulty), but not store the actual contents. Every actual piece of content is maintained in other location and in AREA we just save the link (typically an URI) to it.

A. Learning Resources

Typically, repositories maintain learning contents. Nevertheless, in AREA, learning contents are just one of the several types of learning resources that can be involved in lesson plans. Following the new pedagogical approaches that guide the iTEC project, the AREA referatory maintains information about different types of learning resources:

- Contents. These are materials that contain information, such as: multimedia documents, videos, podcasts, slides, images, simulations, questionnaires, etc. These are the traditional learning materials.
- Tools. They are any kind of software application or hardware devices that can be used by teachers and learners during an educational activity. Examples of applications are communication tools, authoring tools, learning managing systems, etc. Examples of devices are video cameras, interactive whiteboards, GPS-enabled devices, etc.
- People. People from outside the school in the role of experts or examiners may be involved in learning activities. For example, the local police chief can explain some traffic rules, a doctor may talk about healthy habits, someone from the city hall may explain the local government, etc.
- Events and locations. External events might be interesting learning resources to support and complement learning activities. For example, a roman museum or an exhibition about the ancient Roman Empire can may an excellent opportunity to complement a lesson about that particular historical period.

AREA maintains in its referatory information about these kinds of learning resources. It is quite clear that it doesn't make any sense to maintain the last three types of resources in the system. The information about each resource will include a classification in accordance with different categories (e.g., type, educational level, difficulty).

B. Learning Arrangements

In addition to the learning resources, AREA also maintains a different kind of component that we name as learning arrangements. We distinguish among four different types of arrangements:

- Activities. An activity is a de-contextualized description of a teaching/learning practice with a particular purpose. Activities can include different types of proposals: teachers and learners working in the classroom, learners doing research outside of the school, learners in groups collaborating on-line, etc. A key issue about AREA Activities is that they are devised to be innovative, promoting new pedagogical approaches (e.g. flipping the classroom, working with experts, going outside the school, benchmarking, making, showing to others) and involving new technologies (e.g. tablets, interactive whiteboards, GPS devices, games, interactive environments, Web 2.0, collaboration tools). Activities are provided in a de-contextualized way (actually they are abstractions), without any reference to particular subjects or target learners. The idea is to facilitate its eventual application to different contexts. In this way, they don't include any reference to particular resources, such as specific tools, people or events. Instead, they include requirements, such as: a video-editing tool, an expert to assess student productions and provide feedback or an outside event to inspire students. Fig. 1 shows a view of an activity in AREA. It contains several sections: description, keywords, interaction, teacher motivation, student motivation, guidelines for preparation, introduction, development and assessment, ideas for using technology, and requirements related to resources.
- Sequences. A Sequence is just an aggregation of learning Activities that can be used together in a certain order to develop a larger teaching/learning experience. The Activities in a Sequence are arranged in a particular order and in some case, but we can have optional or alternative Activities. Sequences are also de-contextualized.
- Guides. The key difference in relation to the previous arrangements is that a Guide needs to be contextualized. The idea underlying in this arrangement is to describe what is intended to happen during several teaching/learning sessions. Thus, it is similar to a lesson plan, but it follows a very specific structure that involves the next sections: identification/description, technological setting, contextual setting, Sequence (or set of Activities) and for each Activity the learning Resources involved. The contextualization of the Guide is achieved through the specification of the

technological and contextual settings (see next section), namely: applications and devices available, language, location, dates, learners' age, educational level, etc.

- Experiences. This arrangement is devoted to documenting what has happened during the performance of the Guide in the classroom. AREA enables teachers and learners to attach videos, pictures or comments to Activities during the several teaching/learning sessions.

C. *Referatory Functionalities*

The AREA referatory maintains information records about learning Resources and Arrangements. Different data are maintained for each type of element. Nevertheless, AREA provides a common functionality related to the population, search, browse and classification.

There are several ways in which new learning Resources are included in the AREA referatory. First, users can introduce information about new Resources in an indirect way. Using the curation functionality described in section IV, new resources will be added automatically. Secondly, it implements harvesting and enrichment algorithms for collecting and populating the referatory in an autonomous way from repositories and sources available on the Web. Our research group has developed this functionality using semantic technologies in the context of the iTEC project [7].

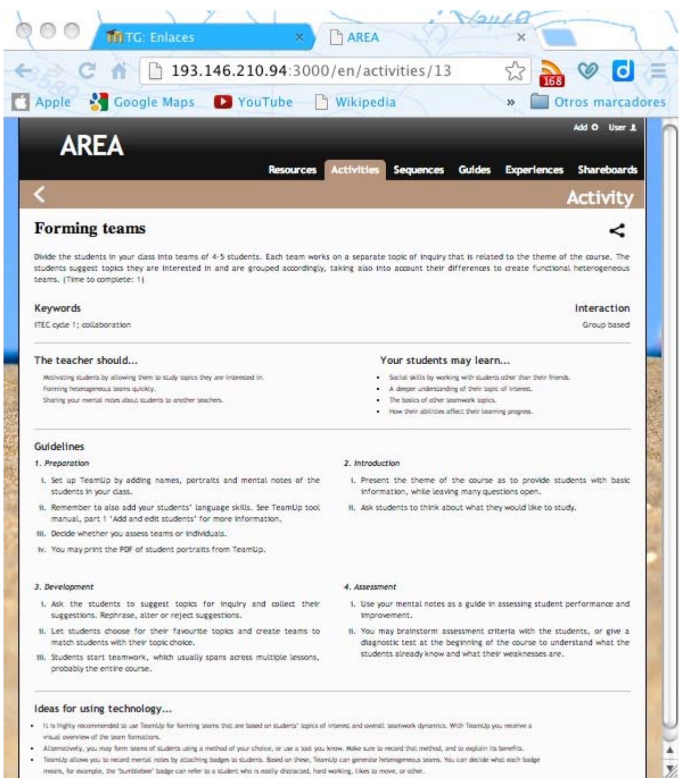

Fig. 1. Representation of an educational activity in AREA

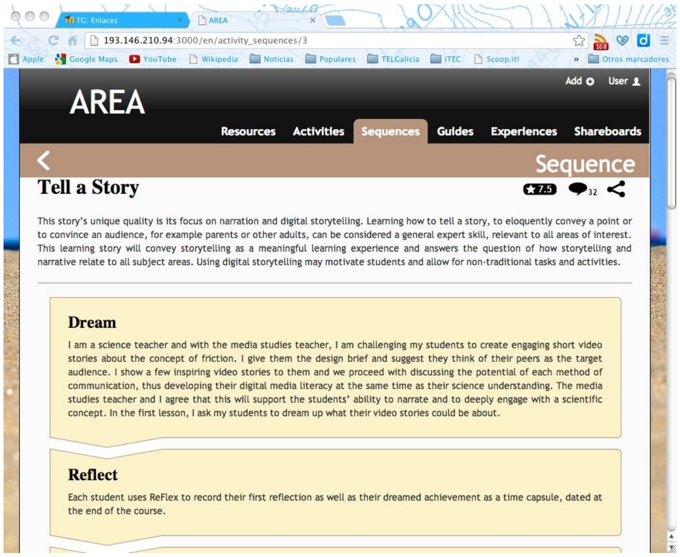

Fig. 2. Initial representation of a sequence of educational activities in AREA

Another set of AREA functionality involves searching and browsing Resources and Arrangements. Search is supported through keywords matching. Browse is supported through a set of categories in which resources and arrangements are classified. Resources and Arrangements are continuously ranked taking into account its classifications in several categories (e.g., educational level, subject, interactivity level) and real use. Indeed, every record in AREA that contains information about a Resource or an Arrangement includes a set of paradata information. This information involves items such as: the number of users that have explored the record, the number of times the element was used, the number of recommendations, the number of times it was provided as a response to a search query, etc.

III. A SUPPORTING ENVIROMENT FOR LESSON PLANS

AREA provides an authoring environment to create Guides (lesson plans) and to document learning Experiences. These arrangements are created from learning Resources and other arrangements (Activities and Sequences) available in AREA. The Guides and Experiences created by a teacher can be made private, as they are intended for personal use. Nevertheless, in case they are maintained as public, other teachers can use them as inspiration or directly as a template for the creation of new Guides and Experiences.

A. *Creation of Guides*

Using the authoring facility teachers are supported to create learning Guides. Guides can be created from scratch using the learning Activities/Sequences and Resources described in the AREA referatory. In addition, a teacher can take as a starting point an existing Guide (created by herself previously or by another teacher) and modify it to produce a new Guide.

In the normal flow, teachers create Guides before the teaching/learning process is initiated. Then, they can use the Guide as a script to know what to do (herself and her learners) during teaching/learning sessions. Nevertheless, AREA doesn't provide any functionality to support the automatic enactment of the Guide. It is not a kind of IMS Learning Design engine [8]. As it is shown in sub-section C, a Guide can just be used by the teacher to document and track what actually happens during the teaching/learning sessions. Taking into account this functionality, the teacher can modify a Guide after the teaching/learning sessions have been initiated.

Figure 3 shows the interface that enables the creation and edition of Guides. It depicts how we have divided the guide in four sections, which are: the identification, the technological setting, the contextual setting, and the sequence of Activities. It follows a description of each one of these sections:

- Identification. The first section is composed of a title and a brief description of what the teacher intends to do and achieve. It can also include an image and several user-defined tags. As any other resource in the AREA referatory, a Guide can also include paradata information that will be shown in this first section, but not during the authoring stage.

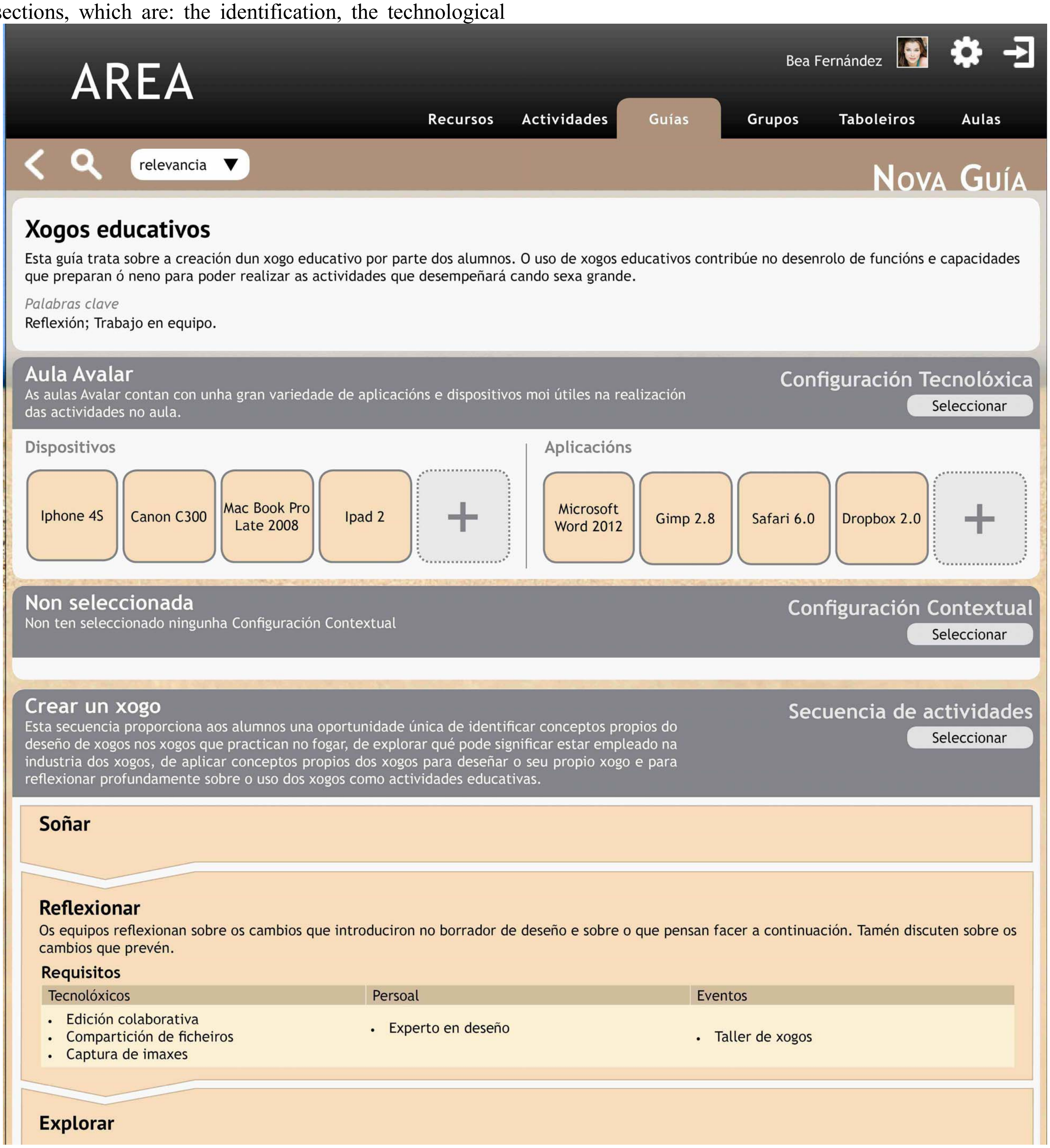

Fig. 3. Edition of a Guide in AREA

- Technological setting. This is the first part in the characterisation of the classroom and the school as the environment where the educational activities of the Guide are going to be performed. This part includes all the technological resources available for the teacher and the learners to carry out the Activities included in the Guide. The technological setting elements are divided into two categories: devices and applications. Technological settings may have been created before the edition of the Guide. For instance, a teacher in an administrator role might have been included the different technological settings available at their school, such as classroom with audio-visual equipment, or a computer room with Internet access. Other teachers may choose a technological setting from the ones available in AREA (at their school) when creating their Guides. Besides, it is also enabled to create a new technological setting using an existing one as a template, as well as to create a new technological setting from scratch. In order to support all the options listed above, an editor for technological settings is integrated into the editor for Guides. As the figure shows, this element is composed of a name, a description, and the set of devices and applications. The system also provides the user with detailed information about every available application and device.

- Contextual setting. This part completes the characterisation of the environment where the Guide will be carried out. As with the technological setting, the user can either select an existing one, to make a copy of an existing one for its later modification, or to create a new one from scratch. In the figure, we can see how the system notifies the user that he/she does not have any contextual setting selected. At this point, the system provides an editor that enables to perform the actions for modifying or creating a new contextual setting. The purpose of this part is to characterise the educational context where the experience is going to be carried out (see Table 1): the age of learners, the subject, the educational level, the working language, the spatial and temporal location, etc.

- Sequence. The system provides the teacher with a fully featured editor for learning Sequences at this part of the Guide. In AREA, a Sequence is composed of a title and a description, as well as an ordered set of learning Activities. As in the other parts discussed above, the user is allowed to modify an existing educational Sequence or to create a new one from scratch. In order to compose the sequence, the Activities in the AREA referatory can be used as building blocks. The editor for sequences allows the teacher to browse the different Activities available in the system, enabling to review all their particular features. Each activity selected by the teacher to be included in a Guide is actually copied into it, and in this way it can be particularised for the Sequence. Thus, the teacher can assign a particular title and description to the Activity and modify any data. This modification is not transferred to the original activity.

TABLE I. ITEMS IN THE CONTEXTUAL SETTING

Name	Description	Data Type
Id	Contextual setting identifier	URI
Name	Given to the contextual setting	String
Description	Short description	String
Creator	Identifier of the person who created the setting	URI
Subject	Knowledge subject to be developed in the Guide	VocTerm
Keywords	One or several works providing some specific details to the subject	String
Language	In which the Guide will occur	VocTerm
Age range	Of the learners for whom the Guide is intended	VocTerm
Educational Level	Of the learners for whom the Guide is intended	VocTerm
Address	Location where the Guide will be carried out	Object
Start Date	When the Guide will be initiated	Date Time
End Date	When the Guide will be finished	Date Time

B. *Assigning Resources to Activities*

Previous section describes the initial steps to create a Guide, but it is not the full story. To be finished, the teacher needs to select Resources that fulfil the needs specified by the Activity requirements. As it is explained in section II.B Activities are provided in a de-contextualized way, with no actual reference to specific Resources. Nevertheless, Guides are contextualized arrangements. Indeed a key part of a guide is the specification of the technological and contextual settings. Therefore, in order to complete the Guide, requirements in Activities need to be matched to actual Resources available in the technological setting and suited to the contextual setting. A key general idea underlies this behaviour: an Activity can be carried out in different settings using different Resources, in the worst case just paper and pencil.

AREA provides some specific functionality to support teachers during the matching of Resources to requirements:

- First, taking advantage of the developments in the iTEC project [9, 10] recommendations about the more suitable Resources for each requirement or for the Activity as a whole can be provided. The recommendation functionality takes into account the particular requirements for each Activity, as well as the particular context in which the activity is going to take place (specified in the technological and contextual settings). A key objective of these recommendations is to ease the inclusion of new Resources, particularly technological resources that teachers might not be aware of. Thus, the teacher can select (with the assistance of the system) the Resources that are going to be used in the Activities.

- Second, teachers can use the search and browse functionalities of the AREA referatory to look for Resources directly.

- Third, AREA is able to notify the teacher when some requirements are not fulfilled.

C. Documenting Learning Experiences

AREA also support teachers documenting learning Experiences. The key idea here is to attach outcomes and products generated during the development of the teaching/learning sessions to the Activities planned in the Guide. Users can include photos, video clips, audio podcasts, comments, etc. They can also include references to Web sites and pages used during the learning process (e.g. a Blog or a Facebook page).

This documentation can be generated during or after the development of the teaching/learning process. We hope this kind of documentation can be will promote teachers action. Other teachers can use learning Guides as a reference for carrying out innovative educational experiences in their classrooms. We think that if other teacher can see what actually happened during the development of the Guide, this could move them to use the same Guide or create a new one. In addition, the documentation of a learning Experience can be used to communicate the classroom activities to learners from different classrooms of the same school or other schools. It might even be helpful for parents to know what their children are actually doing in the classroom.

IV. A CURATION PLATFORM

AREA is also a curation platform for learning Resources and Arrangements. Teachers can create shareboards (private or public lists) and collect learning resources, learning activities, lesson plans and any kind of Web document related with their learning/teaching interests. This functionality is similar to the one available in existing platforms such as Scoop.it or Pinterest.

A. Curation of Web Documents and AREA Elements

When users browse the web, they can find interesting documents (for instance, some YouTube video, an interesting tweet, a Slideshare presentation, a photo or an info-graphic on Pinterest). At this point, users can use the AREA extension (available for Firefox) in order to add the document to a personal shareboard. Actually, the Web document is not added to AREA, but an extract of the document. In addition, user can also aggregate on their shareboards extracts from AREA Resources and Arrangements.

An extract is a summary of a Web document (also AREA documents). It includes a title, a link to the original item, a short text and an image (optional). The key point about an extract is to be as representative as possible of the resource it refers to. In other words, the user should be able to clearly remember the original element by just seeing the extract. In addition, extracts.

As it is discussed above, users can create extracts from documents that they find when browsing the Web. Then, they include and classify the extract on a personal shareboard. The user can rate the extract, comment and tag it. Once the new extract is on the shareboard of the creator, other users (those who follow the one who created the new extract) can see it and add the extract to their own shareboards. All the comments made for the same extract are viewed on all the shareboards in which the extract was included.

B. Curation Functionalities

This part of AREA is conceived as a social application where users can find other users with similar interests and create communities. A user can decide to follow the shareboards of other users, provide suggestions of resources/arrangements to friends, comment and rate resources/arrangements, etc. A reputation policy is established to promote action and participation in AREA.

The process of content curation gives to extracts (and therefore to the elements that they represent) a measure of its relevance for users. For instance, an Activity that was included in many shareboards has a lot of relevance. The same thing happens with Resources, Sequences, Guides, and Experiences: they gain relevance when they are included in shareboards. Apart from the process from calculating relevance described above (which is quite plain) AREA contemplates a (vertical) content curation mechanism, relating Activities to Guides and Guides to Experiences.

This is related to the concept of curation by aggregation during the authoring of Arrangements: when a user includes an element into another element, the former gains relevance. For instance, when a Resource is included into an Activity, that particular Resource gains relevance. The same thing happens with Activities: the more times they are included into Sequences, the more relevance they gain. Sequences, in turn, become more relevant as they are included in guides; and, the more experiences for a guide, the more relevant that particular guide is.

This curation knowledge is used to maintain a user profile and to update the information available in the AREA referatory on learning Resources and Arrangements. Eventually, taking advantage of this information, we provide recommendations to users when they are looking for a particular Resource or when they are authoring a Guide.

V. RELATED WORK

During the last years many initiatives have been provided to empower teachers creating their own course contents. Some of these initiatives are the following ones: Students Circle Network (www.studentscircle.net), Tiching (www.tiching.com), Didactalia (www.didactalia.net), Connexions (www.cnx.org), Eduteka (www.eduteka.org) and Saylor (www.saylor.org). In general, these are Web applications that support teachers providing contents, creating their own course contents through the aggregation of contents, and sharing contents and courses with other teachers. Some key differences between these initiatives and our development are the exclusive focus on contents and the lack of specific proposals to support technological and pedagogical innovation. AREA is not just about content, but also about other kind of resources: people, events, tools. In addition, de-contextualized and abstract models of activities and sequences are provided for inspiration, in conjunction with recommendation functionalities.

Some of these initiatives such as Eduteka involve a social network service than enables to relate users and their resources. Similarly, Tiching provides paradata information about the contents included. This kind of functionalities facilitates the development of curation processes and the creation of communities of interest. In AREA we have also conceived these functionalities in a similar way, but in the context of a broader set of resource and arrangement types.

AREA can also been related to other initiatives more focused on the development of electronic textbooks. In Europe the eTernity project (http://etextbookseurope.eu/) has been proposed to fulfil educational requirements for e-textbooks as a channel for creating interactive, adaptable, personalizable resources to improve learning, education and training. In Latin America the LATIn project (http://www.latinproject.org/) will encourage and support local professors and authors to contribute with individual sections or chapters that could be assembled into customized books by the whole community. These initiatives are involved in the development of open and electronic textbooks. AREA could be used as an authoring tool of electronic textbooks, but mainly the teacher version of such books.

VI. Conclusion

The approach to educational guides taken in AREA is a step forward from traditional guides, as it encourages the use of technology and innovative activities in the classroom. In this sense, one of the objectives of the system is to propose the use of different devices and applications to teachers, some of which they may not be yet aware of.

The documentation of educational experiences plays a very important role in the transmission of what is actually performed in the classroom. This information may be crucial for the elaboration of new educational guides. In a similar way, teachers may find interesting to follow a particular guide in their educational practice, basing their decision on previous experiences of other teachers with that same guide.

The AREA project will allow us to evaluate to what extent the content curation concept may be useful in real-world teaching/learning practice. In our view, the AREA approach to content curation has strengths in allowing teachers to compose new educational Guides, which can aggregate educational resources that they found in the Internet; and enabling the contribution, sharing and discovering of educational resources and arrangements, which later can be recommended to teachers in accordance with their interests and previous activity in AREA.

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Distributed Version Control for Curricular Content Management

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Abstract—**Educators have at their disposal many digital content sources, from textbook publishers to open courseware repositories (OCRs) to specialized collections to shared resources from a network of peers. It is rare one needs to go create new lecture materials, instead one can download and adapt to fit their needs. The proliferation of such resources is expected to result in great productivity for educators, particularly those in higher education where time demands relegate content development to the back-burner. But are we seeing such productivity? Are courseware repositories spawning heavy reuse? Or are issues integrating content to courses causing a loss in productivity and greater frustration? These are the questions being investigated by the Distributed Version Control for Curricular Content Management project. This work-in-progress project has conducted a local faculty survey of curricular content development and used the results to drive the initial implementation of a distributed version control tool for curricular content management**.

Keywords—curriculum development, software tools

I. Introduction

At the 2013 ACM Special Interest Group for Computer Science Education conference (SIGCSE 2013), Peter Norvig led a Google session on Massively Open Online Courses (MOOCs). In concluding his presentation, he indicated that (paraphrase) *we have to start thinking of courseware development as an engineering process, much like software development*. We agree with this perspective, as we believe there has been a significant shift in courseware requirements driven by continuous change, change in learners' content consumption behaviors, and the disruption caused by online technologies. Linear (waterfall?) workflows need revamping in the face of these forces; in fact we contend this is already taking place and it is the understanding of the engineered process with associated tool support that will drive innovation.

The Distributed Version Control for Curricular Content Management (DVC4CCM) project is a first step at applying a software development best practice to the curricular content development process. The problem of curricular content management is similar to an open source community source code control problem. In open source, the ability to take and customize the source code to meet domain requirements is central to the value proposition. The problem of an instructor obtaining, customizing, and integrating curricular content from multiple sources is not unlike the open source problem. The instructor must 1) identify resources (or subsets of resources), 2) ensure the resources are available for use in the target context (licensing), 3) adopt the resources into the learning context (formats and modalities), and 4) ensure the content flows in a seamless fashion to support learning outcomes (integration and customization). These activities are laborious and frustrating, as the time to locate, assemble, and integrate content from available sources can be as burdensome as the time it takes to create content from scratch.

The larger research question the DVC4CCM project aims to address is the understanding and improvement of curricular content management patterns for higher education instructors. The methodology uses a survey instrument to understand curricular reuse, and based on the results to identifies viable version control workflows from the software engineering community. The initial technology solution is a customized wrapper around the popular Git distributed version control system to facilitate content integration and reuse. This work-in-progress paper frames the research problem, describes the survey vehicle, and presents the initial tool implementation.

II. Research Methodology

Source code control and configuration management (CM) are established competency areas in software engineering. CM has largely evolved through client-server tools like the Concurrent Versions System (CVS) or subversion (SVN) which employ centralized repositories for software artifacts and an optimistic approach to managing change. To generalize, the centralized repository maintains the baseline copy of artifacts (the *mainline*), developers work on local copies of artifacts, and the client tool maintains metadata to describe the deltas against the mainline. The most common and accepted ([6]) workflow is a *branch-and-merge*, where developers work on shared branches, and merge changes into the mainline. The prevailing mantra is to 'check in early and check in often' to reduce the probability of long, painful, and error-prone merges. Techniques for managing long-running branches range from creating *sandboxes* to maintaining *private branches*.

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In a distributed version control system (DVCS), change is managed among multiple distributed repositories, usually by creating complete copies of artifacts in each repository (though this is not always the case). The presumed centralized repository to many endpoints model is replaced by what is effectively a peer-to-peer repository approach.

The value proposition for DVCS over the traditional centralized model is that change is allowed to proliferate, and consumers can manage what changes they want by determining which changes they *pull* from a peer repository. This is an important improvement over traditional CM, which implicitly tries to minimize change through the 'check in early, check in often' mantra. In practical terms, the flexibility to define advanced workflows opens the possibility for supporting new collaborations between artifact creators. For our initial exploration, we evaluated workflow patterns evolving in DVCS practice, surveyed department faculty to determine typical curricular creation patterns, and implemented a tool to support a workflow for curricular content management.

A. *CM Patterns for DVCS*

Software houses are rapidly adopting DVCSs and evolving best practices such as identifying appropriate workflows. We reviewed workflows for software development with an eye toward curricular content management, and summarize our thoughts on some of the potentially applicable ones here.

1. Branch per developer – In this pattern, a coach is responsible for the stability of the code base. Developers maintain a cloned local repository in which to work, and a public repository with read access to other members of the team. When a developer is done with implementation s/he commits changes to the local repository. When the developer is ready to submit changes to the mainline, s/he pushes the changes to the public repository and notifies the coach. The coach pulls changes from the developer's public repository to a local repository and verifies they meet quality standards. If they do, the coach publishes these changes to the mainline repository and notifies other team members [1]. This configuration pattern ensures the stability of codebase. It also helps in maintaining releasable version of the project at all times. This pattern is suitable for small agile teams, but the setup would be extremely complex if the team is large, and thus this pattern does not suit for medium to large teams [1].

2. Feature separation through named branches - In this pattern [2], developers create named public branches in their own repositories for working on distinct independent features. Adopters select which features to assemble into an application or system by determining what named features they wish to pull and integrate from the various public options available. The mapping of this workflow to curricular content could go like this: an educator may get materials from one of the repositories. When s/he makes changes a new named branch from the repository is created. When another educator wants to create a curricular module, s/he can pick from any named branch based on features desired. If there is a central repository maintainer, that person may choose to maintain and evolve the mainline by merging in the named branches, but there is no requirement on adopters to only use the mainline version.

This pattern helps to develop features collaboratively and also allows the user to check for which feature a given change was added. It is best suited for large to medium agile teams but does not scale up well if the project has a lot of small features.

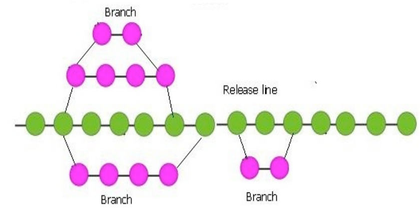

Figure 1: Feature separation through named branches

3. Working off named stable bases - Software developers often work on a project's mainline so that they get all the latest changes and do not have to deal with huge merge conflicts when committing their code. However, the mainline often has unstable and untested code, which can cause rework problems if changesets must be rolled back, potentially impacting all changesets committed after the problematic changeset. The 'Working off Named Stable Bases' pattern solves this problem by allowing developers to work off a stable tested revision instead of potentially unstable mainline. When the revision is stable it will be tagged as stable and other developers may start working off this revision.

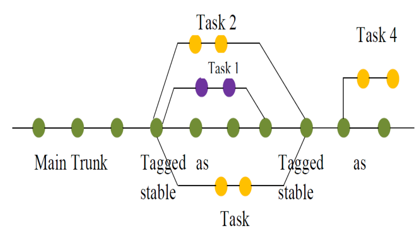

Figure 2: Working off named stable bases

This pattern is most suited for large projects where developers work on unrelated tasks. This approach might not be suitable for projects where many developers are working on the same or related tasks [3].

4. Other configuration management workflow patterns - We reviewed several other CM patterns. These were not selected as they were either too close to the workflows described above or did not fit the workflow requirements.

- Episodic Collaboration [3]
- Local Branching [1]
- Private Versioning Workflow [4]
- Incremental Workflow [4]
- Independent Development Workflow [4]
- Staged integration lines Workflow [1]
- CVS-like Workflow [2]
- One-off patch submission Workflow [2]
- Centralized Workflow [5]
- Integration-Manager Workflow [5]
- Dictator and Lieutenants Workflow [5]

B. *Faculty Survey*

In order to figure out the process used by educators perform collaborative courseware development, we created a survey for the faculty of our department The survey consists of 26 questions about the sources of course materials and how one incorporates change. 15 faculty completed the survey, though not all answered every question. Survey result highlights:

- 87% said 61-100% of materials are in electronic form.
- 87% said 21- 60% of course material changes per year.
- 67% said they have revisited older versions of materials.
- 60% said adapting outside materials is inconvenient.
- 67% said adapting outside materials takes about 1-4 hours.
- 50% said they thought of sharing course materials with others, but could not find the right platform/mechanism.
- 80% said they have incorporated changes to their notes based on contributions from others.
- 40% said they reuse course materials from colleagues.
- 75% said they use email to share updated materials back with the originator.
- All (100%) said they construct their current course materials using their last year's course materials.

Of course this is a small single-source sample, and the results expected. It is not a stretch to think this is representative of most places (certainly broader study is needed).

C. *Workflow selection and implementation*

We used these results to determine which of the workflows we reviewed might address the most significant change management issues. We determined that a combination of *Feature separation through named branches* and *Working off named stable bases* is the best candidate solution. The former allows adopters to maintain a separate space for material, so they can make available their own materials when needed and make changes at the same time. However, this might work for only a small number of materials. It will be difficult to manage if there are many borrowers and if all borrowers submit back to the originator with updated materials. The latter workflow will help solve these problems. Adopters can go ahead and submit their files to the repository and inform the originator, who can tag it as stable for future adopters. Figures 4 and 5 depict the customized workflows implemented in DVC4CCM.

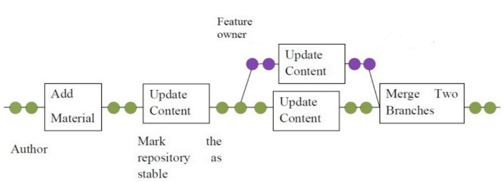

Figure 3: Custom workflow if author merges branches

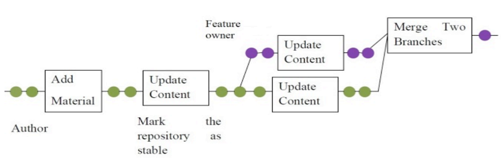

Figure 4: Custom workflow if feature owner merges branches

DVC4CCM is implemented as web application enforcing these custom workflows. The tool wraps the open source Javagit codebase (javagit.sf.net) and allows end users to perform actions based on the state of the workflow and a defined role with respect to that workflow. Users of the tool can create a repository or download an existing repository. A user who creates a repository is the *owner* of that repository and can submit content to it. When a user submits content to the repository, s/he will be asked whether to mark the repository as stable. Only repositories which are marked as stable are available for others to download. Adopters get a copy of the materials in the repository by using the tool to indicate intended use, including whether a new feature will be added. If a new feature is intended, the backend creates a new branch. Then later, once the user submits content and marks it as stable, the named branch will be available for others to download. After the feature owner submits content to the repository, both feature owner and the original author have an option of merging the named branch. If the feature owner merges, the merged changes will go to the branch, but if the author merges, they will go to main trunk (master). For now, both the branches are compared against each other and names of the changed files are displayed to the user. The user can download both the repositories and do a manual merge and submit the updated repository. Going forward, DVC4CCM will provide auto merge feature and present merge conflicts to user.

VI. Summary and Future Work

The aim of this project is to create a change management system which reduces the amount of effort needed by educators to build course materials. This system helps educators share their course materials with other educators. Similar to open source software development, educators can also participate in collaborative course development which ultimately results in better course materials. The approach is to provide a tool (DVC4CCM) that hides the complexity of DVCS from curriculum authors and adopters, and to enforce workflows to enable an innovative yet managed curricular evolution process.

There is significant work required to evolve this approach. Study of existing curricular development processes needs to be expanded, and perhaps include textbook publishing processes. The initial analysis and definition of our customized workflow should be re-evaluated in light of additional study, and data collected on the utility of the workflow in managing curricular change. The tool requires refinement and evolution based on end user study. In short, as Norvig stated, the engineering of a curricular content management solution is required, and as in software, is a process that requires maintenance and evolution.

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Coexistence of Cloud Technology and IT Infrastructure in Higher Education

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***Abstract*—Early 2012 Luleå University of Technology started a project on adopting cloud technology for implementation in the university's IT-infrastructure. This work-in-progress article describes the results of its pre-study phase aiming at understanding the feasibility of integrating and/or migrating main IT-infrastructure components into an IaaS system and opening ways for making university's resources more accessible to a wider public. Numbers of logistical, technical and education related challenges make such transition far from being trivial. The article focuses on the educational aspect of the pre-study. Specifically, work flows in education process of several courses in different disciplines in natural and engineering sciences were analyzed from the student and teacher perspectives. In the article a schematic of a sustainable IT infrastructure adjusted to the needs of higher education will be drafted. Further, technical readiness and challenges of using cloud technology for university scale IT-infrastructure are discussed.**

I. Introduction

Most of the current IT-infrastructures at Universities were designed and deployed at times of mostly campus-based education, following the "One-Solution- Fits-All" approach. Nowadays, with the growing number of courses given on distance and unique requirements on software content in almost every course in all disciplines the existing infrastructure became extremely stiff and inefficient. In many cases it fails providing flexible services with an acceptable quality both to teachers and students. Another problem appears with the all growing mobility of students: The uncertainty in number of students to be handled in each semester (even in the scope of a particular course) makes it difficult for the IT departments to estimate the need and to correspondingly dimension the IT-system. Normally, university's IT administrations over-dimension their infrastructures in order to stay competitive and provide a satisfactory quality of experience. This obviously leads to an increased cost associated with purchasing and maintaining the equipment. Besides the economical component the environmental impact becomes one of the critical factors that universities have to deal with nowadays. Universities as governmental organizations need to take environmental considerations into account when implementing European Union policies on ICT sustainability. Cloud technology and specifically the infrastructure as a service (IaaS) modality is an excellent alternative to an outdated and inefficient local infrastructures.

For Luleå Technical University (LTU [1]) with seventeen thousand students and four thousand stuff members the demand on the functional IT infrastructure is high. LTU is located in five geographically distributed campus areas, with each campus having both a general purpose and a specialized computer set-ups. Besides the standard set of applications as in a general purpose PC, the PC's in specialized labs have extra hardware and/or software depending on the course requirements. Currently more than four hundred different applications has to coexist in different configurations in order to satisfy students' needs and teachers' requirements on educational software. To ensure the compatibility of applications the requirements are collected by IT administration one semester before the course start, the compatibility is tested and custom installation images are created. Before the start of a new semester the customized images are deployed. To preserve the usability of the PC labs for students and teachers the deployment usually takes place during weekends and nights. Overall this process is expensive and not flexibility for teachers and students.

[1] http://www.ltu.se

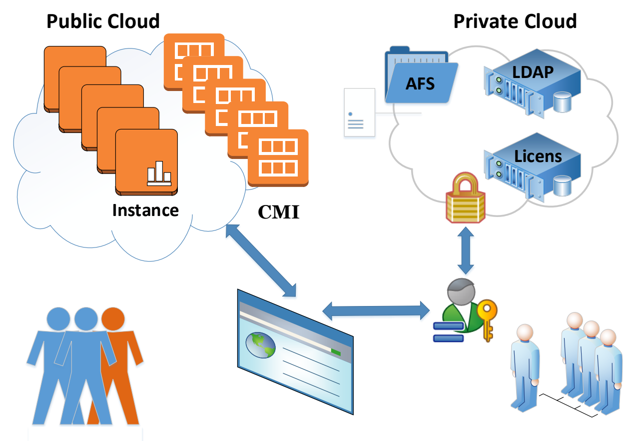

Fig. 1. Envisioned future infrastructure for higher education.

While the idea of using cloud technology in education is not new [1], the related existing work is often limited to courses related to cloud computing [2], [3] or e-Education [4] including the well-known success story of EdX [5]. Compared to other works on *education in the cloud* we address the needs for flexible IT infrastructure from the teachers, students and IT administrators perspective.

The on-going project on adopting the cloud technology for implementing the IT-infrastructure at LTU has the following objectives:

a) Students should be able access computing resources from anywhere, any time;
b) Students should be able to customize the working environment using administrator rights;
c) Teachers should be able to influence the setup of the computing resources both before and after the course start;
d) The solution should be scalable and energy efficient;
e) The solution should minimize the human resources needed to deploy, set up and maintain the IT platform for the course.

This work-in-progress article describes the results of the pre-study phase of the project aiming at understanding the feasibility of integrating and/or migrating the main IT infrastructure components to the cloud as well as drafting the initial design of the architecture.

II. Vision of a Sustainable ITS

In order to increase the flexibility of the IT infrastructure both for teachers and students we envision a scenario where each course with standard hardware requirements owns a unique software solution in a form of a dedicated virtual machine image. Further we refer this dedicated virtual machine image as course virtual image or *CVI*. This image can be started as an instance in the cloud environment or downloaded for usage on a local computer with an available virtualization software, for example such as Virtual Box [6] or VMware [7].

Figure 1 depicts the envisioned *"one-course-one-CVI"* scenario. The infrastructure is a hybrid cloud solution where the private cloud is maintained on the local IT infrastructure and the public cloud is outsourced to an infrastructure as a service (IaaS) provider. The private cloud contains services for student authentication (LDAP [8]), application licensing service (License), and distributed files system (AFS [9]). On the public cloud the course's specific CVI's are stored and run by students or staff. Students access the pre-deployed CVI from the course web page, by choosing either to launch an instance or download the image for local usage. The students' global home directory is added as a network-mapped drive to the instance. Therefore, students can store their files across all CVIs. After the CVI started, students gain administrator rights on the instance and are able to further configure it and install additional software. When students log out, the instance is stopped and resources are not wasted unnecessary.

III. Improved Process of Managing ITS resources

The current process of deploying software needed for courses is challenging. The IT service collects teachers request for the course specific software one semester in advance. The software is installed and the interoperability is tested in a dedicated testbed. The ITS personnel needs to have a deep expertise in all the deployed software to test the functionality. whenever changes in the software are needed shortly before or during the course it becomes an expensive matter for the IT administration. We advocate that this situation could be substantially improved. The envisioned future process is illustrated in Figure 2, a teacher makes a request to the local IT administrator specifying course computational need including

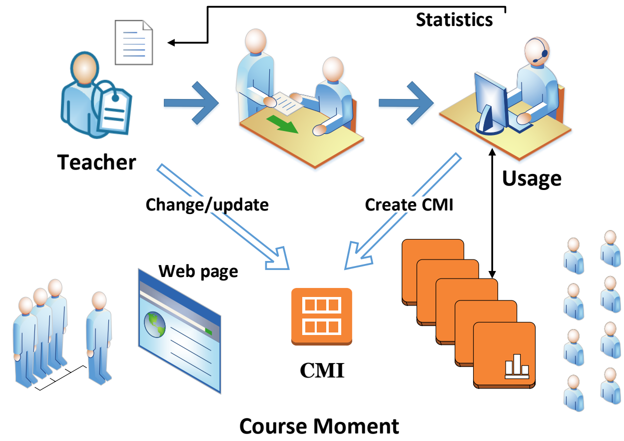

Fig. 2. A process for the creation of course CMI in the Clouds Infrastructure.

for the course needed software. The CVI is created by the IT administration and is deployed in the public cloud. Since none of the other courses would be affected, if needed, the teacher could further customize the CVI by herself. The access to CVI is enabled from the course's web page for the students. This approach not only makes the infrastructure easily maintainable and flexible but also removes the following human resource consuming steps:

- Tests related to software interoperability between different courses;
- Resolution of conflicts between different software;
- Deployment of the software on the physical machines;
- Management of student access rights on the lab computers.

From the teacher perspective the *"one-course-one-CVI"* approach gives valuable insights on the students' work load distribution during the course. This is achieved by monitoring the activity of instances within the particular course. As a matter of fact, the billing of the resource usage is based on the per-hour usage of the instances. Thus anonymous (no student names are connected to a particular instance) statistics are available on monthly bases from the public cloud provider which can be used to analyze the work load.

IV. Experience and Feasibility

As part of the project the IT needs of several courses were powered by Amazon Web Services cloud infrastructure [10]. Amazon AWS was selected as cloud service provider because it offered the desired programing flexibility and provided educational grants.

The feasibility testing was performed outside the current IT infrastructure. Three courses within computer science education were selected for the test group. Prior to the start of the courses a front-end was developed for generating log-in credentials associated with usage of Amazon AWS, and for managing the AWS resource usage. The CVI as created containing the necessary software for the course.

So far the teachers' and the students' experiences with the in-cloud IT infrastructure were positive. From the teachers and students perspective the biggest value was a ability to personalize the working environment as well as an ability to access courses' software at anytime from any location in a straightforward way. The IT administration of the course for the deployment of needed software was minimal. Several on-fly updates of the software were performed during the course which also required minimal effort from the IT administration. On the criticism side, the students using remote desktop often experienced lag. While the quality of experience could be to some extend improved by selecting a more computationally powerful virtual machine, the network delays were in many cases dominant.

The teachers highlighted advantages of cloud-based infrastructure in terms of a flexible software set up and prior to all an ability to deploy new version during the course's run. The CVI was updated and new version deployed in a matter of ten minutes. Additionally, the transition was transparent to the students without disturbing the learning process.

After a week of usage we could notice that students were not properly turning off the instances and they were left running during long time periods. Therefore an application for an individual resource usage monitoring and automating the process of stopping the instances was developed. Even though this costs additional work for the IT administrators, once deployed this add-on did not require additional maintenance. It also became clear that providing valuable statistics of resource usage to the teacher was not a trivial task and required development of customized tools.

V. Challenges and Future Work

The benefits of using cloud infrastructure in higher education are evident, the important ones are: extreme flexibility when setting up the course software, the course can be given to any number of students, the course's software is accessible from anywhere either online or locally. Numbers of logistical, technical and education-related challenges make, however, such transition far from being trivial. To the best of our knowledge there is no user and cloud management application for the integrated environment of the hybrid cloud together with LDAP, AFS and Licensing services. Such application, nevertheless, is feasible to develop on-cite. One of the next steps in the project is an investigation of economical cost for such development.

The most challenging aspect to overcome when adopting the cloud-based IT infrastructure for education is legal issues. Firstly, licensing of software used in the courses is vendor specific. While some software vendors use per-user licensing, other require users to be located on campus which makes the situation problematic. Secondly, the legal aspects related to privacy and national education laws and regulations are not obvious to resolve when matter comes to deploying the educational infrastructure to as hybrid cloud. While there are many studies about privacy in the cloud (see also references therein) our proposed solution overcomes many of them because student identification, authentication as well as their private files are stored in local infrastructure. We, however, foresee a substantial work load on the legal department in order to determine the appropriate setup.

So far we are optimistic that the benefits provided by our "one-course-one-CVI" vision outweighs the legal and logistical challenges. The next step in our work will be to make economical and legal analysis of the project as well as to deploy a pilot setup and to evaluate students' experience on a bigger scale.

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Who else could participate in my Lesson Plans?

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***Abstract*—This paper introduces the iTEC SDE (Scenario Development Environment), a recommendation system to assist teachers in the creation of lesson plans. A key functionality of the SDE is the recommendation of people. Basically, taking into account new pedagogical approaches, this system manages information about potential lesson plan contributors and provides recommendations on the best available people to participate in specific learning activities. The SDE has been developed as a multi-criteria recommender focused on supporting learning activities in particular technological and educational contexts. In this way, it manages information about the devices and applications available in the classroom and the features of the students, such as educational level, language, age, location, etc. The final goal of this system is to support teachers creating lesson plans in which they can develop new pedagogical approaches involving new technologies and external resources, such as people from outside the school. Eventually, this will contribute to engage students and improve learning.**

Keywords—Resources beyond content, Semantic technologies, Recommender systems, Semantic enrichment

I. INTRODUCTION

Designing lesson plans at different educational levels, ranging from K-12 to higher education, involves the integration of several resources intended to improve the efficiency of the learning process. Among these resources we can find traditional tools (e.g., pencil-and-paper, books, video) but also many others available as a consequence of technological progress. Thus, it is common for teachers to consider during the design of lesson plans new technological devices available in the classroom (e.g., whiteboards, tablets), online learning objects (e.g., simulators, educational multimedia materials, assignments) or just applications available online that, according to their experience, may improve communication or the overall educational experience (e.g. wikis, blogs, forums).

Traditionally, in many areas of knowledge it is common to rely on reference works (e.g., Tanenbaum's Computer Networks in the field of Computer Science, Feynman works in physics, etc.). Further away, in the new pedagogical approaches (e.g. flipping the classroom) it is also becoming usual the involvement of external people and experts in educational activities. The global interconnectedness that the Net presently offers greatly facilitates access both to these reference works created by experts and to the experts themselves. In some areas, it is customary to include in learning activities conferences and seminars taught by academics from other institutions or industry professionals. This practice is certainly more common at higher education, however it can also occurs in elementary and secondary education. For example, K-12 student parents could be requested to participate in their children classroom activities, the police chief may visit a school to talk about drivers' education, or a doctor can be invited to virtually promote healthy lifestyle.

Currently, while there are many solutions to assist teachers in discovering digital learning objects, or even learning tools, to be included in lesson plans, these solutions are not so popular when trying to identify people who may contribute to our lectures to enhance the learning process. Moreover, traditional online search engines are not specifically designed to find people, let alone to identify people who fit a specific educational setting in a particular context (e.g., geographical proximity, language, expertise, whether they are available for online interaction, or their seasonal availability). In this paper we present a system for locating, among other resources, people who can make an effective contribution to particular learning activites. Our proposal integrates a recommendation system based on the characterization of a learning activity and the specific context in which it is developed to identify potential candidates to participate in it. The recommender system uses existing people directories as an initial source of information on which semi-automatic enrichment procedures are applied to complete the available information with data relevant from an educational point of view that is still missing. It also includes a mechanism to capture information from publicly available online sources to populate the initial database with additional individuals who may provide relevant educational contributions.

The rest of this paper is organised as follows. Next section, Section II, introduces the SDE, our recommendation system, and the context in which this recommender has been developed. Then, Section III describes the Semantic Model used to represent the information available in its Knowledge Base, including descriptions of people, which are enriched from data of external sources, as shown in Section IV. Section V explains the recommendation functionality and the algorithms used in the SDE. The paper finishes presenting the first results of its application in practice in Section VI and some conclusions in Section VII.

II. SDE: SCENARIO DEVELOPMENT ENVIRONMENT

The European Commision's FP7 iTEC project (Innovative Technologies for an Engaging Classroom) [1] is intended to provide answers to a common situation in European schools: in spite of having more and more sophisticated tools available (e.g. interactive blackboards, last generation learning management systems, collaborative tools, advanced mobile terminals), mainstream education practice has not evolved yet to be able to take the most of these new resources. iTEC aims to provide

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solutions to this situation by developing engaging scenarios for learning. For this purpose, it declares as one of its main commitments “to build a prototype assistant for advising users on how to find, select and combine resources to support learning plans”.

The iTEC SDE (Scenario Development Environment) is a key element to fulfil such iTEC objective. It is a software agent (used from the user interface provided by a tool called Composer [2], aimed to allow teachers to make up lesson plans from learning activities) that provides recommendations on different types of resources (i.e. applications, devices, people, and events) taking into account the specific requirements of the learning activities, together with any other information.

The SDE has been designed as a Knowledge Based System (KBS), i.e. a system based on Knowledge Technologies that uses Artificial Intelligence-related techniques in problem-solving processes to support human decision-making, learning and action [3]. These systems include a repository, the Knowledge Base (KB), that stores the knowledge of the domain experts using some kind of knowledge representation mechanism (in our case, OWL [4] to represent ontologies, RDF [5] to store actual facts and SWRL [6] to register logic rules). When constructing a KBS, the correct design and characterization of the underlying semantic model is at least as important as the development of its functional components and subsystems. For this reason, existing methodologies for the development of traditional software systems such as the Software Development Unified Process [7], Scrum [8] or Extreme Programming [9] are insufficient to guide developers throughout the different stages of the construction of KBS systems. Indeed, we propose an approach that combines both Software Engineering and Knowledge Engineering techniques, previously used successfully in other projects [10] [11]. More specifically, we follow guidelines from the Unified Process for the design and development of software components and an approach close to the principles of Methontology [12], including relevant aspects of UPON [13] and DILIGENT [14], for the design of the Knowledge Base.

The SDE relies on data from existing iTEC registries [15], namely People & Events Directory, iTEC Widget Store and iTEC Composer (cf. Figure 1). This information is periodically harvested from different JSON endpoints (REST like services) and transformed according to the designed Semantic Model (which is described in the next section). Besides, the introduction of semantic technologies at the core of the SDE facilitates the integration of data from other external sources. These sources, that can expose its data in heterogeneous formats (e.g. RDF, HTML, HTML+Microformats), are used to complement the information available or to enrich the resource descriptions stored in the registries. Examples of these sources are DBPedia [16], Google Scholar [17], LinkedIn [18], etc.

III. The Semantic Model

To develop a KBS it is needed to define a proper semantic model that collect the conceptual and heuristic knowledge in the domain (Universe of Discourse). This model serves as a foundation to explicitly describe, in a way that software application can process, all the information elements involved in the system.

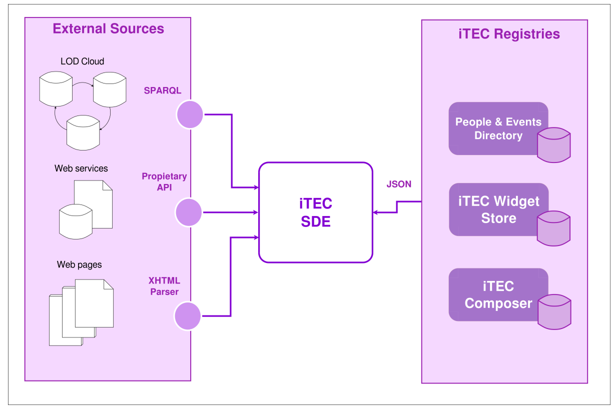

Figure 1. iTEC SDE Data Sources. Communications diagram

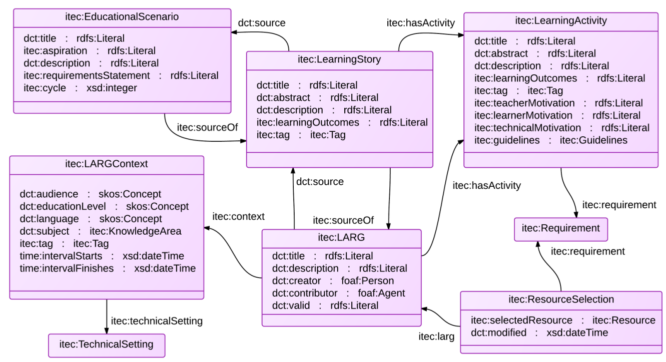

Figure 2. iTEC SDE Semantic Model. Partial view of the base classes

Our Semantic Model is composed of both an ontology, identifying all relevant terms needed to describe the existing conceptual elements and their relations (cf. Figure 2), and a set of inference rules to capture the existing heuristic knowledge that cannot be expressed using Description Logic formalisms. This model, together with the information gathered by the system from existing databases and external data sources, configures the Knowledge Base of the SDE.

As shown in Figure 2, in iTEC, the starting element for lesson plan designs are the Educational Scenarios (ESs). An ES describes a specific educational practice where activities are developed using some resources and technological elements. In some cases, the activities require the participation of specific people. The most relevant component of a scenario is its narrative part, where a real educational case is represented including real students and teachers, specific resources, etc. A typical example may be as follows [19]:

“I am a science teacher who wants to combine elements of formative and summative assessment to enhance my teaching and my students’ learning. First of all I choose a topic from the curriculum and I prepare a test to assess my students’ understanding and knowledge of this topic using a classroom response system. With this information I begin to develop a class wiki with headings based on the outcomes of my students’ knowledge and the areas that they are struggling with. Students are organised into teams (mixed or similar ability or a combination of both) and must complete assigned sections of the wiki based on the data from the classroom response assessment and other observations and evaluations I have made during the teaching of this topic and class. In the next lesson the class build the wiki using the headings as a framework, carrying out research, and using the web and other traditional resources like textbooks."

The next abstraction level includes the Learning Stories (LSs) and their main building blocks, namely Learning Activities (LAs). A LS is a narrative description of a learning proposal that is more concrete than a scenario and is more helpful to teachers when designing their lesson plans. It can be seen as the generalization of a scenario and it shows how several generic LAs may be combined to construct a consistent lesson plan. In turn, LAs can be seen as building blocks to be included in several LSs. Each LA includes information on educational objectives, motivation for the involved actors (e.g., students and teachers), proposals on technology usage, and recommendations on resources to use, indicating when resources are required, desirable or just recommended. Resources may be described either as actual specific resources (e.g., Skype, a Photo Camera) or as a collection of open requirements that may be satisfied by several resources (e.g., a synchronous communication tool, an expert on the topic covered in class that is online available). They also include teacher guides detailing how the LA should be implemented in a specific classroom (e.g., time needed, introduction, preparation, evaluation and assessment) and how to adapt the material to a specific course.

LSs and LAs are the foundation of LARG (Learning Activities Resource Guide) specifications. Teachers can customize the initial LAs and LSs introducing locally available resources to fulfil pending requirements. Moreover, they must define a particular learning context where this LARG will be deployed. This element, named LARG Context, includes both educational elements (such as the language used for teaching/learning, the particular topic/s covered in the LA, or the learner's age range) and other elements such as the tools available in the classroom (Technical Setting) or the place and the dates on which the activities occurs. Hopefully, the final outcome (i.e., the LARG) will be detailed enough to be directly implemented, and open enough to be easily adapted to different classroom settings.

The Semantic Model includes, also, the modelling artifacts to describe resources. Regarding the people modelling (cf. Figure 3), our Semantic Model reuses widely used specifications as FOAF [20] or VCard [21] and add new relationships to take into account the particularities of the project. For example, we define properties to store the person's expertise (which which can be numerically graded) and their language skills.

IV. The Knowledge Base

The people recommendation functionalities provided by the SDE depend, to a long extend, on the information available in the Knowledge Base about potential contributors to the LAs. Basically, the more comprehensive the information is the better and more accurate recommendations will be provided. Therefore, it is a key issue to have as many potential contributors as possible, and as much information about each one of the contributors.

In the context of the iTEC project, the project partners are providing the information about potential contributors through

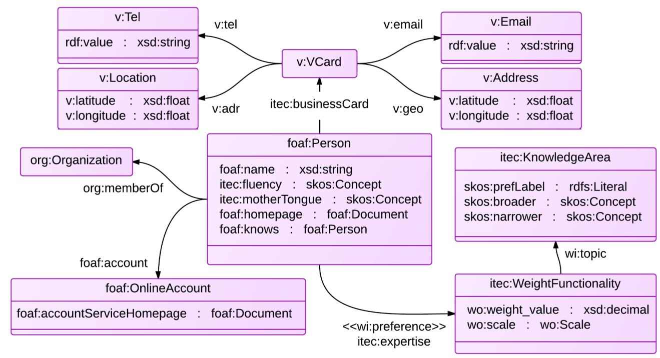

Figure 3. iTEC SDE Semantic Model. Partial view of the $Person$ class

the iTEC People & Events Directory [22]. This system is the main data source for people information in the SDE Knowledge Base and it allows to register information manually. However, it presents some drawbacks. On the one hand, this is a way to register the information, but it is a hard work and not easily sustainable. On the other hand, in practice, the information registered is not complete and further information about user skills, competences and expertise is usually missed. In order to reduce these disadvantages, we have designed a method to improve the information. Based on the Web 2.0 principles, many Web sites, social networks and applications maintain large amounts of information about people on the Internet [23]. Many times this information is freely available and reusable. Therefore, it is feasible to collect this information in a semi-automatic way and to get new data to enrich the records about potential contributors available in the Knowledge Base. This process is known as semantic enrichment [24].

A. Semantic Enrichment

We can find in the literature some experiences on the location of experts according to the information available on the Web (e.g., [23], [25]). These systems rely on information extraction techniques [26] applied to several types of information sources. The process of detecting whether two different records in two different sources deal with the same real-world object, the same individual in this case, is specially relevant in our context. This process is known as Record Linkage, and it corresponds to the foundation of the proposed enrichment algorithm.

According to our interests, available sources can be classified into semantic and non-semantic sources. Semantic sources express hosted information in a "machine-interpretable" way (i.e., they express information according to a Knowledge Representation language), like the nodes of the Linked Open Data (LOD) Initiative network [27]. These sources support information enrichment in a direct way, as fetched data don't require to be converted into RDF. Besides, there are tools available (e.g., SILK [28]) that support the automation of record linkage processes. Regretfully, LOD doesn't include all information required to enrich experts [25]. In these cases, we will have to extract information from non-semantic sources, that is, sources hosting information not expressed in a knowledge representation language, but according to another popular representation languages (e.g., HTML, XML, SQL, etc.). These sources are fairly abundant, and include rich and detailed information. To extract information from these sources, a wrapper has to be developed [26]. A wrapper is an information extraction agent that fetches unstructured pieces of data and transforms them into structured information (i.e., RDF in our case). The design complexity of these wrappers and its reliability and soundness is eventually determined by how the original information is structured [29]. For example, data expressed in XML require less complex wrappers than data expressed in HTML.

B. Enrichment experiencies

To enrich available information on experts at the iTEC People & Events directory, a collection of agents has been developed to inspect several semantic and non-semantic sources. These wrappers were specifically aimed to enrich properties used by the recommendation algorithm (cf. Section V). In this case, the main factor to determine whether an experts fits a given educational activity is his or her expertise. Typically, an indication of the expertise of individuals is provided by their scientific publications [25]. Therefore, the most relevant sources for the pursued enrichment process are those sources that provide information on academic publications in an accessible way. In any case, the recommendation algorithm will compute final rankings according to additional relevant factors, like languages spoken, location, contact details, etc. This latter information may be extracted from social platforms like Facebook or LinkedIn [23].

With respect to non-semantic sources, two enrichment modules have been developed that include the logic required to extract information from Google Scholar profiles (i.e., HTML-coded pieces of information) and through the LinkedIn's API (i.e., XML data). For these sources, already available search services are used to reduce the complexity of record linkage. This process is based on 1) triggering a search query using the expert's full name as registered in our knowledge base; 2) each name in the list of returned results is compared with the target name according to a Jaro syntactic matching heuristic [30]; and 3) profiles above a predefined similarity threshold (i.e., 0.96) are considered as corresponding to the target iTEC expert. This way, we are able to extract information on a given expert's academic publications and his or her co-authors, interests, skills, languages, location, etc.

To process semantic sources, an enrichment module has been developed that performs information retrieval on a collection of LOD nodes using the SILK tool, which has been conveniently configured according to our interests, that is, it will fetch information about real people (i.e., foaf:Person and akt:Person properties), having a name (i.e., foaf:name y akt:full-name properties) that is conveniently similar to the iTEC experts' name according to the Jaro matching heuristic (i.e. similarity threshold of 0.96). The analyzed repositories (e.g., DBLP) provide diverse information on each expert, including his or her scientific publications.

C. Enrichment results

Most of the information extracted through the enrichment process can be directly adapted to the iTEC data model to be inserted in the Knowledge Base. This is the case of properties like languages, online contact details, or experts' location. However, other factors are fairly complex to adapt and require further processing prior to their insertion in the Knowledge Base. The most apparent case corresponds to the locally defined expertises according to a pre-defined vocabulary including 37 knowledge areas. Several concepts defining skills and knowledge obtained through enrichment do not fit to any actual scheme. To infer iTEC expertises from these heterogeneous concepts we rely on the ample hierarchical scheme of universal concepts available at DBPedia. In a nutshell, for each retrieved knowledge area, 1) the homologous entity in DBPedia is obtained using SILK; 2) once detected, we seek among the parent and children concepts a concept referencing an expertise collected in the iTEC vocabulary, at a distance of no more than five hops; and 3) if such a concept is found, we infer that the target expert do have the expertise corresponding to the iTEC's knowledge area.

As the information extraction process can be automatically and periodically executed [26], enrichment enables us to periodically update available information on each iTEC expert. This way, information available on experts evolves in sync with the actual evolution of experts' experience and skills [25]. Besides, this approach also enables the enrichment of the experts directory by including experts in the analyzed online information sources that were not initially considered. However, only co-author information is used to locate additional experts. This way, enrollment of new experts is kept under control, as we know for sure that new experts will at least share some expertise with existing experts, and they will have already collaborated with existing experts in the past. We understand that profiles satisfying these criteria would be more prone to be involved in iTEC's Learning Activities.

V. A RECOMMENDER SYSTEM FOR PEOPLE

Traditional recommendation systems focus on recommending the most relevant items to users. Moreover, they usually consider a single attribute of a given item. These systems define an utility function based on a two-dimensional model: $Items$ and $Users$ [31]. More recently, Context-Aware Recommendation Systems (CARS) deal with modelling and predicting users' tastes and preferences incorporating available contextual information into the recommendation process as explicit data categories [32]. In this case, they use a three-dimensional approach (i.e. $Items \times Users \times Context$) or even a multi-dimensional model considering different contextual information as additional dimensions (e.g. Location, Time). [33] identifies relevant context dimensions for TEL applications and analyse existing TEL recommender systems along these dimensions.

A main difference in the iTEC SDE is that the user asking for the recommendations (i.e. the teacher that creates the lesson plan) is not the main role in the recommendation. The leading role is played by the learning context. The particular users' characteristics are shifted to the background and are used just to improve the characterization of the learning context, but the key issues to take into account in the recommendations are the features of the classroom, the learners and the Learning Activities themselves. Nevertheless, as discussed before, our recommender system focuses, among others, on recommendations about people. Thus, our recommender system has an utility function defined as:

$$u : People \times (LAs + Context) \rightarrow Rating \tag{1}$$

Therefore, the recommender considers the characteristics of individuals, the collection of predefined requirements defined for activities, and also the corresponding learning context where these activities will take place. Taking this information into account, the system analyses the data in its Knowledge Base to produce sorted lists of the individuals potentially more suitable to that particular situation. This process is organized into three phases:

1) Pre-processing: input data are processed, particularly learning activity requirements and LARG Context, to create a formal description of extended requirements taking into account the needs of the activities and the realization context.
2) Filtering: a set of SPARQL queries is composed using the extended requirements mentioned above. This query is sent to the Knowledge Base to fetch a list of potentially valid individuals to execute the activities.
3) Relevance calculation (sorting): in order to sort individuals in the list, the recommender computes an estimated relevance value for each of them. Next subsection explores the algorithm.

A. Relevance algorithm

The SDE semantic model includes a large number of properties. Taking into account the complexity of people descriptions (cf. Figure 3) and both the number and the heterogeneous nature of the variables included in LARG Context, our recommender system was developed according to the guidelines of Multiple Criteria Decision Analysis (MCDA) [34]. More specifically, as proposed in [35] or [36], we treat the recommendation problem as a multicriteria decision problem to model this class of problems. Thus, we use an utility function which combines several rating factors to reduce multiple-criteria recommendation problem to a single-criterion one.

The approach adopted (proposed in [34]) identifies four steps to implement the decisor: (1) definition of the Object of Decision, (2) criteria modelling, (3) global preference model and (4) decision support process. The three first steps are devoted to analysing the system in order to identify which are the best methods to be applied in each level. The four step is devoted to selecting specific implementation mechanisms according the previous analysis. We summarize below the results of the three first steps:

1) Definition of the Object of Decision: our recommender purpose is to produce sorted list including potential candidates to participate in a lesson plan. Thus, the object of decision is choice (to select the most appropriate elements) and specially ranking (to sort them according to their appropriateness).
2) Criteria modelling: we need to identify a family of criteria that enables the comparison of different candidates according to several points of view. In this case, we define a consistent family of both measurable and ordinal criteria that takes into consideration most relevant properties (included in the semantic model) to distinguish individuals to participate in a lesson plan. More specifically, we defined nine different criteria. According to each particularities we used different value assignment strategies to create its marginal utility functions, always using the interval $[0, 10]$ as general evaluation scale. Besides, to avoid penalizing some individuals against others for the lack of information, we will assign a neutral value ($c = 5$) when there is no information. Using these value assignment strategies and normalizing values for each criteria, we obtain the marginal utility functions for each factor. Table I describes each of the factors and the used strategies.
3) Global preference model: this stage is devoted to developing a strategy to aggregate the different criteria to express the preferences among several alternatives in the potential candidates set. In this case, we use an Multi-attribute utility approach, i.e. we built a value system to aggregate preferences for each criterion and, after that, we aggregate these marginal preferences into a single utility function. More specifically, we define the general utility function (u) as the weighted sum of the marginal utility functions of each criterion (f_i). According this, the total rating of an individual p, is computed from the general utility function of that person:

$$R(p) = \sum_{n} w_i * f_i(p) \tag{2}$$

where n is the number of criteria and w_i the weight assigned to i's utility function. Values of w_i are set taking into account the ratings assigned by a group of experts with both pedagogical and technological expertise (iTEC Control Boards). Table II summarizes these values.

Table II. FAMILY CRITERIA

Criteria	$\overline{w_{c_{f_l}}}$
Language	7.87
Expertise	7.78
Experience	7.17
Communication facilities	6.87
Personal relations - Trust	6.48
Organization	5.78
Rating	5.70
Location	5.30
Personal relations - Knows	4.96

VI. PRELIMINARY RESULTS

The recommender system implementing enrichment and recommendation strategies proposed in this paper has been tested in the framework of iTEC workshops through a friendly testing prototype (cf. Figure 4) [37]. This UI allows to select and to combine different predefined Learning Activities and LARG Context's variables in order to obtain best recommendations on people. In this situation, most of partners in iTEC pedagogical work packages consider that recommender has the potential to lead innovation in the classroom.

Table I. PEOPLE CRITERIA

Criteria	Description
Communication facilities	This criteria takes into account the communication tools that a person participating in a learning activity has available. Thus, this criterion prioritizes individuals whose communication channels belongs to the specified set of tools available in the LARG. According to this, it will take value $c = 1$ when none of the individual's communication channels match some of the tools included in the specified Technical Setting; and $c = 10$ when some of the individual's communication channels belong to the activity's Technical Setting.
Experience	This criteria considers the previous experience of a person, according to the learning activities performed by this person. Its aim is to prioritize people who have already contributed to some of the learning activities in the LARG. Thus, it will take value $c = 10$ when the person has already performed some of the learning activities; and $c = 1$ when this fact is not explicitly stated.
Expertise	Expertise of a person in a given subject. It should be noted that according to the semantic model, expertise is measured on a scale (including in the interval $[0, 10]$). Thus, the value assigned according this criterion is computed as the arithmetic average of the expertise measures (levels) of the individual has for each of the subjects specified in the educational context.
Language	This criteria is intended to prioritize people having as their mother tongue the languages in which an learning activity is developed. In this case, value $c = 1$ will be assigned when there is information about the individual's mother tongue(s) but none of them is specified by the requirement; and $c = 10$ when some of the mother tongues matches at least one of the activity languages.
Location	This criteria indicates the degree of geographical proximity of the person to the location of learning activities occurs. It should be noted that this factor will not be taken into account for people acting as online collaborators in a LARG. It will take value $c = 1$ when the distance between the person and the learning activities' location is larger than a predefined threshold distance; and $5 \leq c \leq 10$ when the distance is smaller than this threshold. In this case, concrete value will be assigned using the equation 3. $$10 - (distance/threshold) * 5 \quad (3)$$
Organization	This criteria is intended to prioritize people belonging to the same organization as the LARG's creator. Thus, it will take value $c = 1$ when the person belongs to a different organization; and $c = 10$ when both the person and the LARG's creator belong to the same organization.
Personal relations - Knows	Similar to trust factor, it considers existing relations between the LARG's creator and the potential candidates to participate in a learning activity. It will take value $c = 10$ for people known by the LARG's creator; and value $c = 1$ otherwise.
Personal relations - Trust	Indicates the degree of trust that the community, as a whole, has in the person to be selected. The associated value is aimed at quantifying the reliability of a person according to the trust relations provided by the user community. As this property has a binary value, it will be computed as a quotient between the number of people who rely on the individual and the total number of people in the community.
Rating	Indicates the degree of popularity of a person in the community. The associated value may be obtained from community ratings, typically using an arithmetic average.

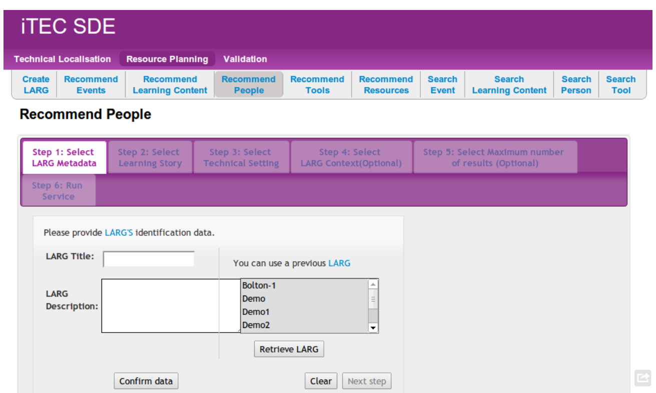

Figure 4. iTEC SDE Testing Prototype

In this first experiment, we have successfully enriched the descriptions of the 46% of the people initially available on the Knowledge Base (extracted from the CEN LTSO [38] experts directory). Among the most important enriched properties we can mention: about 1500 potential expertise properties were added (although most of them could not be directly related to the iTEC Knowledge Area vocabulary terms), 81 online accounts were included (through which it is possible to contact the experts), 56 profiles were complemented with information about its location, 50 new spoken languages were found, and 316 knows properties among people were set. In absolute terms, about 130,783 triples were extracted from external web sources.

VII. CONCLUSIONS

The authoring of quality lesson plans is not an easy endeavour for teachers. Mainly, when lesson plans are required to adopt new pedagogical approaches and to include new technologies or other resources different from the traditional ones. This requires not just to be able to define the several activities to be carried out, but to know about the more suitable tools and to get in contact with suitable people that could provide a positive contribution to the activity. The iTEC project is intended to facilitate this endeavour and the iTEC SDE is called to play a key role on it by providing recommendations to teachers that assist them in the assembling of activities and resources in lesson plans.

The literature about recommender systems in e-learning includes several developments. Nevertheless, to the best of our knowledge, there is neither any approach taking the learning activities and context as the reference element to provide the recommendations, nor people has been considered as a learning resource to be recommended. Therefore, we have been experiencing different problems. Some of them are directly related to the end user (e.g. usability, user feedback). Other problems are related to the availability of the information needed to provide the recommendations. In this paper we have shown the key ideas underlying the SDE development and some of the solutions we have been exploring to solve the lack of information issues. At this point, semantic technologies and Web information can provide a good solution to support the operation of the system in a large scale and in a sustainable way.

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Should Makers Be the Engineers of the Future?

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Abstract - **Engineers participate in the Maker movement. Some Makers do not pursue formal engineering education but both the engineering field and their own vocational advancement could readily benefit. We seek to understand Makers and how they are inclusive or exclusive of what can be expected from engineers. From the *Engineer of 2020* list of characteristics (National Academy of Engineering, 2004), we highlight *practical ingenuity*, *creativity* and *lifelong learning* for likely opportunities to leverage the Maker experience. The mission of this research is to develop a theory, inductively grounded in data and deductively built on literature, illuminating the *knowledge*, *skills*, and *attitudes* of Makers, describing their *pathways* in formal engineering education to better inform future innovations in order to improve the *practical ingenuity* and *lifelong learning* of our future engineers. Artifact elicitation interviews, based on the method of photo elicitation and critical incident technique interviews will be administered to participants. Results from the inductive and deductive analyses will be triangulated to generate a preliminary theory of Maker knowledge, skills, attitudes, and pathways. This theory, inductively grounded in data and deductively connected to literature, will describe aspects of Makers, along with how their pathways intersect with formal engineering education experiences.**

Index Terms – making; tinkering; engineering pathways; engineering education

INTRODUCITON

A Maker is an emerging colloquial term we use to describe a group of do-it-yourself-minded individuals participating in informal communities supporting building and prototyping technical proof-of-concept exploration and ad-hoc product development. A Maker is a modern-day tinkerer, hands-on doer and fashioner of stuff. The range of expertise could be large but novices and experts alike share an enthusiasm for building and creation. Individuals and groups embark on projects of all sorts, led primarily by their interests and curiosities, informed by their skills or the skills they want to learn. They show off their work readily and share their technical recipes with those interested. Ascribed directly to Make magazine and Maker Faire festivals [1], making encompasses anyone, young and old alike, that describe themselves as part of such a community. They participate in communities of practice at Maker Faire festivals. They populate community maker spaces and hacker spaces [2] and use commercial maker venues [3] to gather together.

MAKERS AND THE ENGINEER OF 2020

The elements of the *Engineer of 2020* description that resonate with Makers include practical ingenuity, creativity and lifelong learning [4]. Can a Maker be considered an engineer and vice versa? Is the Engineer of 2020 a Maker? We aim to explore the possible overlap between what we can discover about Makers and what literature describes about engineering students and practicing engineers. The *Engineer of 2020* [4] synthesizes the characteristics wanted out of the next generation of college engineering graduates: analytical skills, management, communication, creativity, dynamism/flexibility, ethical standards, leadership, lifelong learning, practical ingenuity, and professionalism.

MAKERS, MAKE MAGAZINE AND MAKER FAIRE

A Maker creates technical artifacts, personally undertaking a project often without prior expertise. The do-it-yourself ethos is historically rooted in efforts like *Popular Mechanics* magazine demystifying everyday stuff for hobbyists and the *Whole Earth Catalog* [5] surveyed everyday tools for the counterculture movement of the 1960s. Additional real-world touchstones are the growth of Radio Shack stores and the television program MacGyver. Technology and sharing of information has greatly increased the ability for smaller communities with shared interests to coalesce and grow.The label Maker is a self-determined one assigned by affinity or involvement in a larger making community. *Make* magazine was founded in 2006 as a quarterly publication and presents "DIY Projects, Inspiration, How-tos, Hacks, Mods & More" [7]. It has published more than 30 issues and has a circulation of 300,000. *Make* is a central participant in championing making, described as "a central organ of the maker movement" ("More than just digital quilting," [8]. Maker Faire has been an outreach effort of *Make* magazine, convening flagship, multi-day fair events in select cities and supporting smaller, regional one-day events around the country. Its credo is to "celebrate arts, crafts, engineering, science projects and the DIY mindset" [7]. Cross-disciplinary workshops for informal science and engineering educators and academics and teachers have been held [1]. Topics of discussion included creativity informing K-12 education, inspiration to STEM learning and collaborations between Makers and teachers, academics and informal science community members. Different intellectual communities have focused on different aspects one can relate to making. The human-computer interaction field has

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studied hacking and tinkering in the context of DIY and tools and practices [9,10] design research, ad-hoc prototyping and tinkering using local objects [11]. Flexible space for activity are growing in popularity at hacker spaces [2] and maker spaces in academia [12,13] and fab labs [14].

RESEARCH QUESTIONS

The constructivist grounded theory research questions are:

RQ1. *What knowledge, skills, & attitudes do Makers possess that could be related to engineering?* (Makers as engineers)

RQ2. *How do pathways of Makers intersect with engineering?* (Makers' pathways to engineering)

RESEARCH METHODS

Population and Sampling: This study samples the population of adult Makers in order to understand how their paths intersect with formal engineering education. Exhibitors at flagship Maker Faires are being recruited to create a pool of potential participants. To answer the research questions about Makers, a stratified purposeful sampling strategy [15] is being used for initial selection of the participants. Participants will be selected to maximize variation across the target strata, while oversampling for underrepresented groups and ensuring that all participants self-identify as Makers. Makers who have a formal engineering education degree will provide insight into how formal engineering education has helped them in their who have chosen pathway. Makers who have informal engineering education experience will provide breadth to the study and illuminate how informal education experiences influence engineering pathways and career choices. Following analysis of data from an initial group of participants, a Preliminary Theory is being developed and theoretical sampling done "on the basis of the emerging concepts, with the aim being to explore the dimensional range or varied conditions along which the properties of concepts vary" [16]. Theoretical sampling will strengthen the theory by purposeful selection of participants.

Screening Questionnaire: Potential participants are being asked to complete a short online screening questionnaire. The questionnaire consists of multiple choice and short answer questions check for self-identification as a maker, collect age, demographic, and years as a Maker data, determine if potential participants have formal or informal engineering education experience, and determine if potential participants have an engineering-related career or hobby. Results from the questionnaire have been used to select initial participants. A first set of study participants were recruited and interviewed in September 2012.

Artifact Elicitation Interviews: A semi-structured artifact elicitation interview [17] is conducted in person (and continued via Skype if necessary) to examine the knowledge and skills a Maker develops as a result of making creations, and the attitudes they have about making, engineering, and their careers. The interview relies on a physical artifact/creation that the Maker has created. Further questions also rely on references to the artifact to elicit "thick description" [18]. Artifact elicitation interviews extend the qualitative inquiry approach of photo elicitation [19, 17, 20, 21], where interviews that rely on photos "evoke information, feelings, and memories that are due to the photograph's particular form of representation" [17] and stimulate "latent memory, reducing areas of misunderstanding, eliciting longer and more comprehensive accounts of ideas... eliciting values and beliefs, and connecting to core definitions of the self to society, culture, and history" [22]. In addition, photo elicitation method has been used successfully in engineering education [22,23,24] and other STEM disciplines as both a research and pedagogical method. Artifacts created by Makers are similar to photos in the sense that they embody the knowledge, skills, and attitudes that Makers hold, making artifact elicitation appropriate to study the concepts in RQ1.

Constructivist Critical Incident Technique Interviews: A semi-structured constructivist critical incident technique interview [25,26,27] has been conducted in person (and continued via Skype if necessary) to examine the educational and career pathways of Makers and how they intersect with formal engineering education and careers in engineering. The interview consists of questions designed to examine college and career decision points and how they relate to engineering. Interview questions in later interviews will evolve to address emergent themes discovered in interviews with earlier participants. [27] used critical incident technique interviews to study decision making in a variety of fields, and the method have been used very successfully in engineering education research [28]. This technique aligns well with RQ2 to understand decision points contributing to pathways of engineering.

Data Analysis: Interview transcriptions are currently being analyzed in parallel both inductively and deductively to generate a theory. One part of the research team is using open coding [16] and theoretical memoing [29] to conduct the constructivist grounded theory [30] inductive analysis. Sorting and theoretical coding [29] will be used to connect the resultant themes into a theory. Simultaneously, other members of the research team are deductively analyzing the data using thematic analysis [31] based on a coding scheme derived from the relevant conceptual frameworks.

PROPOSING A MAKER THEORY

The synthesized theory will identify knowledge and skills of Makers that relate to engineering, in addition to their attitudes about engineering and how their pathways have (or have not) intersected with formal engineering education. This theory will be of particular use to the engineering education community aspiring for the Engineer of 2020 and beyond. It will be useful to researchers studying pathways, student attraction and retention, and informal science and engineering education. The theory will also be transferable to other disciplines interested in attracting Makers.

This project is a work in progress. Initial date collection occurred in September 2012 at the World Maker Faire New York with 12 participants. Interviews have been transcribed and are in process of an initial parallel inductive and deductive coding. Interesting initial findings suggest the social nature of Making and presenting and sharing work in a larger community of practice. Participants are also motived by a wide range of interests exhibited beyond traditional engineering education experiences.

IMPORTANCE OF THIS WORK

Workplace Call to Action: Faced with a dynamic world of complex problems crossing disciplinary boundaries, our country needs technical and engineering talent to solve challenges, e.g., NAE Grand Challenges [32], of the future now. The talent necessary to solve these problems largely comes from a formal engineering education system challenged with producing sufficient numbers of qualified engineers. However, there are useful qualifications beyond the expectation of the traditional. Qualities like *practical ingenuity*, *creativity*, and *lifelong learning and engagement* are indispensible to the workplace.

Broadening Engineering Pathways: A more inclusive vision of engineering crossed with making could build future engineering capacity as well as raise awareness to the general public of the work and impact such work offers. While we do not equate engineering students, practicing engineers and Makers completely, possible overlaps and stories of pathways within can be transformational. Consider the benefits to STEM and resulting societal benefits for those who have influence over student decisions like teachers, school counselors, and parents to have an appreciation of the multiplicity of pathways into such careers or the value of technical literacy, both based in problem solving or making. This may be especially true for underrepresented groups.

Informed Educational Efforts: Makers create their inventions wholly out of their imaginations. Their work is done outside the confines of established engineering education curricular activities. But their commitment and engagement is something that can be better understood to advantage our teaching in the classroom. This approach also aligns with project-based learning as a teaching method in the classroom, a call made in [33]. Engaging future engineering students may mean developing curriculum and pedagogy that allows students to apply knowledge and *make.*

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Knowledge-generation epistemology and the foundations of engineering

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Abstract - **This paper suggests that the purpose (goal) and manner (method) of knowledge application and generation usefully distinguishes engineering and scientific knowledge. This method could be significantly useful in distinguishing the scientific and engineering components of engineering education, as well as underscored the centrality of social context to engineering work, and engineering values. This paper presents a brief exploration of the epistemology of knowledge, specifically distinguishing the development of scientific knowledge from the development of engineering knowledge. It outlines a pragmatic theory of knowledge which provides a means by which to reliably distinguish, particularly in a learning environment, the critical terms of 'science', 'engineering science' and 'engineering.'**

Index Terms – Philosophy of Engineering, Philosophy of Engineering Education, Epistemology.

INTRODUCTION

A cursory introduction to the literature of the philosophy of engineering reveals competing viewpoints on what distinguishes scientific from engineering knowledge, including engineering (and technology) as applied science [2] and the influence of knowledge generation as a means to distinguish between 'scientific' and 'engineering' knowledge. When seen through the lens of a pragmatic theory of knowledge, the crucial characteristics of scientific knowledge include that scientific knowledge is theory bound, and scientific knowledge is developed to explain the way the world works. [1] Engineering knowledge can be considered a distinct form of knowledge since scientific and engineering knowledge aim at different ends. In short, science aims to explain and technology/engineering aims to create artifices. "Technology, though it may *apply* science, is not the same as or entirely *applied* science" [3].

Engineers are individuals who combine knowledge of science, mathematics, and economics to solve technical problems that confront society; "… a person who applies science, mathematics, and economics to meet the needs of humankind" [5]; alternatively defined, "Engineering is the art of directing the great sources of power in nature for the use and convenience of man" [6].

Individually, engineers are those who engage in the practice of engineering. The root of the word engineer derives from engine and ingenious, both of which come from the Latin root *in generare*, meaning "to create." In early English, the verb engine meant "to contrive" or "to create." The word engineer traces to around A.D. 200, when the Christian author Tertullian described a Roman attack on the Carthaginians using a battering ram described by him as *ingenium*, an ingenious invention. Hence an engineer is a person responsible for developing such ingenious engines [of war] [5]. At their roots, engineers are problem solvers – ingenious problem solvers. Engineers create products and processes to improve and to enhance the convenience and beauty of our everyday lives [7]. Thus, engineers are civilizers, since civilization in its most elemental sense means bringing humans physically out of the state of primitive savagery [6].

Engineering knowledge is rooted in scientific knowledge; however they appear to be separate spheres of knowledge that are both man-made [8]. Historically, each engineering sub-discipline has developed its own body of knowledge, whether codified or not [9,10,11]. Among engineering educators, it is commonly accepted that engineering knowledge, however much based on the study of mathematics, science and engineering science, is insufficient. "…there is a big gap between scientific research and the engineering product which has to be bridged by the art of the engineer. The creative, constructive knowledge of the engineer is the knowledge needed to implement that art." [3]

Beyond engineering knowledge and skill, there are the behaviors that help engineers succeed, bring honor to their profession, and make technology a force for good in the world. Engineers are expected to link effectiveness and creativity, where conscientiousness is the virtue suggested to be the most valuable for engineers [6]. In sum, engineers identify problems, construct solutions, and use their knowledge and skill to change the status quo into a new situation that is better, both individually and for mankind.

The types of knowledge produced, as well as the processes by which knowledge assimilated and utilized are different among these groups of persons. Central to these sociological distinctions and their respective knowledge generation/use is the relationship of different technological disciplines to one another, and how the technological disciplines effect knowledge generation.

SCIENCE AND ENGINEERING

'Science' and 'Engineering' are broad disciplines each with long histories and significant nuances among them. The viewpoints common to each discipline are however different. The viewpoints of science and engineering are idealistic and pragmatic respectively [12].

The nature, or goal of science as a whole, is to explain how the world works, as determined through experiments and their artifacts. Knowledge generation, from the perspective of scientists is approached via creating a hypothesis first, and testing it second. These scientific findings and related technologies are often codified, and managed by a body of scientists, and transmitted through published works and education.

The nature of engineering is for addressing human needs/problems, and generally applies domain-specific heuristics for building a system, or components intended for system deployment. [13] The lessons learned and identified technologies are often (though not always) codified, and may be transmitted informally, or formally to other engineers in the form of best practices, or where applicable, via a hypothesis that generalizes the best practice and testing of that hypothesis. In either case, the more formalized engineering findings are often codified, and managed by a body of engineers, and transmitted through published works and education.

Both science and engineering involve the identification of and development of technology, and both include significant relationship to and roots in mathematics. The tested formalizations of theory, identified technology, and best practices can lead to the creation of new branches of engineering and/or science. While these processes share significant similarities, their viewpoints make them epistemologically different; the value driving scientific knowledge development is that of explanation; the value driving engineering knowledge generation is application. These differences in value change the epistemological character of the knowledge.

EPISTEMOLOGY AND KNOWLEDGE

Briefly stated epistemology is the study of knowledge as justified belief. Development in epistemology since the work of David Hume has focused on identifying the justified true belief about what a single person knows. When applied to disciplines or communities, it also includes the requirement that to qualify as knowledge, a proposition or set of propositions must be endorsed by an appropriate community. Hence, there is both an individual and a significant sociological aspect to knowledge and justified belief. Individuals produce candidate claims for knowledge, and these candidates become knowledge, once they are endorsed by the appropriate community using agreed upon standards. [1] Components of the *method of the human mind* [14] and of Polanyi's *Personal Knowledge* [16] are outlined as foundations for individual understanding, followed by an outline centered on Polanyi, Sorokin and Vanderburg for the sociological approaches to epistemology [17,18].

Individual and Communal Knowing

Lonergan argues for what we may term a "method of the human mind," consisting of *experiencing, understanding*, and *judging*, underlies all specialized forms of knowing. This basic heuristic method or structure is tailored in various ways to meet the particular requirements of specialized contexts such as everyday practical life and the fields of mathematical and empirical science. [14]

In the "method of the human mind," experiencing provides us with data and depends upon adherence to a norm of attentiveness. Our striving to make sense of the data (e.g., "What is it?), promotes us from experiencing to attempts to understand; to finding the form, pattern, meaning, or significance of what we have experienced. Inquiry and imagination yield insights, which are expressed in concepts and definitions to provide a formulation of the understanding we have attained. Inquiry, insight and formulation embody a norm of intelligence. Because understandings may be misunderstandings, we cannot stop with them but must go on to ask the critical question, "is it really so?" The process of answering this question thematizes our desire to move through critical reflection to judgment. Judging marshals and weighs the evidence to assess the adequacy of our understanding. The evidence is adequate if it shows that the conditions necessary for something's being so are all met. If the conditions are met, within this context our knowing reaches a "virtually unconditioned" state, whose conditions for justified belief are all fulfilled. Thus the understanding is no longer is conditional and until proven otherwise, rather it must be true. The norm embodied in these operations of judging is that of reasonableness. The overall method is adjusted based on the perceived need for timeliness, precision, comprehensiveness, universality, and/or completeness. [14] This is where the viewpoint of knowledge is critical, as individual need or use for the proposition and the social context affect the manner in which something is known.

Thus knowing is a process, involving both covert and overt human actions, which involve the application of personal and social criteria. These knowledge-generation actions apply to the production of scientific and technological things. Polanyi describes covert actions to include operations such as sensing, perceiving, imagining, understanding, judging, and deciding. The overt actions include operations such as speaking, writing, drawing, calculating, grasping, shaping materials, and using tools. [16]

Individual knowing is a precursor to the community endorsement necessary for knowledge and justified belief to become part of the body of accepted knowledge. Both covert and overt actions have an internal structure that Polanyi calls a *from-to* relation. A skillful achievement, whether practical or theoretical, is the *to-* term of this relation, and the subordinated particulars constitute the from term. He suggests a movement metaphor for this relation when, in discussing the *from-to* relation in acts of knowing. [16] Sociological models of the epistemological process by which we create scientific and technological products also embody a movement metaphor. As presented in Table 1, Sorokin breaks the process into three stages, which are used here as an outline of the individual + communal knowledge development process. [17] For technical development, Vanderburg proposes a "technological cycle" with five phases. [18] In both models, the movements are from each earlier stage or phase to the next one.

Table 1. Correspondences between knowledge development stages [17], and phases of technological development [18]

Sorokin (3 Stage) Model	Vanderburg (5 Phase) Technological Cycle
1. Mental Integration	1. Invention
2. Empirical Objectification	2. Innovation and Development 3. Application
3. Socialization	4. Diffusion
	5. Displacement

This movement parallels Lonergan's proposals. According to Morelli and Morelli, Lonergan similarly "identifies the scheme of recurrence which constitutes technological, economic, and political advance: *situation – insight – communication – persuasion – agreement – decision – action – new situation – insight,*" etc.[15]

Mental Integration: In defining "mental integration," Sorokin states that the "integration of two or more meanings into one system is an act of creation occurring in the human mind." [17] This treats it as a covert act "in the human mind." Vanderburg's description of "invention" includes both covert acts, covert states, and overt acts [18], although the acts of exploring and working out details are usually overt actions, including actions such as writing, calculating, sketching, building physical models, and conversing with others.

Empirical Objectification: Sorokin's characterization of empirical objectification emphasizes the need for "empirical vehicles through which [new knowledge propositions] can be conveyed to others." [17] These can be incarnated through documents, examples, products, or other means. They key point among these processes is the development and presentation to a wider (more than individual) audience.

Socialization implies that the "empirical vehicles" are utilized to share knowledge among individuals, led by agents of socialization. He adds that most of the thousands of texts and artifacts produced never succeed in socialization, in being accepted and used by anybody but their authors. [17]. The key here is that people are the agents of socialization, and socialization efforts begin early in the process and continue throughout. When the original inventor or discoverer attempts to explain his idea to another person, he is an agent of socialization. When members of an original group attempt to persuade controllers of resources to support their project, market products, etc., they are agents of socialization.

The point of these phases is to recognize that individuals produce candidate claims for knowledge, and these candidates become knowledge once they are endorsed by the appropriate community using agreed upon standards. [19] The importance of the different stages is two-fold: first to recognize the importance of the inner mental state of a single individual, and to understand the difficulties this presents with respect to the certainty with which one can assert that someone actually 'knows' something. Among philosophers, this has led to "devising doomed criteria by which we can determine whether an individual uttering a proposition with X, Y, and Z properties can be said to 'know' something. The criteria are doomed because they ignore contingency, historical and otherwise." [1]

A pragmatic view of knowledge, on the other hand, shifts the emphasis to the criteria that the community has devised. But, even here, the criteria must meet some bottom line condition. For the pragmatist the bottom line is successful action. C. I. Lewis put it this way: "the utility of knowledge lies in the control it gives us, through appropriate action, over the quality of our future experience" [4]. This provides a key to understanding scientific knowledge, particularly in distinguishing it from other types of knowledge.

UNDERSTANDING SCIENTIFIC KNOWLEDGE

Moving from these more generalized forms of knowledge-generation to study those used in engineering and science is not straightforward. Common sense knowing is a form of the general method of the mind [14] where the process is tailored to the requirement for timely action and has less need for great precision, comprehensiveness, universality, or completeness, especially where attempting to meet such standards would only delay action unnecessarily. Common sense is content to find out only what we need to know right now, in this particular context, and to formulate itself allusively and incompletely in rules of thumb, examples, proverbs, and parables. Because its concern is our practical living, it relates things to ourselves rather than to each other, as the mathematical equations of science would do. In this sense, scientific knowing (sciences) develops from common sense and may be more or less distant from it. This distance is critical, and plays a difficult role in the development of a 'new' science. For example, botany, relying on descriptions of plants as they appear to us, is much closer to a common sense method than the current study of plant genetics. Yet, botany is a well-recognized subfield within biology, and both common sense and theoretical approaches are used in its pedagogy.

Lonergan distinguishes mathematical and empirical scientific heuristic structures. He subdivides empirical approaches into classical and statistical types. Classical approaches yield an intrinsic intelligibility and pertain to systematic aspects of reality, marked by schemes of recurrence. Statistical approaches pertain to non-systematic aspects of reality and yield no intrinsic intelligibility but, rather, probabilities, ideal frequencies around which actual events tend to cluster randomly.

The central point is that scientific claims derive their meaning from the theories within which they are associated; hence, *scientific knowledge is theory-bound.* The dynamic process in which scientists continuously revise what they are willing to endorse – and by which they examine their assumptions and their methods – is at the very heart of the strength of the sciences. This is a dynamic process that develops ever more refined approximations of objective truth, with both the challenge that it points to objective truth, and at the same time constantly criticizing the approximation as it is currently known. Thus, despite the theory-bound nature of scientific knowledge, the self-critical process of scientific inquiry ensures that the knowledge it claims is the best available at that time insofar as it is judged "best" according to community standards. The ultimate aim of scientific inquiry is explanation. Thus, in the context of a pragmatic account, the ultimate success of the use of scientific knowledge is explanation. [1]

UNDERSTANDING ENGINEERING KNOWLEDGE

Both science and technology may borrow from or rely on each other in various ways – they constitute two distinct forms of knowledge since they have distinguishably different ends. Science aims to explain and technology/engineering aims to create artifacts. Vincenti puts it this way, "technology, though it may *apply* science, is not the same as or entirely *applied* science" [3]. This is important, as the explanatory value of a scientific theory (e.g., its application) is subsequently judged by its usefulness not in accurately estimating the objective truth that may be involved, but rather for a different end: how the application of the scientific theory helps in the creation of an artifact that meets some human need.

Engineering refers to the practice of organizing the design and construction and operation of any artifice which transforms the physical or social world around us to meet some recognized need. Engineering – like science – is an *activity* with specific objectives. Consequently *engineering knowledge* concerns *the design, construction, and operation of artifices for the purpose of manipulating the human environment.* [1] One can reasonably narrow the focus of engineering knowledge to the topic of "design knowledge," by concentrating on design.

"Design" in this context denotes both the content of a set of plans (as in "the design for a new airplane") and the process by which those plans are produced. In the latter meaning, it typically involves tentative layout (or layouts) of the arrangement and dimensions of the artifice, checking of the candidate device by mathematical analysis or experimental test to see if it does the required job, and modification when (as commonly happens at first) it does not. This is a process of refinement, subject to a perceived need for timeliness, precision, comprehensiveness, and/or completeness. As such, this procedure usually requires several iterations before finally dimensioned plans/specifications/requirements can be released for production, and the effort is judged by its results – the usefulness of the design and/or product [1] [3]. This refinement process has been reasonably characterized as heuristic, and the development of such heuristics is central to the engineering method [13].

'Usefulness' is a fundamentally subjective value; it is necessarily a social construction that depends upon the social and historical situations in which the problem and those solving the problem exist. This is a challenge in engineering and to engineering education in particular, as the study of historical and social values and value construction is typically lacking in engineering curricula [6].

The concept referenced here is often referred to as 'subjective truth', that is a truth by agreement, an agreement of persons. This shows up in the engineering method as the value of the engineering artifact/effort is assessed by specific *subjects* (e.g., stakeholders); the requirement is there because the users want it, etc. In short, the 'who' of the problem is essential to solving the problem. In specific engineering sub-disciplines such as requirements engineering, incorrect assessment of the 'who' (subject) of the problem is considered a major process failure. Gause and Weinberg put it this way: "People have problems, systems have requirements" [20]. Thus, understanding and applying the 'pragmatic' approach in engineering is assessed by subjects for whom the engineering method is applied. The subject, and thus subjective truth remains central to engineering. This is another area where scientific knowledge differs significantly from engineering knowledge.

INTEGRATING SCIENTIFIC AND ENGINEERING KNOWLEDGE

Comparing the knowledge generation processes involved, engineering and science appear related, but significantly different, differentiated in both purpose and manner. This follows the distinctions suggested by Lonergan in his observations on empirical science. One of the distinctions between mathematical and empirical science/research is the empirical researcher's return to overlooked or neglected data that "forces the revision of initial viewpoints."

> "The circuit, then, of mathematical development may be named immanent; [as] it moves from images through insights and conceptions to the production of symbolic images whence higher insights arise. But the circuit of [empirical] scientific development includes action upon external things; it moves from observation and experiment to tabulations and graphs, from these to insights and formulations, from formulations to forecasts, from forecasts to operations, in which it obtains fresh evidence either for confirmation or for the revision of existing views." [14]

One of the key pragmatic distinctions between this iterative scientific approach and the engineering approach is its goal: The scientist aims at explanation: universal, reliable, comprehensive and sufficiently precise formulation of knowledge; the engineer aims at timeliness, completeness, with sufficient precision and comprehension. These values affect the knowledge generation, retention and use.

Pitt provides a similar comparison of scientific and engineering knowledge:

> "First, the characterization of scientific knowledge as theory-bound and aiming at explanation appears to be in sharp contrast to the …task-specific knowledge of engineering that aims at the production of an artifact to serve a predetermined purpose.
>
> "The second important difference between the two forms of knowledge [is]… the manner in which engineers solve their problems does have a distinctive aspect. The solution to specific *kinds* of problems ends up cataloged and recorded in the form of reference works which can be employed across engineering areas. For example, measuring material stress has been systematized to a great extent. Depending on the material, how to do it can be found in an appropriate book. This gives rise to the idea that much engineering is "cookbook engineering," but what is forgotten in this caricature is that another part of the necessary knowledge is knowing what book to look for. This a unique form of knowledge that engineers bring to problem solving. [1]

The viewpoints of science and engineering are idealistic and pragmatic respectively [12]. The nature of science explains how the world works and this can be learned though experiments (producing artifacts). Knowledge generation, from the perspective of scientists is approached via creating a hypothesis first, and testing it second. The nature of engineering is for addressing human needs/problems, and generally applies domain-specific heuristics for building a system. What distinguishes scientific knowledge from engineering knowledge is not the creation or use of artifacts/technology, rather it is the values stemming from the scientific and engineering viewpoints and how they are pragmatically applied (purpose and method). This distinction in knowledge generation is both individual and social; it affects the use of the knowledge, and shapes the manner in which it is generated.

APPLYING A PRAGMATIC THEORY OF KNOWLEDGE

The pragmatic theory of knowledge, at least as outlined here identifies purpose (goal) and manner (method) of knowledge application and generation as distinguishable characteristics that can be used to distinguish engineering foundations. Historically the 19th Century 'French' (Science and Math) and 'English' (Apprenticeship) schools of engineering have significantly influenced the training and values of current engineering training [6]. The science and math school emphasizes knowledge and knowledge generation whereas the apprenticeship school emphasizes pragmatic application. The difficulty lies in trying to integrate these schools, when the science and math approach de-emphasizes the pragmatic, and the apprenticeship approach de-emphasizes knowledge generation. The foundations of engineering, as argued in this paper, necessarily include both pragmatic knowledge and pragmatic knowledge generation. Furthermore, the knowledge-generation epistemology implies that engineering foundations are more than just the knowledge of science and mathematics, more than applied math and science, and more than pragmatic apprenticeship of an engineering design method. Engineering, at its foundations is 'both' using science 'and' pragmatic, and more than both: it is about generating and using knowledge for a purpose and with a method that is more than theory, more than descriptive: it is useful.

This 'both and' view that emphasizes both goal and method of engineering can be very useful in trying to help distinguish a particular engineering discipline from its related foundations in math and science (natural or otherwise). Similarly it can be used to help distinguish emerging engineering disciplines from their respective math and sciences (e.g., see [21]).

PRACTICAL IMPLICATIONS

This epistemological work also suggests that there is a significantly engineering philosophy that should be reflected in engineering education. This implies that an engineering approach is more than engineering knowledge – rather, that it is both knowledge and approach. The implications of applying this epistemological lens to the current practice of engineering education could be significant in several areas such as accreditation/program development, defining traits for engineering education, and for exploring affective domain learning.

This epistemological lens would be particularly useful in developing both a consistent definition for, and mechanism for distinguishing the 'scientific' and 'engineering' components of accredited engineering degree programs, such as those accredited by ABET and other national- and international boards [21]. Using this or a similar epistemological lens would allow for more consistent discussion, communication, and training for accreditors and program developers. This would be particularly useful for delineating the scientific roots and contributions of engineering sciences (e.g. Thermal Science), or sciences with significantly shorter histories than most natural sciences (e.g., Computer Science) [22].

Another area where this epistemological lens could be well applied is in helping undergraduate engineers reasonably frame and value what they actually do, Lonergan calls this self-appropriation and argues that if you "[t]*horoughly understand what it is to understand ,. . . not* *only will you understand the broad lines of all there is to be understood but also you will possess a fixed base, an invariant pattern, opening upon all further developments of understanding.*" [14]

Knowing more explicitly what it is to know and to solve problems in engineering will give undergraduate engineers fuller anticipations of the paths to solutions. They may come to appreciate more fully how the value of their work, of an engineering solution, lies in a timely, sufficiently complete, sufficiently precise solution that is in fact delivered. This shifts the emphasis onto understanding sufficiency, involves understanding and applying the social context of their work, and away from single-solution thinking, away from 'analysis paralysis' where the 'best is the enemy of the good enough.' An example of this it is not the one single, best right answer, that comprises good engineering. Rather the best *engineering* answer(s) are judged pragmatically, and routinely involve social context (e.g. a company, a customer). While this emphasis appears in common to engineering curricula (e.g. ABET), this work suggests that this is not a facet of engineering education, or a 'nice to have' aspect, but rather is intrinsically necessary to the foundations of engineering.

A third area where this approach could be useful for engineering educators lies in helping to shape discussions surrounding the affective domain of engineering. Currently, the authors' expectations are that essentially all engineering program-level outcomes, and probably course-level outcomes are routinely voiced in terms of cognitive domain outcomes. This, and related works (e.g., [1,3,6,13]) suggest that the engineering community has significant, if not universally communicated expectations for the affective domain of engineering graduates. While these philosophical perspectives provide a framework for such explorations, they strongly imply that such work in using these epistemological lenses would both inform and help guide exploration of affective domain expectations for engineers and engineering programs. This area remains to be significantly explored.

Conclusion

The pragmatic theory of knowledge, briefly presented, uses the purpose (goal) and manner (method) of knowledge application and generation to distinguish types of knowledge: engineering and scientific. The pragmatic theory of knowledge provides a means by which, particularly in a learning environment, the critical terms of 'science', and 'engineering' can be reliably distinguished.

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Contemplations on Results from Investigating the Personal Epistemology of Computing Students

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***Abstract*— "Personal Epistemology" is the analysis of the ways in which an individual perceives what constitutes knowledge, its boundaries, how it is justified, and how it is related to learning. While investigation of metacognitive strategies used by students is now an established research topic within Computer Science and Information Technology education, the study of personal epistemology is relatively undeveloped. This is so despite there being significant epistemological issues associated with learning the subject itself, such as those concerned with the way in which programming exercises change from convergent to divergent problems, or the process by which software project management problems very quickly become ill-defined. In this paper, we describe a preliminary investigation into the personal epistemology of two cohorts of computing students. We review some models of personal epistemological development and describe an empirical study in which we investigated the dimensions of epistemological beliefs of two cohorts of computing students. The results show that there appears to be a wide range of epistemological belief amongst computing students. Finally, we make some observations about the importance of personal epistemology for learning in Computer Science and outline further work in this area.**

Keywords – personal epistemology, epistemological beliefs, learning, ill-structured problems.

I. Introduction

Personal epistemology, that is, an individual's conception of knowledge and their understanding of the process of knowledge acquisition and learning [1], has been an ongoing area of research in educational psychology for over thirty years now. While it has only recently begun to be studied as part of subject-specific pedagogical research, it has nevertheless been applied to a wide and growing range of disciplines. In part, this interest has been generated by evidence that more "sophisticated" epistemic beliefs are correlated with higher-order, metacognitive skills which may have a direct impact on learning. For example, there is evidence that epistemological considerations play an important role in the self-regulation of learning, that more "sophisticated" beliefs are often correlated with higher-order learning outcomes [2], and that epistemological factors play an important role in the solution of ill-structured problems [3].

The subject itself has been termed "the subjective counterpart of philosophical epistemology" [4]. The difference between the two is that personal epistemology investigates how the philosophical concepts affect the individual at a psychological level [5] and recent research has tended to focus on how it relates to learning and its application to pedagogy. As a research field, it may be considered to have originated in the developmental psychology of Piaget [6], while its application to tertiary education began in the mid-1960s with the work of Perry [7]. While subsequent work has reconceptualised personal epistemology in a number of different ways, there are common elements that run through the work of almost all researchers such as the recognition that an individual's understanding may develop over time. Following Perry, this may be seen as taking place in a one-dimensional, linear fashion or it may occur within some kind of multidimensional space characterised by the kinds of different epistemological beliefs suggested by Schommer [8]. Regardless of the details, this development is considered to have important implications for learning and consequently for teaching and assessment practices. Development in an individual's personal epistemology is seen as a progression from an initial phase characterised by a simplistic or naive conception of knowledge in which propositions and theories are seen as dualistic (right or wrong), to more nuanced and sophisticated "evaluative" views which take account of evidence and judgement. It should also be noted that while many researchers use these terms, there are some [9] who question the practice of using psychologically-loaded words such as "naive" and "sophisticated" and instead prefer to describe the ends of the development spectrum as "non-availing" or "availing" depending on whether such beliefs inhibit or promote learning.

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Most educators would agree that one of the most important goals of a university education is to encourage the development of learner autonomy so that an individual may deal with the challenges posed by lifelong learning. There has been much recent work on the development of sets of graduate attributes which address this need for post-university, professional competences [10], many of which are based on the use of higher level, metacognitive skills such as analysis, reflection, and critical thinking. However, research has tended to show that educators struggle to promote development of such skills despite acknowledging their importance [11]. The relevance of an individual's beliefs about knowledge for such metacognitive activities may play a part in this and can be seen, for example, when considering self-regulatory skills such as planning, monitoring and evaluation, all of which involve the prioritisation and integration of information from various sources. A key element in this is the ability to engage in a process of justification of one chosen alternative over others. Such justification, however, requires the evaluation of claims about knowledge, the forms it takes, its sources, how it is constructed and how it may be apprehended. These concerns are essentially epistemological in nature and suggest that such issues play a crucial role in determining a person's fundamental orientation towards learning and the strategies that are chosen to engage with a subject.

In order to start to investigate this field in the discipline-specific context of Computer Science education, we feel that it is necessary to look at the epistemological responses found in a range of students. In previous work [12], we made a small-scale, preliminary analysis of the epistemic beliefs of a relatively mature cohort of students based on data gained from Schommer's "Epistemological Beliefs Questionnaire" [13]. In this paper we compare that data with another set from a group of first-year students who display a much greater range of responses. We believe that this gives us some understanding of the scope of epistemological belief that is present in computing students. It would also appear that there is a need for an instrument that is much more finely tuned to the subject itself.

We begin this paper by presenting an overview of some of the relevant background research in the field before describing the developmental model that underlies Schommer's questionnaire which was used to try to gain insight into personal epistemology of our students. We discuss the results of this experiment and finally we conclude by suggesting further research directions that would be relevant to Computer Science Education.

II. BACKGROUND

A. *Epistemology and Computer Science Pedagogy*

The primary motivation for our current work is consideration of the evidence that students' epistemological beliefs do indeed affect the choices they make about the way in which they learn by influencing a variety of cognitive and metacognitive strategies. These include the explicit choice of learning strategies [14], academic performance [15], cognitive processing [16], openness to conceptual change [17], text comprehension [18], moral reasoning [3], and strategy use [14]. Research suggests that the sophistication of an individual's epistemological beliefs has a strong impact on learning. Students who believe that knowledge is certain are more likely to draw absolute conclusions from contingent information [8] while those who believe that an individual's capacity for knowledge is fixed are less likely to persist in formal education [13]. Students who believed that knowledge is quickly acquired are more likely to comprehend information poorly while those who believe that knowledge is simple are more likely to settle for a memorization study strategy rather than using higher-level cognitive processes such as critical analysis, elaboration and reflection [19]. Moreover, students who view ability as innate and thus fixed may be less inclined to develop and use advanced reasoning skills when thinking about ill-structured issues [3]. An appreciation of the importance of these beliefs by teachers may therefore contribute to a greater understanding of the psychology of student learning and so may provide insights into more effective pedagogical strategies in areas for which reflection and critical thinking are required.

One such area would be the solution of divergent or ill-structured problems. This class of problems typically does not have single optimal solutions and there may only be heuristic procedures to find acceptable results among a range of possibilities. Consequently, there is a greater need to justify any option that is chosen. A number of common pedagogical practices, such as group projects, involve these open-ended problems and we would anticipate that this field of study would contribute to our understanding of effective practice in these areas. In addition, careful attention to epistemological issues may contribute to a greater understanding of the transition from convergent to divergent problem-solving that frequently arises in computer science education. Examples include the increase in complexity that occurs as novice programmers undertake more sophisticated tasks and the transition from "programming" to "software engineering". This work also connects well with our earlier efforts to develop a theory for setting up open-ended group project learning environments [20, 21, 22].

Finally, there is an important link between epistemology and perceptions of knowledge within a discipline-specific context and the concept of identity. A basic question about subject identity is what it means to be, say, a computer scientist. Is it simply a matter of studying a particular set of techniques or is there some epistemological approach or methodology that distinguishes the practitioner in that field from one in a neighbouring discipline. For example, is there a process of "learning to think like a computer scientist" which is different from learning to think like an engineer or a mathematician. A related question is how professionals from that discipline induct students into the broad community of practice in which the subject is studied [10]. These issues involve an explicitly epistemological perspective as they deal with what counts as knowledge in the subject domain, how such knowledge is acquired and an ability to reflect on how the process is justified to a wider community. It would be interesting to investigate the degree to which current members of the computer science community share a specific conception of knowledge and a common understanding of "ways of knowing" within the subject, and also how this is passed on to new graduates. This, in turn, may have practical implications for issues associated with identity such as curriculum development, academic and industry retention practices, and lifelong or lifewide learning [23].

B. Models of Personal Epistemology

While investigation into the development of an individual's conception of knowledge was a central part of the work of Piaget from the 1930s onwards, research into this area has increased substantially in recent decades. The first study, which specifically addressed the topic in the context of Higher Education, was that of Perry which proposed a general scheme in which epistemological understanding developed through nine stages, grouped together into three phases. In the initial phase, often categorized as absolutist thinking, an individual sees knowledge in polar terms as either right or wrong. Uncertainty is due to lack of analysis of suitable data and can be eliminated by straightforward procedures such as direct observation, appropriate introspective examination or through appeal to some expert authority. In the next phase, this naïve position shifts into a more relativist stance. There is a significant reaction against the previous dualistic view to the extent that knowledge is now perceived as inherently uncertain and idiosyncratic to the individual, with recognition of the possibility of multiple views, which may depend on context. The main feature of the final phase is an epistemological understanding in which knowledge is constructed by comparing evidence and opinion on different sides of an issue. Knowledge is seen as constructed through a process of reasonable inquiry leading to a well-informed understanding. It also recognizes the contingent nature of personal knowledge, exploring the implications of commitment to individual views. Perry, therefore, presents a model of personal epistemological development which is a linear spectrum ranging from initial "simple" or "naive" views to the more "sophisticated", evaluative stance which he saw as desirable in graduates.

Subsequent work on this type of developmental model has extended the analysis in a number of different directions but, as indicated by Hofer and Pintrich [24], a common element in such work is the retention of a movement from an initial dualistic, objectivist view of knowledge, through to a more subjective, relativistic stance to a final contextual, constructivist perspective of knowledge and its acquisition and justification. As pointed out by Kuhn [20], this evolutionary structure has practical implications for teaching as epistemological factors determine how students view the components of a theory and its relationship to reality. As an example, consider the development of high-level metacognitive skills such as those associated with critical thinking. At an initial, absolutist level, claims about knowledge are seen as facts which are either correct or incorrect. Critical thinking is therefore perceived to be a straightforward matter of comparing such statements to reality in order to determine their truth or falsity. At the more relativistic level, assertions are considered merely to be opinions, none of which is more compelling than any other, and so any may be selected on personal preference. At this stage, critical thinking is largely irrelevant as justification is limited to the statement of subjective views. It is only at the final, evaluative stage that assertions are considered to be judgements that can be appraised by argument and reference to evidence. As a consequence, it is primarily at this stage that critical thinking, seen as a method for promoting coherent, logical argument, will be considered useful.

C. Epistemological Beliefs

This concept of a single, integrated continuum of development was, however, challenged in the work of Schommer (later Schommer-Aikins) in a series of papers [8, 5, 26, 13] which drew on Perry's work but incorporated significant elements from other researchers. These included work by Schoenfeld on the speed of learning [27], beliefs about innate intelligence [28], Kitchener and King's work on reflective judgment [29], and Ryan's work on epistemology and comprehension [15]. While accepting the idea of personal epistemological development, she suggested that it was better conceptualised as a multidimensional belief system, the dimensions of which may be only weakly bound to each other. She retained the idea of a developmental continuum from what she, too, characterised as "naïve" views to more "sophisticated" ones, but applied it to each of the key epistemological beliefs and suggested that development may occur in each at different rates. Epistemological development, in this model, was therefore better described by a trajectory in a multidimensional space rather than by progression along a line.

The main instrument used by Schommer for this analysis was her Epistemological Beliefs Questionnaire. This seeks to establish the respondent's level of commitment to a range of statements which reflect a particular epistemological belief. Examples of these include "People who challenge authority are over-confident", "I try my best to combine information across chapters or even across classes", "The most successful people have discovered how to improve their ability to learn", and "Things are simpler than most professors would have you believe".

The questionnaire itself was based on the hypothesis that there were five dimensions through which epistemological development takes place: structure of knowledge, stability of knowledge, source of knowledge, speed of knowledge acquisition, and the learner's control of knowledge acquisition (see Table 1). The first three of these were influenced by Perry's original model. The speed of learning dimension was based on the work of Schoenfield, and the control of knowledge dimension was influenced by Dweck's work on implicit intelligence.

One difficulty with the study of personal epistemology is that we do not observe these beliefs directly but only infer them from behaviour so these dimensions are, in some sense, hidden. Moreover, several behaviour patterns could result from the same belief. For example, according to Schommer et al [5], if one considers the dimension for "structure of knowledge", the naive epistemological view is that knowledge is essentially simple and that complexity is due to inadequate analysis rather than any inherent conceptual ambiguity in the information or the interrelationships involved. If a person held this view, there would be a tendency to oversimplify complex information which could manifest itself in two ways: they could tend to focus on one aspect of the problem and neglect others, or else they could artificially reduce the complexity of the relationships between the constituents of the problem by a process of inappropriate compartmentalisation. The epistemological views about structure of knowledge therefore give rise to two subsets of observable behaviour. Using the naïve behaviour as a descriptor, these would be termed "Seeks single answers" and "Avoids integration" and the questionnaire was developed to elicit responses that could be tied to these behaviours. Using this type of analysis, Schommer identified twelve different observable behaviours for the five hypothesised dimensions of belief (see Table 1).

Table 1. Schommer's Dimensions of Personal Epistemology

Dimension	Explanation	Development Continuum	Subset Behaviours (labelled by "naïve" view)
Structure of Knowledge	How students think about the structure, relationship and organisation of knowledge in a particular domain.	From "*knowledge as isolated, unambiguous bits of information*" to "*knowledge as highly interrelated and integrated set of concepts*"	• Seeks single answers • Avoids integration
Stability of Knowledge	How students think about the contingency of knowledge and the way theories may change over time.	From "*knowledge as unchanging*" to "*knowledge as contingent and subject to continual revision and change*"	• Avoids ambiguity • Knowledge is certain
Source of Knowledge	Where students think domain knowledge can come from.	From "*handed down by authority*" to "*derived from empirical evidence and reasoning*"	• Don't criticise authority • Depend on authority
Speed of Knowledge Acquisition	How students think about the speed at which they acquire knowledge.	From "*learning as occurring quickly or not at all*" to "*a view of learning as a gradual process*"	• Learning is quick • Learn first time • Concentrated effort is a waste of time
Control of Knowledge Acquisition (Ability to Learn)	How students think about their capacity to control the acquisition of knowledge.	From "*a view that the ability to learn is fixed at birth*" to "*a view that it can be improved over time*"	• Can't learn how to learn • Success is unrelated to hard work • Ability to learn is innate

Given a dataset of responses to the questionnaire which measure the observable behaviours, the hypothesis that these behaviours are correlated with specific epistemological beliefs can be tested using the statistical procedure known as exploratory factor analysis, which looks for latent variables (factors) that underlie and give rise to the measured, observable data.

Schommer's conceptualisation of personal epistemology as a belief system has been extremely influential in the educational psychology literature as a model of epistemological development. It provides a methodology for quantitative analysis of epistemological data and can also accommodate instances in which students exhibit sophisticated epistemological beliefs in one dimension but less complex beliefs in another, something which is more problematic in one dimensional models. There has, however, been criticism of this approach due to reported difficulties associated with replicating the factor structure she described [27]. This leads, among other things, to ambiguity in the number of dimensions, i.e. important beliefs, that characterise an individual's personal epistemology Nevertheless, there are a relatively large number of studies that use the method and we have attempted to follow her methodology in our study.

III. Method

A. The Participants

Our study involved datasets from two groups of students. The first set of data was collected from a group of twenty-five respondents involved in a globally distributed group project [21]. The sixteen respondents from Uppsala University, Sweden, were enrolled in the IT in Society course unit while the nine respondents from Rose-Hulman Institute of Technology, USA, were following the Computing in a Global Society course unit. Both course units were taught in English. The students participating in the course in 2012 were aged between 20 and 38. The majority of students were pursuing a major in computer science or information technology, but some students were studying other technical majors. Most students had studied for at least three years at the university.

The second data-set was obtained from eighty-five respondents out of a class of one hundred and ten first year undergraduates in the School of Computing Science and Digital Media at the Robert Gordon University, U.K. These students were aged between 18 and 40 with the majority of them having entered university from secondary school. They were registered on a variety of computing degrees ranging from Computer Science to Business Information Systems.

The data for dataset 1 was collected at the beginning of the academic year at the start of the course when both Swedish and American students were in Uppsala. All students who were present completed the questionnaires during academic contact time. Dataset 2 was collected in the first week of the undergraduate term just after the Induction period. All students who were present completed the questionnaires during academic contact time.

B. The Instrument

The main investigative tool for the study was Schommer's Epistemological Beliefs Questionnaire, which seeks to investigate a range of epistemological commitments by asking respondents to indicate levels of agreement to a series of sixty-three statements on a five-point Likert scale. As described in section 2, these statements are grouped into twelve sections which describe different attitudes to learning and act as observed or measured variables for further statistical analysis (see tables 2 and 3).

Exploratory factor analysis was performed on this group of twelve averages using MINITAB. The aim of this technique is to reduce the dimensionality of the space of variables by looking for latent factors that underlie the structure of those observed variables. Eigenvalues of the correlation matrix for the measured variables were extracted using principal component analysis, in order to determine the number of factors, and a table of factor loadings for each set was produced. A loading for a particular variable with regard to a factor quantifies the variation of the measured variable that is explained by that factor and so a high loading indicates a strong correlation between the measured variable and latent factor while a low value indicates that the factor contributes little to the measured variable. Interpretation of the factors themselves proceeds by rotating the axes in the factor space so that the loadings show high values for a few variables and low values for the remaining ones. Following Schommer's original paper, orthogonal varimax rotation was used for this.

The communality for each measured variables was also calculated. This is a measure of the reliability of the number of factors used and is the variation of the observed variable that is accounted for by all the latent factors under consideration. So, for example, a communality of 0.75 for a particular measured variable indicates that 75% of the variation in that variable is accounted for by those latent factors.

IV. Discussion of Results

A. Number of Factors

Principal Component Analysis was used to extract the eigenvalues of the correlation matrix for each of the two datasets. In both cases, analysis of the eigenvalues suggested five latent factors underlying the measured variables. Exploratory factor analysis with five factors was carried out on each dataset, using MINITAB, and a table of loadings for each set was produced. These were rotated using an orthogonal varimax rotation and the results are displayed as table 2 and table 3.

The ratio of sample size to number of measured variables for dataset 1 is relatively small, but the communalities were reasonably high (for real data). In her original paper, Schommer used a loading threshold of greater than 0.5 to determine contribution to measured variables but, for this dataset, we used a higher value of 0.6. The size to number of variables ratio for the second dataset was better and so, here, we used Schommer's original loading threshold to identify factors. Schommer reported that four factors emerging from her statistical analysis. In both of our datasets, principal component analysis suggested five factors. Comparative analysis with four factors shows that there was no significant reason to reduce this to four in either case, although there did not appear to be a consistent interpretation of what these factors represented.

Table 2. Factor Loadings and Communalities for Dataset 1

Variable	F 1	F 2	F 3	F 4	F 5	Com'ity
1. Seeks single answers	**0.73**	*-0.11*	*-0.24*	*-0.21*	*0.29*	*0.73*
2. Avoids integration	*-0.04*	**-0.85**	*0.01*	*-0.11*	*0.03*	*0.73*
3. Avoids ambiguity	**0.90**	*-0.19*	*-0.04*	*-0.06*	*0.01*	*0.83*
4. Thinks knowledge is certain	*0.15*	*-0.06*	*0.13*	*-0.06*	**0.90**	*0.87*
5. Depends on authority	*0.14*	**-0.74**	*-0.08*	*0.28*	*-0.07*	*0.65*
6. Don't criticise authority	*0.46*	*0.26*	*0.56*	*0.38*	*0.12*	*0.76*
7. Ability to learn is innate	*0.19*	**-0.78**	*0.29*	*-0.14*	*0.09*	*0.75*
8. Cannot learn how to learn	*-0.34*	*-0.14*	*0.09*	**0.76**	*0.14*	*0.73*
9. Success is unrelated to hard work	*0.01*	*0.09*	*-0.01*	**0.85**	*-0.17*	*0.76*
10. Learn the first time	*-0.22*	*-0.10*	**0.77**	*0.06*	*0.20*	*0.70*
11. Learn quickly or not at all	*0.54*	*-0.04*	*0.53*	*-0.43*	*0.11*	*0.76*
12. Conc. effort is a waste of time	*-0.11*	*-0.18*	**0.70**	*-0.02*	*-0.49*	*0.71*

B. Identification and Interpretation of Factors for Dataset 1

An examination of the loadings for dataset 1 identifies a number of similarities and differences with the results reported by Schommer and others. The first factor (F1), i.e. the one associated with the largest eigenvalue, has a large contribution to the variables "*Seeking single answers*" and "*Avoiding ambiguity*". These behaviours seem intuitively to be related (even though Schommer categorised the first as referring to the structure of knowledge and assigns the latter to views on the stability of knowledge) and it seems reasonable to us that both behaviour descriptors relate to an avoidance of multiple representations of knowledge. We would therefore categorise both behaviours as indicating some kind of belief related to the Structure of knowledge dimension. The fifth factor (F5) is associated with the single variable "*Thinks knowledge is certain*" which Schommer categorises as pertaining to the Stability of knowledge. There also appears to be one factor (F3) which underlies the belief that if one is going to learn something then its should be possible to "*Learn it the first time*" and that "*Concentrated effort is a waste of time*". These, again, seem intuitively to be linked and Schommer categorises both of these variables as referring to the Speed of learning. A fourth factor (F4) is strongly associated with the view that one "*Cannot learn how to learn*" and that "*Success is unrelated to hard work*". Schommer categorised both as concerned with innate ability to learn, but the loading for the similar measured variable, "*Ability to learn is innate*", is small on this factor. A final factor (F2) is negatively correlated with the measured variables "*Avoids integration*", "*Depends on authority*" and "*Ability to learn is innate*", i.e. the group would tend to integrate knowledge from different sources, not rely on authority and trust their own ability, which we see as being associated with the Control of knowledge acquisition dimension. We thus have two factors capturing slightly different aspects of this dimension.

Two variables, one tracking the view that you should not "*Criticise Authority*" and one that "*Learning is quick or not at all*" do not have an above-threshold correlation with any of the five factors. This is the case even if the number of factors was increased to six. The main substantive change in this case is that "*Depends on authority*" would become a single-variable factor. Conversely, if we restrict to four factors, in line with Schommer's original paper, the high loading for "*Thinks knowledge is certain*" would vanish to be replaced with a moderate loading for this variable on F1 (0.56). However, the communality for this variable then decreases to 0.32 suggesting that this action would not be sensible.

C. *Identification and Interpretation of Factors for Dataset 2*

While principal component analysis of the second dataset also indicated that there were five factors, the pattern of (rotated) factor loadings (table 3) is quite different from the previous data, and more difficult to interpret. There is also a considerable difference between the distributions of loadings for this dataset and that reported by Schommer.

The first factor (F1) appears to underlie the variables "*Cannot learn how to learn*", "*Success is unrelated to hard work*", and that it should be possible to "*Learn [something] the first time*", which are all categorised by Schommer as referring to a naive belief about the speed of knowledge acquisition. There is also a reasonably high loading for the behaviour "*Concentrated effort is a waste of time*" which Schommer associates with the view that learning is innate, but also, perhaps, suggests a negative belief about learning as some kind time-related process. The factor (F2) has high negative loadings on "*Ability to learn is innate*" and one "*Learn(s) quickly or not at all*" which also mixes behaviour associated with a view that learning ability as innate (in the first case) and about speed of knowledge acquisition (in the second), although in a different way to the first (F1). This may suggest that the data is trying to capture two aspects of the beliefs underlying these behaviours, although not the ones reported by Schommer.

There is one factor (F3) that contributes to the variables "*Avoids ambiguity*" and "*Depends on authority*". Schommer proposed that the former behaviour was due to a belief about the stability of knowledge so this pairing may indicate that the first year students saw authority as a stabilising element for knowledge. Another factor (F4) has high loadings for the behaviours "*Avoids integration*" and "*Thinks knowledge is certain*" which seems to mix structure and stability of knowledge. The fifth factor (F5) contributes highly to behaviours "*Seeks single answers*" and "*Don't criticise authority*" which seems to mix structure and source of knowledge factors. Although there was a some degree of mixing of Schommer's factors with the first dataset, it seems much more pronounced with the first year cohort and this could perhaps be due to lower levels of academic maturity.

The interpretation of the data for the second cohort is, in general, more problematic than for dataset 1, although the sample set is bigger. It is interesting to note however that there appears to be a broad division between those factors (1 to 3) that refer to views about knowledge (which Schommer identified as coming from the developmental work of Perry et al) and those concerning knowledge acquisition (factors 4 and 5), i.e. which pertain to learning. This is found in both data sets and may reflect a basic characteristic of the results.

Table 3. Factor Loadings and Communalities for Dataset 2

Variable	F 1	F 2	F 3	F 4	F 5	Com'ity
1. Seeks single answers	*0.08*	*0.04*	*0.24*	*-0.13*	**-0.73**	*0.61*
2. Avoids integration	*0.02*	*0.07*	*0.29*	**-0.77**	*-0.23*	*0.72*
3. Avoids ambiguity	*0.08*	*-0.18*	**0.59**	*-0.33*	*-0.18*	*0.53*
4. Thinks knowledge is certain	*-0.15*	*-0.11*	*-0.31*	**-0.78**	*0.12*	*0.76*
5. Depends on authority	*-0.18*	*-0.03*	**0.78**	*0.17*	*0.04*	*0.67*
6. Don't criticise authority	*-0.18*	*-0.48*	*-0.20*	*0.05*	**-0.58**	*0.64*
7. Ability to learn is innate	*0.21*	**-0.78**	*0.01*	*-0.05*	*0.19*	*0.70*
8. Cannot learn how to learn	**0.81**	*0.09*	*0.10*	*0.09*	*-0.03*	*0.69*
9. Success is unrelated to hard work	**0.67**	*-0.05*	*-0.33*	*-0.06*	*0.15*	*0.59*
10. Learn the first time	**0.69**	*-0.23*	*-0.16*	*0.10*	*-0.24*	*0.62*
11. Learn quickly or not at all	*-0.02*	**-0.73**	*0.18*	*-0.02*	*-0.20*	*0.60*
12. Conc. effort is a waste of time	**0.63**	*-0.11*	*0.24*	*-0.05*	*0.46*	*0.68*

V. Conclusion and Further Work

Our aim in this paper has been to start to address some of the issues around personal epistemology within the discipline-specific context of Computer Science Education and the study should be seen as an initial attempt towards this goal. The main technique used is factor analysis and while this form of investigation can be quite sophisticated, we would want to emphasise the exploratory nature of the process. Our analysis does not reproduce the factor loadings described in Schommer's paper, but her work examined a much more general set of students than ours and our main interest here is not to replicate Schommer's findings but to use her work to investigate a multidimensional developmental model in a discipline-specific context. Schommer obtained four of her five hypothesised dimensions through exploratory factor analysis whereas we obtain five factors from this procedure.

We would stress some of the limitations of this study. Factor analysis requires a reasonable sample-size to variable-number ratio and the first cohort was at the very lowest limit of this. Internal consistency measures for the questions in the questionnaire were not high. Both of the groups studied were quite socially diverse and qualitative further analysis suggests that the questionnaire appears to be quite sensitive to linguistic and cultural factors. This may have contributed to rather poor internal consistency measures for the variables.

Finally, the discipline-specific nature of the group was not adequately addressed by the questionnaire. As, ultimately, one of the things we wish to investigate is whether an individual's approach to knowledge and learning contributes to a sense of subject identity and belonging to a community of practice, we believe that it is likely that an instrument with a much greater fit to the disciplinary context is needed for further work in this area.

Nevertheless, despite these issues, we anticipate that further enquiry into personal epistemology will offer significant insights into a range of problems which affect the performance of students on Computing degrees. Among the most important of these is greater understanding of the different methodologies students take when asked to solve well-structured and ill-structured problems [31, 32]. These are common across the Computing curriculum wherever there is a divergent, open-ended aspect to the solution process and some research appears to [33] indicate that different epistemological approaches are taken for each sort of problem. Further work to investigate this area is underway.

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Liberating Engineering Education: Engineering Education and Pragmatism

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Abstract— **The experts in pedagogical and curriculum development such as John Heywood and others have advocated that the liberating element of liberal studies are vocational elements of liberal education [1-2]. Since the 1960s, this statement constituted some of the leading work in curriculum development, managing mastery, and retraining programs of continued education in Europe and the US. It should be noted that some experts are viewing engineering education with a liberal art perspective [3-6] as well. This paper would like to argue a new twist in this argument.**

This paper will examine the following: The liberating essence of engineering education is the practical/pragmatic elements of engineering. The liberation is achieved by injecting pragmatism into engineering education. Changing our pedagogical approaches can do this liberation. We should help our students to use their knowledge gained from mathematics, sciences, and other fields to focus on making, building, examining, designing, and inventing things. Liberations for engineering come out of making change by designing, building, and inventing. This is the main missing piece of most engineering curricula.

This paper reviews research and activities in pedagogical development of engineering curriculum throughout the last century and especially after World War II. The paper reviews distinct directions and curriculum trends that dominate engineering education and will raise the main question: "What makes engineering special and different from sciences and mathematics?" The paper provides the support for this argument by examining the main trends of engineer development to prove that the practical/pragmatic aspects of the engineering fields are the true essence that uniquely distinguishes the engineering education. Consequently, the pragmatic essence of engineering (which needs to be reflected in the engineering education) has been (and must be) the unique identifier and the liberating element of the engineering curricula.

The idea of liberation is meant as a guiding concept to help educators reflect on pragmatic essence of engineering when balancing between mathematical rigor, scientific basics, engineering systems level thinking, and identifying a common knowledge base and methodologies.

Keywords-component; philosophy of engineering; pragmatism and engineering; Dewey and engineering; engineering education; practical engineering; new curriculums in engineering; liberating;essense; essense of engineering

I. INTRODUCTION

As engineering educators, our goals are well defined: To inspire, train, and educate the future engineers, enabling them to successfully embark on a lifelong journey of engagement with problems and doing engineering! We would like our students to have the right scientific, mathematical, cultural, and worldwide perspectives as well as engineering know-hows to be able to face the challenges of their generation and solve problems that our generation has not been able to solve. They will also have to face new problems. Some of these problems will be unknown problems with dimensions, perspectives, and spectra of difficulties that are not predictable from our vantage point.

Our main set of questions has to include, "What should we teach?", "Should we teach everything that we know?". It is very tempting to pack our curriculum with as many important (or what we think is important) items, basics, formulations, mathematical tools and scientific theories to make sure that they know what we do, or they know what we think is important for them to know. However, the issue of packed curricula has been one of the worries of great educators [7-11].

In this paper we would like to address such questions from a slightly different perspective. What makes engineering education unique and valuable has to be the pragmatic aspects of the education. The following example can provide a simple perspective of what is meant by the pragmatic nature of the engineering education. Students who learn how an inductor works will learn a few equations. Then by working/playing with actual inductors and measuring the terminal characteristics of inductors and using them as circuit elements, students learn much more than the set of equations that describe the element. In this process students make mistakes, learn from them, and try different things. They find out how at times things do not work exactly according to the conceptual/abstract part that is depicted by the equations (or they find out they have misunderstood the conceptual part and need to fix their understanding). During the interactions, examinations, and reflections students will not only have a working knowledge of the inductor and better understanding of the set of equations that are necessary to describe the element, they will also know more about themselves and their conceptual relationship with their respective field of studies. This is a bridge that connects the conceptual (mathematical and theoretical) parts of the learning to the personal experience and brings the general knowledge to the contextual basis for the students. This is a necessary and integrated interaction between theory and practice that is the essence and the belief structure of engineering.

Engineers should be trained as creators, designers, inventors, and practical people who can go from "thoughts to things" [12]. It is the intention of this paper to argue that what makes engineers free to create the future inventions, tools, devices, ways to do things, and get things done is the essence of practicality and the pragmatic approach that has defined engineering throughout the history. The "essence" of engineering can be defined as the conscience of engineering, the core and the spirit of engineering.

In fact we need to achieve a delicate balance between a) knowing the abstract concepts that physical sciences and mathematical rigor offer, b) engineering know-hows that have been developed over time, which includes engineering process, design, manufacturing, and all valuable knowledge, that helps engineers make things and create useful products and c) open-mindedness for creating new things, designs, products and solutions that are the practical part of engineers' lives. Finding the delicate and practical path (which is not a unique one) for students of different interests is going to be the challenge of all engineering educators and curricula developments.

II. MOTIVATION AND GOAL

The meaning and the essence (the core and the conscience) of engineering is not an easy task to be reviewed nor discussed in any single research paper. This is a humble attempt to shed light on few important guiding points that can help our decision-making throughout the development path. The author is naturally more focused on the curricular development and attempts in North American universities. It should be noted that engineering education has produced great results, great inventors, designers, thinkers, and problem solvers; the value of this education has historically been proven [13-18]. Consequently, the goal of this paper is not to invalidate the wonders and achievements of the traditional engineering education, but to see if we can ask better questions and focus on guiding essence that will help us develop future curricular approaches in more practical and effective ways.

We need to continue educating the next generation of systems level thinkers, problem solvers, and pragmatic achievers to lead the future technological developers and innovators. We have been very successful, but things are changing. There are numerous studies that are looking at ways we need to change our focus and approaches. There are various points of views: a) traditional engineering approaches (which have always been very valuable), b) various non-traditional approaches that bring new attempts to modify the traditional ways with new perspectives, and c) modern and newly innovative ways of revolutionize engineering curricula for the next century [3-6,13-24]. The question that remains is "what is the main item that makes engineering education different from all others?" In order to have a better idea we need to review where we are and how we got to this point in engineering education.

III. A BRIEF HISTORICAL PESPECTIVE ON ENGINEERING EDUCATION IN 19TH AND 20TH CENTURIES

Grayson identifies the following stages in the history of engineering education in United States and Canada [19]

- 1862 and before: Genesis
- 1862-1893: Period of growth
- 1893-1914: Period of development
- 1914-1940: Period of evaluations
- 1941-1970: Scientific period
- 1970-1990: Diversification

For the purpose of this paper we are going to identify the period of 1990-present as the turbulent time called Modern Days. Due to some technological development and advancement these years forced major revisions on engineering curricula based on multidisciplinary nature of the modern sciences and engineering needs. It is important to realize that especially during the last decade we are witnessing great changes in the global economy, global competitiveness, global interactions as well as in the society expectations and assumptions of what engineering is and what engineers can do [3,7,8].

We have already seen many changes demanded by our current capabilities and needs that require big changes in our approach to engineering education. The logical way to develop the possible paths is to re-examine the philosophical basis of engineering that will lead to effective development of engineering education [3-9,11,17].

Engineering education has gone through many great changes due to the demands of the time's political, social, and global constraints. While engineering as a creative productive field has been with us since the dawn of civilization [17-19,23], the systematic approach for educating engineering professionals did not necessarily start as early. Perhaps "the Corps du Genie" in France (initiated in about 1679 and solidified as operation in an institution in 1749) [19] is a good example of institutional engineering education attempts in western civilization. Most of the engineering training was conducted in master/apprentice interactions. To date, we do believe that working with an expert (a master) is essential for practical engineers and this model is used in our professional engineering certification. However, expanding this model to university level classes and education has been proven not trivial [24].

In North America, from the Genesis state all the way to the end of the 20th century the need for engineering that resulted in expansion of the need for engineering education were related to conflicts, industrial growth, and economical as well as political competitiveness [19].

Most of the developments all the way to late 1960's were more or less due to the demand of having skilled engineers who can do things. This was a pragmatic approach in which engineers where operators who would design, modify, build, operate, and make things happen. Many inventions, implementations, and great technological advances were attributed to such attitudes that engineers had. During such times, engineers, physicists, other scientists, and mathematicians would work together, synergize their actions to make new technologies, and create new things.

After World War II few things were clearly needed. There was a need for designing, implementing, modifying, and operating complex systems [25]. So, science and engineering educators started to work synergistically to fulfill the need.

Engineering education, due to the pragmatic aspects of the approach, were very successful in these years and one can see a notable involvement in project management, field operation, and design of the space projects by engineers and engineering graduates. In a sense, those are the golden years of engineering. These golden years of engineering (focusing on major and large scale projects) also overlapped the Cold War era, due to the need of creative and practical professionals.

World War II was a transformational time for engineering education. The development of communications and weapon systems were mostly void of engineers as project leaders. The main achievements in radar and communication and the advanced weapon systems that eventually lead to the atomic power were lead by physicists with the help of engineers. Almost all of the key leaders in weapon development, communications, and other related areas were physicists and scientists.

Upon reflection many engineering schools starting with MIT and other national leaders identified what the engineering curricula lacked. Consequently, there was an infusion of more science and mathematics in engineering education. Consequently, during the 1950's and 60's engineering faculty were instrumental in bringing mathematics and a more physical science base to engineering curricula.

Perhaps the great increase in demand for more integration of engineering, mathematics and physical sciences was triggered by Sputnik and the race for space exploration, which was followed with the very competitive phenomena of the Cold War.

Engineering and undergraduate education changed significantly after WWII and the Cold War due in large measure to federal funding to support research. With the increased emphasis on research, most college faculty were hired who could contribute to this research focus and the number of faculty with significant industry experience declined. Curriculums began to change to strengthen more theoretical basis; naturally the practical aspects did not get as much time as they used to [19].

One particularly significant change was the emphasis on engineering science. The American Society for Engineering Education had released the findings of a study referred to as the Grinter Report which provided a framework for the advancement of engineering and engineering science in 1955 which followed with other reports in the 1960's [26]. The report also suggested that the country needed two types of engineering programs: one that was a continuation of the practice oriented programs of the past with upgrades in math, science and liberal arts; the second focused on engineering science to prepare graduates for careers in research labs and academia [8-9].

The success of the space project was immense. The space project allowed huge amounts of money to be devoted to schools and university programs. Engineering programs had a good share of them and what the 1950's, 60's, and 70's showed was the practicality and capability of engineers. The Mercury and Apollo programs had engineer managers (the original Mercury astronauts all had engineering education as well as some military training and flight experience.)

In the 1960's and 70's, due to success of the space program and the large projects in communication, the power industry, manufacturing, and defense many universities tried to create environments that would attract large-scale projects that would, in turn, attract federal level funding. It should be noted that many of the grand projects that were given national funding, such as the space program, were successful synergies that would bring mathematical, physical, abstract and practical elements of sciences and engineering together. These programs overall did have a practical focus and inspiration for larger systems and interaction. Consequently, these programs drew and enabled many leaders and practitioners in engineering [19].

The 1970's and 80's was the era that large government money such as National Science Foundation (NSF) and others were granted and universities demanded a different approach from engineering professors. By the middle of the 70's some engineering departments become leading researchers in practical as well as mathematical and scientific endeavors. During this decade there was a shift from practical experimental work in engineering schools to more mathematical and conceptual work. This effort was aiming at attracting faculty and individuals who can bring more and larger research grants to the departments and schools.

In the 1990's the general trend for colleges of engineering continued to be toward producing graduates with increased math, science and analytical skills. Curricula continued to diverge away from practical skills to theoretical knowledge. The 1990's and 2000's have been years of interesting changes [1-5]. The world became more technologically competitive, and the global economy is more widespread throughout various nations. There were many opportunities for global level work in innovation, invention, and independent design agents. During all of this, one needs to wonder what should we do with the engineering curricula to encompass more of the needed thematic perspectives together with the right detail and rigor to enable our students to roam, create, compete, and invent in the new decades and beyond?

With all this change and interaction in the field, engineering schools are challenging some of the traditional basics. Do we need chemistry or biology? How much physics and in what form do we need for engineering? How much calculus and in what form and approach do engineers of the future need? These are questions that seem to be trivial in a more traditional time, but in the ever expanding, constantly changing, and always challenging world of the mega-disciplinary, where nontraditional areas are created and demand interactions, even the most basic traditions will have to be questioned.

IV. Engineering Education: What does it mean?

As times change and the various demands that are pulling engineering education away from the traditional trends are increasing, every educator is questioning what is essential and what is needed. Engineering remains to be one of the most sought STEM education fields [1-4,27-30]. Many corporations and small and large businesses are indicating the need for more engineering and technically savvy people; this need is increasing and the trend will continue in the next few decades.

On the other hand, engineering is still expanding. There are new areas in bioengineering, reengineering, renewable resource engineering, cyber-security, robust embedded programming and many other fields, which require new courses as well as new mixtures of traditional engineering classes. Currently, we are living in an expansion and mixing of engineering, sciences, social sciences, medical sciences, political sciences, and many other fields. Consequently, many schools are trying to reduce the required classes for engineers and provide more flexible educational pathways in engineering education. Students will have options to go deep in a specialized field, as well as become versatile in multidisciplinary area mixing engineering and non-engineering disciplines.

V. Engineering Education: What makes it different that other areas?

The main issue to focus on is what constitutes engineering, and what is in the core of this education that makes it different from other fields. Many fields claim similar approaches, in a liberated manner, but what makes engineering unique? In addition we should be careful to make sure that the engineering students would not get a confusing message about what engineering is.

What makes engineering education different is a balanced mixture of sciences, mathematics, technical and technological basics, engineering processing, systems level approach to learning and problem solving, design, ethics, and professionalism. Historically, what makes engineering different is the pragmatic approach to problem solving, design, and invention. Engineers are tooled with science and analytical methods to systematically understand problems, and providing working solutions based on functional requirements and constraints that defined and specify the given problem [31-32]. This is, and has to be, the essence engineering education, but at times students do not see this or any practical/pragmatic aspect of engineering in their required engineering classes. Engineering students would like to see ways to achieve what they think engineering is all about: making things, doing things, and inventing [30].

Engineering students are willing to go through the tough classes, demanding schedule, and long extended study of mathematics and physics, if they see what it all means in context. We cannot take the mathematical analysis and scientific focus out of our curricula; we need to put it in the context that is palatable to engineering training. The context that engineers are mostly interested in (has been and will be) is solving practical problems, inventing new things, designing things that will help others and possibly change the world. This is what makes them excited.

Consequently, the liberating part of the engineering education, that seems to be not clear in most of our current curricula (but the intention clearly is there), is what makes our students different from all other problems solvers and critical thinkers. It is the pragmatic part of the education and makes the difference. It is the practical essence that enables the student to modify, improve, create, invent, and design things that makes a difference in people's lives.

It is interesting to note that John Dewey, the American pragmatic philosopher, also reflects what we find interesting in the engineering pragmatism. There are numerous findings that recognize the practical importance of his work for pragmatic engineering education [10,11, 24,33-36].

The way to achieve this in our curricula is to have numerous venues in our programs to enable students in different laboratories and studio settings to design, engage in hands-on activities, play, tinker, build things, and learn the art of engineering. Our curricula need to have more room for practical experiences that allows student to design, implement, fail, and learn to overcome the failures. Tinkering, making mistakes, and learning from all the failures are the most important parts of inventions, design, and learning. Students need to have project that would get them from the thoughts to a finish projects. They need to build things.

There is openness in liberal arts education that is designed to expand the students' minds. That is why more than a few scholars have suggested the progression toward a more liberal education for engineering students [3-9]. If in the liberal education, it is the vocational parts that liberate the student to open their minds, learn, examine, expand their knowledge base and be creative, it is due to the fact that the vocational part enables the student to make a living, to make something tangible [1-2]. For engineering education, it is the pragmatic aspect of the education that will be liberating. Students will find the reason to do all the studying, the seemingly endless challenges of the classes and projects.

VI. ENGINEERING: WHAT WE CAN LEARN FROM THE GREAT PHYSICIST PAUL DIRAC

The great physicist/mathematician Paul Dirac has been one of the most influential thinkers of the 20th century. His contribution to quantum mechanics and to our modern view of the world will last for centuries [20-22]. His name will remain one of the most cited in all sciences, mathematics, and engineering fields. It is interesting to know that Paul Dirac started as an engineering student and left the field to study mathematics and physics. However, his colleagues always mentioned (he also talked about it in his invited talks) that he wished he had stayed in engineering [20]. He thought he could "DO" much more as an engineer. Dirac truly valued all aspects of doing, making, designing, and creating new things that engineers do. He thought that such activities were wonderful capabilities that should not be taken for granted.

His statement reflects his desire to "make something" and to change the world. He felt a liberating element in that essence of engineering. For him engineering offered the noble capability of doing, making, and being transformational for the society. This should be one of the philosophical themes of all of engineering educators and needs to be reflected in our curricular development. For him that was the difference between engineering and science education.

As engineering educators, most of us believe that our intentions include having a practical approach to problem solving and design that uses science and mathematics as the basis. We all know of many classes and programs that are doing very effective jobs in that direction. However, we should also self reflect and always think about the bigger picture.

The main question is: Is the core philosophical basis of our curricular approach truly pragmatic and design based? Or, are we focusing mostly on models, physical formulations, and many important facts? Things we believe all engineering needs to do, but at a level that the pragmatic approach of engineering (that would hopefully result in invention and making things) is becoming a secondary issue [17-18].

Curricular design has to be focused on major outcomes. Thinking about and engaging in design, invention, making new things, and seeking to understand the essence of engineering should be the most important goal. The truth about many programs is that while these are some of our valued objectives, they are not reflected in their major outcomes [6-9].

VII. FINAL REMARKS

This paper reviewed the general trends in engineering education and how it changed as it faced different challenges in the 20th century. The issues of the modern time - changes on global economy and knowledge connection and interconnections - were also addressed. The main goal is to find ways to achieve more effective engineering curricula approaches that will enable our students to face the challenges of the new decades. This paper argues that main point of the development that would benefit students and enable them to be better problem solvers in their future endeavors is creating numerous venues in the engineering programs for design, studios, hands-on activities, and more effective pragmatic classes and activities in the engineering curricula. This seems to be the true essence of engineering that will inspire and enable students to enjoy and benefit from engineering. The pragmatic essence of engineering education needs to be the unifying backbone of all engineering education.

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Finding and Facing the Frontiers at FIE Conferences

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Abstract—**Each year since the founding in 1971, Frontiers in Education Conference participants have sought the newest innovations and concepts in engineering education, i.e., the true frontiers at the cutting-edge of the profession. While those frontiers have obviously changed over the past 42 years, the primary objective of identifying and addressing them has remained at the forefront. This WIP paper describes what was perceived as the main frontiers in each of four periods corresponding to the four decades since the first conference by examining papers from two sample conferences in each decade. In addition to a careful analysis of selected FIE Proceedings, results of a brief survey of long-time FIE leaders and more recent participants are presented as further evidence on identifying the recognized frontiers for each period. Changes during the intervening years of the conference included more formal presentations, required reviews before accepting papers, and references to clearly show the relevance of each paper within the body of knowledge. Currently, papers are categorized as innovative practice, research-to-practice, or research; an emphasis on STEM research nationally has created engineering education departments within universities. Faculty and staff from these departments regularly present their research results at FIE Conferences. The overall goal for conference organizers and program chairs is to make certain not only that accepted papers point to existing frontiers as the major focus of the FIE Conference each year but also include invited speakers, sessions, panels, and keynote addresses that focus on other emerging frontiers.**

Keywords- true frontiers in education, engineering education, cutting-edge educational research, FIE Conference changes

I. INTRODUCTION

The ultimate success of FIE Conferences can be measured by how well conference participants identify and address the true frontiers in engineering education. Currently, FIE Conferences have matured to the point that they rejuvenate themselves annually due to the enthusiasm of first-year, five-year, and ten-year participants who seek to learn about frontiers in engineering education and present their own research in the area. NSF funding has spurred this interest over the years with workshops and conferences such as the "Mapping the Field in Engineering Education Research" conference conducted this spring by Finelli [1]. Both FIE and ASEE annual conferences continue to benefit as arenas to present research findings.

This WIP paper describes the focus of FIE Conferences over the past 42 years by showing an analysis of papers from two sample conferences in each decade [2]. Papers are grouped into categories, e.g., educational technology and self-instruction, that suggest conference participants may have regarded, for the most part, these topics as frontiers at those points in time. Continuing work is underway to identify other true frontiers in retrospection, i.e., those with few papers but ones which have become forerunners of true frontiers emerging later in time. Before presenting an analysis of papers from these four decades, results of a brief survey of over 50 FIE participants shows what they regard as true frontiers, mostly at the present time.

II. BRIEF SURVEY RESULTS

A brief survey asking only two questions was sent to over 50 FIE participants; many had limited experience with FIE and some were long-time FIE leaders, including past and present members of the FIE Conference Steering Committee. Not all FIE leaders were contacted (my apology to them) but representative responses were received. Questions were:

1. What do you regard as the true frontiers in engineering education and how have these changed since you first attended an FIE Conference?
2. How closely and to what depth are we addressing these true frontiers at our annual FIE Conferences?

Typical responses to the first question were:

- On-line learning, international issues, diversity issues (especially in student groups), and resource constraints (such as energy).
- Engineering education research and how it affects the education of large numbers of students, i.e., how best to influence learning.
- On-line and asynchronous learning that accomplishes the challenge of enhancing personalized learning.
- Focus on the K-12 scene.
- Effective teaching for large numbers of students who partially direct their own learning.
- Challenges are scalability, accessibility, credentialing, and cost control in the internet age.
- Connect research to practice in a way that positively affects the success of large-scale educational reform.
- On-demand learning technologies and methods for utilizing them effectively for distance and local learners.
- The generational shift seen in student motivation, affecting linear thinking by multi-play gaming,

hyperlinked movement through information presentation, and attention-span shifts in media-rich environments.

- Blended learning involving web, text, lecture, and lab in the areas of technology and delivery. Building on the body of knowledge in engineering education with the goal of a stronger impact on the discipline.
- Undergraduate and graduate degrees that are totally on-line, including labs associated with these degrees.
- Determining the essence of engineering that must not be sacrificed and reaffirming what our students need to learn (curriculum), developing techniques that adapt our activities to how students learn and obtain wide-spread faculty buy-in, continue to utilize technology for learning, promote women and minority recruitment and retention (stuck at 20%), promote globalization as part of professional practice, and use courses that are not "open" but have the potential of offering effective learning experiences to large numbers of students.

Responses to Question 2 on how well FIE Conferences are addressing the true frontiers varied between "There are a lot of disconnected efforts and little synthesis" to "We are doing a reasonable job but could do better". My own response is that early conferences did an adequate job and have improved considerably to very good in recent years, perhaps overly optimistic among some FIEers.

III. AN ANALYSIS OF SURVEY RESULTS

According to the survey results, the primary current frontiers in engineering education include:

- Learning with an emphasis toward on-line learning and learning strategies for large numbers of students.
- New technologies and methods that promote more effective learning, including blended learning between web, text, lecture, and labs in the areas of technology and delivery.
- Promoting women and minority recruitment and retention.

On-line courses (some leading to on-line degrees) for large numbers of students, the use of improved technology, and recruitment and retention issues remain at the forefront of frontiers at FIE Conferences in the decade of the 2010s.

IV. TOP FIE TOPICS BY DECADES

Table I shows a listing of what may have been regarded as true frontiers at past FIE Conferences. Two conferences were selected randomly from each of the four decades. As an aside, the author is one of the very few FIEers who has a complete file of every FIE Proceedings. Paper topics from the selected Proceedings were grouped into categories with the most popular topics included in the table. The table shows the number of papers, the number of sessions presented at each conference, and the percentage of the total in each case.

My own recollection was reinforced with the review of topics from these conference proceedings. Conference planners were continually asking whether the true frontiers were being addressed. Plenary sessions were held at several conferences with titles of "Trends in Engineering Education", "The Future of Engineering Education", and "Where are the Frontiers?" A diligent effort was evident in keeping the conference at the forefront of the frontiers.

Table I. Top Categories of FIE Topics for Selected Years

Year	Category	Papers	Sessions
1973	Uses of Technology	14 (13.2%)	4 (25.0%)
	Self-Instruction	13 (12.3%)	3 (18.8%)
	Laboratories	8 (7.5%)	3 (18.8%)
	Learning Methods	7 (6.6%)	2 (12.5%)
1980	Computers in Education	17 (20.2%)	4 (16.7%)
	Learning Methods	16 (19.0%)	3 (12.5%)
	Self-Instruction	8 (9.5%)	2 (13.3%)
1982	Humanities and Engineering	10 (16.7%)	4 (20.0%)
	Computers in Education	8 (6.7%)	3 (15.0%)
	Learning Methods	4 (3.3%)	2 (10.0%)
1987	Computers in Education	26 (15.8%)	5 (20.8%)
	Retention and Gender Issues	16 (9.7%)	3 (12.5%)
	Senior Capstone	9 (5.5%)	2 (8.3%)
1991	Retention and Gender Issues	20 (12.5%)	5 (12.2%)
	Design/Senior Capstone	17 (10.6%)	4 (9.8%)
	Professionalism	13 (8.1%)	3 (7.3%)
	Computers in Education	10 (6.3%)	2 (4.9%)
1995	Learning Models	50(18.7%)	10 (16.9%)
	Design/Senior Capstone	25 (9.4%)	5 (8.5%)
	Retention and Gender Issues	15 (5.6%)	3 (5.1%)
2002	Learning Models	45 (31.0%)	9 (31.0%)
	Laboratories	20 (13.8%)	4 (13.8%)
	Computer Science	20 (13.8%)	4 (13.8%)
	K-12 Issues	20 (13.8%)	4 (13.8%)
2007	Learning Models	36 (6.0%)	6 (6.0%)
	Uses of Technology	30 (5.0%)	5 (5.0%)
	Assessment (ABET)	24 (4.0%)	4 (4.0%)
	Computers in Education	24 (4.0%)	4 (4.0%)

V. AN ANALYSIS BY DECADES

Table I shows that learning methods has been a primary frontier since the inception of the FIE Conference in the early 1970s. In addition, the use of technology has continued as a primary theme. Computers are also listed in many of the Proceedings that were examined. What is less evident is that the frontiers have been increasingly NSF-driven, ABET-driven, and gender-driven. NSF funding has greatly influenced FIE participants who have reported findings in NSF-sponsored contracts at universities through the decades. It is the recent

NSF emphasis on STEM research nationally that has prompted the creation of engineering education departments within universities. Faculty and staff from these departments regularly present their research results at FIE Conferences. ABET-driven frontiers are prominent in design, senior capstone, and assessment topics identified in 1987, 1991, 1995, and 2007. Gender-driven issues, including recruitment and retention, are shown in 1987, 1991, and 1995. The author recalls attending a women in engineering FIE session at WPI in 1983 while chairing the Dasher Best Paper Committee.

VI. A NOTE FROM HISTORY

At the request of the then IEEE Education Society president, a report was presented in June 1989 at the ASEE Annual Conference in Lincoln, NE regarding the future of the Society's co-sponsorship of the FIE Conference. Serious questions had been raised at that time about the loose structure of the conference, the review process for conference papers, and whether the Education Society would continue as a sponsoring participant. Wisely, the Education Society report based on the advice of past and present FIE leaders was positive. The FIE Conference Steering Committee then readily took immediate action to resolve concerns and move the conference forward without disruption. It is my opinion that the Steering Committee continues to have excellent leadership and committee membership. My observations in this WIP paper is not meant to overstep their authority but to support their enthusiasm for a better conference. FIE participant input can always be useful, especially in view of thoughtful observations by long-time leaders.

VII. DISCUSSION

The FIE Conference appears to have "taken on a life of its own" in recent decades and reinvents itself approximately every three to five years. Table I does not reveal this observation but focuses on the history of the conference since the 1970s. A mature conference consists of many papers that are based on extrending the state-of-the-art from year to year (or less often); a mature conference has papers that cite the very recent findings as a baseline for further research; and a mature conference has many papers which are appropriate as springboards (with additional work) for journal papers. With its NSF-sponsored STEM research focus, for example, the FIE Conference has an increasing number of papers that fit this mode for a mature conference.

VIII. CONCLUSIONS

This WIP paper has discussed the quest of the FIE Conference planners and participants in their search for addressing the true frontiers of engineering education. It was interesting and informative to receive the survey results and to review the many topics covered in several conferences during the past 42 ears. It is evident that the FIE Steering Committee might be interested in knowing the responses to the survey questions.

If this WIP paper is received favorably by the FIE audience, it is planned to work with the Conference Steering Committee and expand to invited sessions/panels at future FIE Conferences. Conference organizers require cutting-edge results in submitted papers and already seek out invited speakers for identified emerging frontiers in engineering education. .A regular feature with rotating organizers (session/panel chairs) having varied perspectives could focus on identifying these true frontiers.

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An Exemplary Design Framework: A Small-scale Prototype of Home Area Network in a Smart Grid

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Abstract—**In this paper, with a specific application to a Smart Grid system in mind, we present a small-scale prototype system of wireless networks and design details of the prototype system. From the perspective of undergraduate engineering education and learning, we describe how the project team of undergraduate students has overcome technical obstacles and challenges in successfully completing the prototype system. For an outcome of this project, we also derive a set of laboratory experiments for integration into a laboratory-based course for improvement in learning effectiveness and overall undergraduate engineering education.**

Keywords—Smart grid, utility meters, ZigBee networks.

I. Introduction

One of the recent trends in technology development in the United States is modernization of the electric power grid, or the Smart Grid. At the core of the Smart Grid vision are information and communication technologies. For the coordination of the efforts, National Institute of Standards and Technology (NIST) published its latest Framework and Roadmap for Smart Grid Interoperability Standards in 2012 [1]. Reflecting this recent trend onto engineering education, a small-scale prototype of home area network for end users in a smart grid has been developed in our lab with participation of a small group of undergraduate engineering students. The objectives of this project are 1) to develop power- and water-metering subsystems that collect usage data and 2) to develop a software-based graphical user interface (GUI) for a remote monitoring center.

Facilitating collection of energy-usage data and delivery to a remote monitoring center, this prototype is intended to provide an engineering design framework to undergraduate students for application of their classroom-acquired engineering knowledge to contemporary real-world problems and to ultimately enhance students learning experience. The primary functionality of this prototype system is for collection and delivery of energy-usage data from end users, e.g., smart homes, to a remote monitoring center. More specifically, in this prototype system, a set of off-the-shelf wireless communication devices, e.g., ZigBee [2], are employed to establish wireless links between off-the-shelf power- and water-meters and the remote monitoring center with a meter-reading GUI. The set of power- and water- meters are integrated with the wireless communication devices and installed at select target spots in a laboratory setting. The remote monitoring center communicates with its wireless communication devices that receive data from the other wireless communication devices at the meters. The GUI at the remote monitoring center is implemented on a Windows 7-based computer using LabVIEW [3] as a design tool and collects and displays the usage of water and electricity at the target spots. The physical communication link between the wireless communication device and the GUI is realized in two different modes of operation: Ethernet-based and USB-based.

In the following, more details of the prototype system are provided. We also describe how the students have overcome obstacles and technical challenges in implementing the prototype system, as well as how the outcomes of the project could be integrated into courses as a framework for undergraduate engineering education.

II. Overview of the Project

A. Conceptual Architecture of the Prototype System

The concept of this network architecture, as shown in Fig. 1, is to establish communication capability by a) attaching a vendor-specific ZigBee, also known as 485Bee [4], to a vendor-specific software through the Ethernet via RS485 or b) via a RS485 to USB converter, and 3) also attaching a more general ZigBee [2] to a LabVIEW-based GUI via USB. These ZigBees (or 485Bees) will receive signal/data from other ZigBees (or 485Bees) which will be placed in target spots to get the readings from the meters and transmit them over

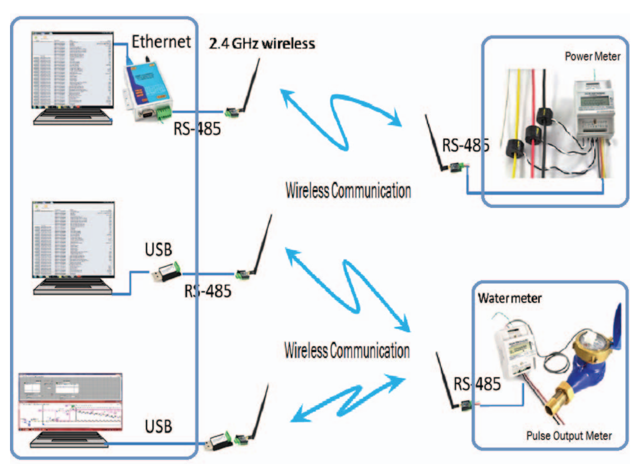

Fig. 1: Architecture of the prototype system

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the wireless communication links to the vendor-specific meter-reading software or a LabVIEW-based GUI built in our lab for proper display of the utility data.

B. Key Components of the Prototype System

The key components of the prototype system include ZigBees, 485Bees, a TCP/IP-to-serial converter, current transformers, water meters, and pulse counters. ZigBee [2] is a type of wireless communication device that uses a protocol of IEEE 802.15.4 to transmit and receive data within a small area at the 2.4 GHz frequency band, with the maximum bit rate of 250 kbps. ZigBee follows the wireless mesh networking proprietary standard which provides high reliability and larger range in communication up to 100 meters. It is inexpensive, hence, allowing the technology to be widely deployed in wireless control and monitoring applications. The power consumption is low and thus, it is cost effective. 485Bee [4] is a vendor-specific system built around the commonly used ZigBee chips. Its features include hard-wired RS485 to wireless ZigBee, communication range of up to 200 meters with a 900 MHz antenna, and an external DC supply in the range of 6V∼42V to power up the circuit board.

A vendor-specific TCP/IP to RS485 serial converter, known as iSerial (version 2) [5], is utilized. This converter is equipped with 8051 CPU, 64 kilo bytes (KB) ROM, 32 KB SRAM, 10/100 Mbps Ethernet, and a serial port that supports hand-shaking Request-to-Send and Clear-to-Send (RTS/CTS). Its features useful for the project include 3-in-1 RS232/RS422/RS485 interface with max. 230 kbps serial interface and 10/100 Mbps Ethernet, support for 4- and 2-wire RS485 with AUTO-SEND and built-in terminator, and IP configuration by MAC address. For the pulse counter for the usage data of electricity, an off-the-shelf device, known as OmniMeter Pulse (version 4) [6], which is also known as the Universal Smart Meter, is employed. This meter works with 4 different voltage systems including 120 volts (2-wires, single-phase, 1 Line and Neutral) and its current range can go up to 5000 amps. An external Current Transformer (CT) (50/60Hz) shown in Fig. 2(a) may be needed to take the measurement.

For water usage, a Pulse Input Meter (i.e., EKM-25EDSP-N v.2) was initially used for the prototype system to keep track of the 3 output pulses produced by the Pulse Output Water Meter [7]. The pulses-to-units ratio was configurable in the meter from 1:1 to 1:9999. These pulse counts were held in the non-volatile memory. But, later, as this device became discontinued, the OmniMeter was used for the purpose of gathering the water usage data from the Water Meter. For the current transformer, split-core CT [8] is used which can be snapped around any of the load wire to take measurements of the load within the range of 1 to 200 amps with an accuracy of 0.1%. The Pulse Output Water Meter shown in Fig. 2(b) produces a pulse for every 1/10 cubic foot (approximately 0.75 gallon, or 2.83 liters) that flows through the meter. These pulses can then be picked up and counted by OmniMeter Pulse v.4.

III. Project Design and Self-directed Learning

The technical details given in this section are the outcomes of the self-directed, hard work by the project team as device manuals often do not have sufficient details for anyone new

(a)

(b)

Fig. 2: (a) Current transformer (b) Water meter

to the devices. These descriptions may still not be sufficient for some readers but are deemed to be able to facilitate easier integration of these devices when combined with the manuals.

A. Configuring ZigBees

X-CTU [9] is a simple GUI supplied by the vendor and is used to configure ZigBees with a USB cable from its board plugged into the computer. For the proper configuration, it is necessary to check first which COM port is used on the computer so X-CTU can use a correct port assigned to the ZigBee. Once X-CTU is invoked, its default screen is for PC Setting. Communication parameters are set for i) 9600 baud rate, ii) no flow control, iii) 8 data bits, iv) no parity bits, and v) 1 stop bit. Once these parameters are set, testing can be performed by clicking on the “Test/Query.” If ZigBee is communicating with the X-CTU via the assigned COM port, a message will pop up showing information about the ZigBee; otherwise, an error message is displayed such as “Unable to Communicate.” If that happens, checking more carefully the parameters in the PC Settings or changing the ZigBee and/or USB cable may be necessary. If all that fails to make ZigBee respond, it is recommended to double check the version of X-CTU as the older versions than v5.2.7.5 exhibited unstable operation on some computers during our lab testing. Then, under the “Modem Configuration” tab, clicking on ‘Read’ will import and show all configurable parameters of the ZigBee. For instance, Channel Number, Personal Area Network (PAN) ID, and/or Baud Rate can be changed. After making necessary changes, clicking on ‘Write’ saves the changes into the ZigBee chip. When all ZigBee chips for the prototype system are configured, testing is desired in a point-to-point mode to see whether two ZigBee chips are successfully communicating with each other. For this, both ZigBees need to have the same PAN ID. Connecting two ZigBees to their respective X-CTU on the same computer or on two different computers, test messages can be entered under the ‘Terminal’ tab and transmitted to the other ZigBee; if the same message is shown on the X-CTU for the second ZigBee, it means that both ZigBees are configured properly and communicate with each other.

B. Connecting and Configuring Metering Devices

Connections to an OmniMeter for metering of electricity usage require careful examination as the instruction sheet that came with the device may not be sufficient for a plug-and-play. As shown in Fig. 3, first, clamp a CT around L1, making sure that the arrow on the CT is facing towards the load. Then, for wiring of the CT, connect the black wire to Port 1 of

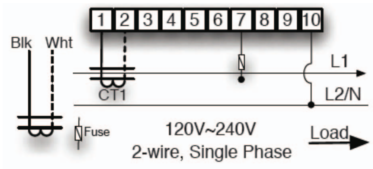


Fig. 3: Connection diagram

the OmniMeter and the white wire to Port 2. Connect a 1.0 amp, 250V fuse between Port 7 and L1 using 16-22 AWG UL standard copper wire. Connect the Neutral wire to Port 10. For connections of RS485 (485Bee), connect Terminal 20(A+) of the OmniMeter to RS485(A) and connect Terminal 21(B-) of the OmniMeter to RS485(B).

For the water meter to properly output the pulse counts, a 240V power was required for the Pulse Input Meter (but not for OmniMeter). As such, for connections to a Pulse Input Meter for metering of water usage, a European travel adaptor (converting 120V to 240V) was employed with its hot wire connected to Port 7, and the Neutral wire connected to Port 8; all positive wires from the Pulse Output Water Meter were wired to the respective Ports 11, 12, and 13, and all negative wires from the Pulse Output Water Meter were wired to Port 14 (the common ground). Then, RS485 was connected as described above for the metering of electricity usage.

C. iSerial Configuration

In order for our computer to be able to communicate with the iSerial, configuration for networking has to be performed. First, check if the Local Area Network (LAN) for the computer uses one of the predefined iSerial-specific IP addresses ranging from 192.168.1.2 to 192.168.1.254 with a subnet mask of 255.255.255.0. With the default IP Address of iSerial being 192.168.1.125, if the IP address of the computer is not in the same domain, i.e., 192.168,1.xxx, the networking parameters of the computer need to be properly changed. For this, with iSerial connected to the computer via an Ethernet cable, type in http://192.168.1.125 into the Internet Explorer for configuration of iSerial. On the configuration window, enter an appropriate username and a password. Click on tabs to go to Administrator>System IP Address, and ensure that IP Address (default: 192.168.1.125), Subnet Mask (default: 255.255.255.0), Gateway (default: 192.168.1.1), and Primary DNS (default: 0.0.0.0 and 192.168.1.1) are set properly. Note that while the IP address for iSerial can be changed, the password must not be forgotten as there is no mechanism to reset the password. These networking parameters are for the static mode of operation. If a custom router that can automatically assign an IP Address is used between the host computer and iSerial, then the Dynamic Host Configuration Protocol (DHCP) mode can be used. To update the iSerial with any changes in this mode, it may be necessary to enable and assign VLAN ID to 0001 and then disable again (to get around a bug in the control software). Then, finally, click 'Update' after making necessary changes.

The iSerial can operate in four modes: TCP Server, TCP Client, UDP Server, and UDP Client. In our case, the TCP Server mode is used. For this, in "TCP Mode" and 'DIDO' Tabs, set Port Number to 50000. On physical connections, 3 types of connections to iSerial are supported: RS232, RS422, and RS485. The default setting for metering is via RS485. The corresponding parameters can be set under UART Control tab such that Baud Rate is set to 1200, Character Bits to 7, Parity Check to 1, and Hardware Flow Control to None.

D. Meter-reading Software

The vendor of the metering devices has initially supplied a software module [10] (that is later replaced by a new software module described below) to read and display received metering data, as well as polling to solicit metering data from remotely located electricity and water meters. For configuration, after opening up the vendor-specific software, go to File>Preferences>COM Port Setup to set up the communication devices. In this setting, each line represents a communication device and the line number is the number that will be used later in the main window for the TCP Port or COM Port number. Under "Meter Type", select v.2 for the pulse meter and v.3 for OmniMeter, and under "COM Port" select iSerial for both. Then, enter "192.168.1.125" for the IP address and '50000' for the TCP Port number. Finally, click 'Save.' Note on which COM Port is listed on which line number as this information will be needed later when the software is used to read data from a particular metering device. Then, in the main window of the software, enter the TCP Port number which is associated with the line number in the COM Port Setup window. Along the line, enter the meter number which can be found on the meter itself. (e.g., for a meter serial number "S/N 000000003016," type '3016'). Before clicking "Read a meter," also enter the meter number and COM Port number right below that button.

EKM Dash [11] is a newer version of the meter-reading software that consolidates reading capability for both Pulse Input Meter (for water meters) and OmniMeter (for electricity meters). To configure, after opening up the EKM Dash, click "Meters>New Meter" to enter the meter name and select an appropriate EKM meter model from the Meter Model drop-down list. Enter the meter number in the Meter Number field (e.g., for "S/N 000000003016", type '3016'). Click on the Remote tab and type in the iSerial IP Address "192.168.1.125" and '50000' for iSerial Port. Change Read Interval from 'Disabled' to "As fast as possible." Click 'Ok' and then "Start Reading."

E. Design of GUI with LabVIEW

In addition to the vendor's meter-reading software, our own software is developed in LabVIEW. LabVIEW typically works with a dedicated data acquisition (DAQ) device from the vendor. However, in this project, the students were challenged to directly connect the USB-based ZigBee to the computer and thus the LabVIEW-based software without using any DAQ device. For this purpose, an existing LabVIEW-based design which was developed for different applications in our lab was provided to the students as a starting point. However, the existing design was for serial communication via RS232 and thus, was not directly compatible with USB. For a proper design, the student team came up with the following implementation:

1) Use **VISA Configure Serial Port** to initialize the serial port specified by VISA resource name.

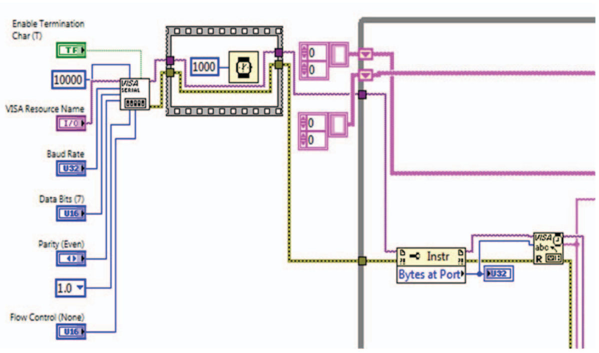


Fig. 4: Implementation in LabVIEW for USB interface

- VISA Resource Name specifies the resource to be opened (e.g., COM8, COM10, etc.)
- Baud rate is the rate of transmission
- Power Meter baud rate is 9600.
- Water Meter baud rate is 1200.
- Data bits are 7 for both Power and Water Meter.
- Even Parity is used for both meters.

2) Use **Property Node** to get or set the properties and methods on local or remote application instances. In our case, the team uses Serial Setting>Number of Bytes as Serial Port.
3) Use **VISA Read** to read the specified number of bytes from the device or interface specified by VISA Resource Name and return the data in Read Buffer.

Fig. 4 shows the implementation in LabVIEW that facilitates the USB-based serial communication.

F. Getting Data Transmitted from ZigBee Systems

As common in 3rd party devices and software, technical details are not known for asynchronous (i.e., serial) communication between the metering devices and the meter-reading software, while the design of our LabVIEW-based GUI requires all the details of such communication to be properly coded in the LabVIEW design file. The student team was instructed to explore techniques of "reverse engineering" to make reasonable guesses of such details and go on trial-and-error testing. For this, the student team placed a third ZigBee to receive metering data from one of the ZigBees attached to the metering device (e.g. OmniMeter) and used X-CTU to monitor what is transmitted between the first two ZigBees and how to synchronize the data for proper interpretation of binary data representing the metering data.

For this experiment, under PC Settings of the X-CTU, test first whether the 3rd ZigBee is connected properly and make sure the settings are appropriate to communicate with the other two ZigBees, e.g., Baud Rate set to 9600, Parity set to Even, and Data Bits set to 7. Then click on the Terminal

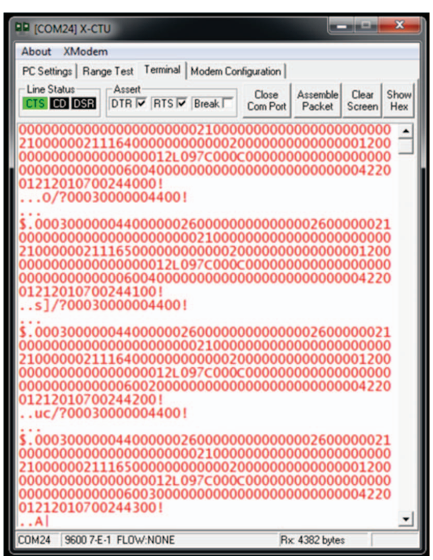
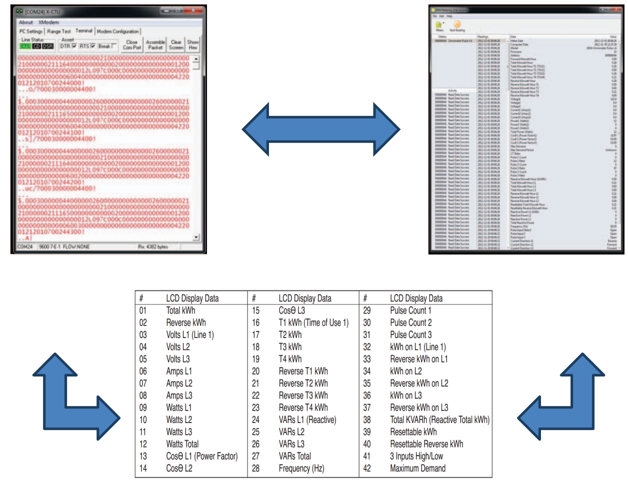
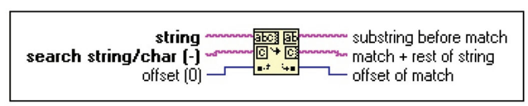


Fig. 5: Communication log on X-CTU interface

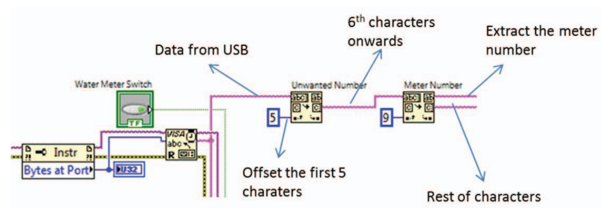


#	LCD Display Data	#	LCD Display Data	#	LCD Display Data
01	Total kWh	15	CosΘ L3	29	Pulse Count 1
02	Reverse kWh	16	T1 kWh (Time of Use 1)	30	Pulse Count 2
03	Volts L1 (Line 1)	17	T2 kWh	31	Pulse Count 3
04	Volts L2	18	T3 kWh	32	kWh on L1 (Line 1)
05	Volts L3	19	T4 kWh	33	Reverse kWh on L1
06	Amps L1	20	Reverse T1 kWh	34	kWh on L2
07	Amps L2	21	Reverse T2 kWh	35	Reverse kWh on L2
08	Amps L3	22	Reverse T3 kWh	36	kWh on L3
09	Watts L1	23	Reverse T4 kWh	37	Reverse kWh on L3
10	Watts L2	24	VARs L1 (Reactive)	38	Total KVARh (Reactive Total kWh)
11	Watts L3	25	VARs L2	39	Resettable kWh
12	Watts Total	26	VARs L3	40	Resettable Reverse kWh
13	CosΘ L1 (Power Factor)	27	VARs Total	41	3 Inputs High/Low
14	CosΘ L2	28	Frequency (Hz)	42	Maximum Demand

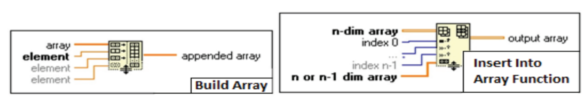
Fig. 6: Differences in GUI



(a) Search/Split String function for coarse extraction



(b) Refinement of string offsets



(c) Build Array for data collection

Fig. 7: Implementation in LabVIEW for data extraction

tab. In the next step, on EKM Dash, click “Start Reading” and see what is displayed on the X-CTU Terminal. Fig. 5 shows some logs of such communication. Then, the next step is to compare the readings collected in X-CTU and those displayed on the EKM Dash (or its previous version, if necessary) and the meter data displayed on the LCD screen of the metering device such as kWh, line voltage, power factor, etc. Fig. 6 shows the information displayed on a) X-CTU (top left), b) EKM Dash (top right), and c) LCD screen of the metering device (bottom), respectively.

To extract the data needed for the LabVIEW-based software, the Search/Split String function in LabVIEW is used as shown in Fig. 7(a). The String is the input value to the LabVIEW module, and Offset is a specific value that cuts the string into 2 parts; before and after the offset value. As further illustrated in Fig. 7(b), in our case, the offset is set to ‘5’ because the first 5 characters are not needed. The rest of the string is fed into another function to be cut again. The next offset is set to ‘9’ to draw out the meter number “300000044,’ and the value can be seen at “Substring before match” in Fig. 7(a). The rest of the values can be chopped in a similar fashion as shown in the figure.

Then, an array table as shown in Fig. 7(c) is built to process and display the data collected on the screen. Using Build Array in LabVIEW, the following values are gathered: Meter Number, Total (kWh), Reverse (kWh), Line Terminal (kWh), Reverse Line Terminal (kWh), Voltage (V), Current (A), Total Power (W), Line Power (W), Power Factor 1, Power Factor 2, Power Factor 3, Frequency, Date, and Time. Finally, the “Insert into Array Function” is used to specify the rows and columns for respective data mentioned above. The table shown in Fig. 8 illustrates the end result of the design in the LabVIEW. Some additional processing has been performed as well, using Case Structure and Boolean to allow the correct 9 digit meter number and also to make sure that the readings are from the correct meter number. Also, a While loop is used to execute the program repeatedly until the ‘STOP’ button is pressed.

G. Integration of Subsystems

Fig. 9 shows the integration of the subsystems around the GUI. As shown in the figure, one of the 485Bees was connected to the iSerial via RS485 and then to the computer through an Ethernet cable (for the meter data displayed on the EKM software). The other 485Bee was connected to the RS485 to USB converter (for the meter data displayed on the LabVIEW-based software). Although not legible in the figure, the EKM software was able to receive and correctly display the incoming data from both meters. In the data collection side, as illustrated in Fig. 10(a), the OmniMeter is powered up by the 120Vac supplied from the wall. The current transformer is clamped around the load line, ensuring that the arrow is pointing towards the current to the load. The 485Bee is then connected to the OmniMeter at terminals 20 and 21. An

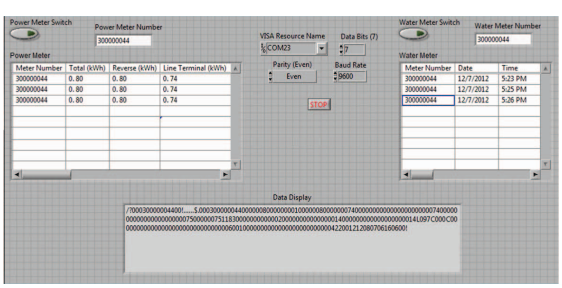


Fig. 8: Snapshot of LabVIEW-based GUI

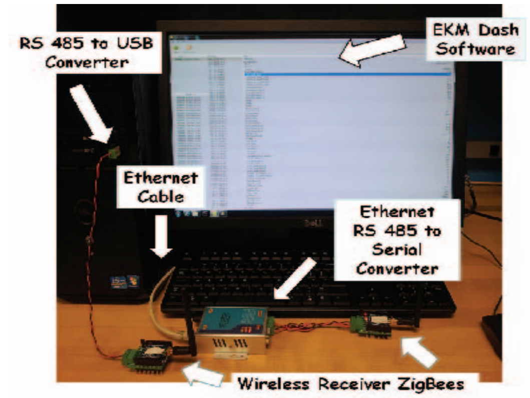
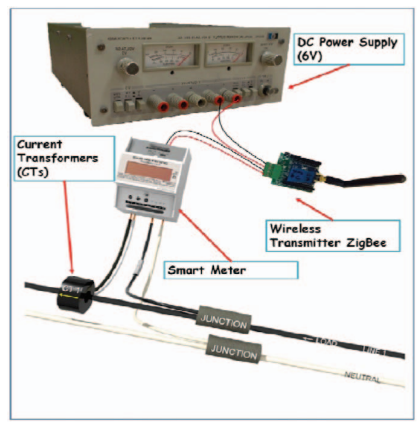
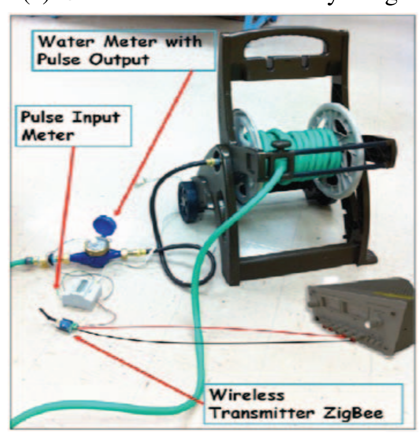


Fig. 9: Connections to GUI



(a) OmniMeter for electricity usage



(b) Pulse Input Meter for water usage

Fig. 10: Illustrative connections of utility meters

external DC power supply of 6V is supplied to the 485Bee in order to power up the 485Bee. The Pulse Output Water Meter (or simply Water Meter) is connected as shown in Fig. 10(b) between the water hoses so as to allow water to flow through. The Pulse Output Water Meter counts and produces a pulse for every 0.75 gallon of water flowing through. From the Water Meter, there are two wires coming out which are connected to the Pulse Input Meter at terminals 11 and 12. The 485Bee powered by an external DC power supply of 6V is then connected to terminals 20 and 21 of the Pulse Input Meter. The Pulse Input Meter is powered up with a voltage supply of 230V from an AC power supply of 120Vac via a travel adapter which is used to step up the voltage. The 485Bees connected to the OmniMeter and Pulse Input Meter communicate with the 485Bees previously shown in Fig. 9.

IV. Application to Curriculum Development

As described in the previous section, the students were able to properly set up the power and water meters in order to obtain the usage data via 485Bees operating at 2.4 GHz. The team also successfully created its own meter-reading GUI in LabVIEW without using any DAQ devices. This GUI was used to replace the EKM software that came with the meters. During the project implementation, there were obstacles and issues. But all of these were believed to lead to an improved learning experience, with all the technical details down to the bottom to make the subsystems and the overall prototype correctly operate. Students expressed the appreciation of the learning from the project, quoting that up until this time they never had such hands-on work successfully completed as described in this paper.

The lab activities and technical details of this project tried with a small group of dedicated students appear to be appropriate for further development of course materials for a larger group of students. As an example, although ZigBee has been widely utilized for data transmission in hands-on projects at various levels including two-year programs (e.g., see [12]), as well as four-year programs (e.g., see [13]), it also offers another undiscovered capability as a tool to observe more details of underlying communication aspects between two communication devices. The utility meters used in this project are fairly new for adoption in engineering education, and appear to generate more students' interests in working with. LabVIEW has been widely adopted in engineering design but, as illustrated in this paper, our new attempt to not using vendor-supplied DAQ seems to create another great opportunity to enhance student learning experience. Suitable for upper division undergraduate students in electrical and computer engineering, the project activities described in this paper could better prepare them for carrying out more complex hands-on projects such as senior Capstone projects [14]–[17]. From the author's perspective, all the lab activities of this project could be applicable to creating a series of laboratory experiments for a semester-long regular course covering introductory communications aspects. As an illustration, Table I shows a suggested list of experiments. Particularly, this set of laboratory experiments combined with appropriate topic-based lectures would be suitable for an introductory communications course intended as an elective course in the first semester of the senior year in a four-year ECE program.

TABLE I: Set of Laboratory Experiments

Lab #	Lab Experiment
1	Serial communication via RS232 and signal measurement
2	Serial communication via USB and signal measurement
3	ZigBee Protocols and IEEE 802.15.4 Physical Layer
4	Point-to-Point/Point-to-Multipoint communication via ZigBee
5	LabVIEW GUI design for serial communication via RS232
6	LabVIEW GUI design for serial communication via USB
7	Application of point-to-multipoint communication to a metering system via ZigBee (& X-CTU)
8	TCP/IP protocols and data exchange
9	Integration of metering devices and data exchange via TCP/IP
10	Integration of metering devices and data exchange via ZigBee

V. Concluding Remarks

We have presented a small-scale prototype system of wireless networks applicable to Home Area Networks for the Smart Grid. In a project period of two semesters, two student teams, each with 2∼3 students for a semester, participated in the project. The student teams successfully configured two types of utility meters and the wireless devices in order to deliver the usage data from the utility meters to a remote monitoring center. The teams also successfully created a GUI using LabVIEW for the remote monitoring center. From the project activities and relevant technical aspects, a set of laboratory experiments has been derived that, when combined with appropriate lectures, would be suitable as an elective course for upper-division ECE students.

Acknowledgement

The author would like to thank the students who participated in this project, especially, those from Nanyang Polytechnic, Singapore, during spring and fall 2012.

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Boole-WebLab-Deusto: Integration of a Remote Lab in a Tool for Digital Circuits Design

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***Abstract*—This paper describes the integration of a remote lab in a tool for educational digital circuits. Boole-Deusto is an educational software tool featuring truth tables, Karnaugh maps, Boolean expressions, finite-state machines and digital circuits. After creating the design through Boole-Deusto, the user can implement the circuit in a remote lab (WebLab-Deusto) with only a few mouse clicks. The user does not need the technical knowledge, time, hardware equipment and specialized software that would normally be required. These conveniences benefit teachers and students alike, especially those involved in basic courses in digital electronics, both at the university and high school levels.**

Keywords—remote labs, digital electronics, software design tools

I. Introduction

Current lessons on digital electronics are usually based on books, exercises, and lab practices. The learning process starts with theory. Then students design some exercises and finally some of these are implemented using different technologies (74XX IC, VHDL/Verilog, CPLD, FPGA...). With this approach, students learn how to design and implement different digital circuits.

Simulators and other educational software tools help teachers and students. However, professional tools like Proteus [1], Pspice [2] or Electronics WorkBench, EWB [3] do not always cover all the educational requirements. Some areas (such as Karnaugh maps) are often neglected. On the other hand, educational tools tend to cover those neglected areas, but to have a very narrow scope. An example of such a tool is the Karnaugh Map Minimizer [4]. Though Boole-Deusto is also an educational software tool, it tries to cover a larger base of educational requirements, including the full design of basic bit-level digital circuits. Nonetheless, Boole-Deusto should not be compared with professional tools, as their focus tends to be on the circuits rather than the design process itself.

Whether they are using simulators or not, students should eventually implement the digital circuit using 74XX IC, VHDL/Verilog, etc. To do this this, students and teachers would typically move to a purposely-equipped laboratory to carry out this experience. However, for several years, there has been another possibility: to use a remote laboratory. These labs have been considered as part of the “Five Major Shifts in 100 Years of Engineering Education” [5].

There is a high amount of remote labs for digital electronics [6 - 9], but most often they are intended for a single, particular device such as a FPGA, CPLD or microcontroller, but without a more general, educational approach.

The main objective of this work is to integrate Boole-Deusto [10][11] with the WebLab-Deusto [12] remote lab, both Open Source projects. Through this integration, teachers and students can design a basic digital circuit under the educational approach provided by Boole-Deusto (involving truth tables, Karnaugh maps, Boolean expressions…), and after this they can implement it in a remote lab with only a few mouse clicks, and requiring only Boole-Deusto and an Internet connection. The process is very straightforward, and no wiring, particular technical knowledge or hardware such as board programmers is needed, nor specialized software such as development studios.

The paper describes in Section II the Boole-Deusto software for combinational and sequential bit-level digital systems. Section III is devoted to a general perspective on the WebLab-Deusto remote laboratory. The integration of Boole-Deusto and WebLab-Deusto is illustrated with examples in Section IV. The paper finishes with the conclusions and future work in Section V.

II. Boole-Deusto Software Tool for Digital Electronics Design

Digital electronics circuits can be classified in two groups: combinational circuits and sequential circuits, depending on whether they have memory (and are hence sequential) or not. Depending on the complexity of the circuits, they can be divided in bit-level and word-level circuits (see Fig. 1). In the first case the circuit is described bit by bit using a truth table (combinational circuits) or a Finite State Machine (sequential circuits).

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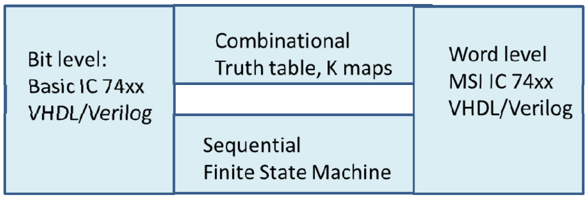


Fig. 1. Digital circuits classification

The Boole-Deusto open-source tool was deployed for the first time in 2000 [13] for designing bit-level digital circuits, both of the combinational and sequential types. The design of these circuits can be seen as a transformation along different representations of the system. These representations can be of textual, numerical, logical, graphical or mathematical nature.

In the design of a combinational circuit (see Fig. 2), the student reads the statement and after understanding it, fills the truth table. It is then converted to Karnaugh maps that are solved to obtain minimized Boolean expressions. These Boolean expressions are converted to digital circuits that can be implemented using AND-OR (or NAND/NOR) logic gates in 74xx IC or using a VHDL/Verilog approach.

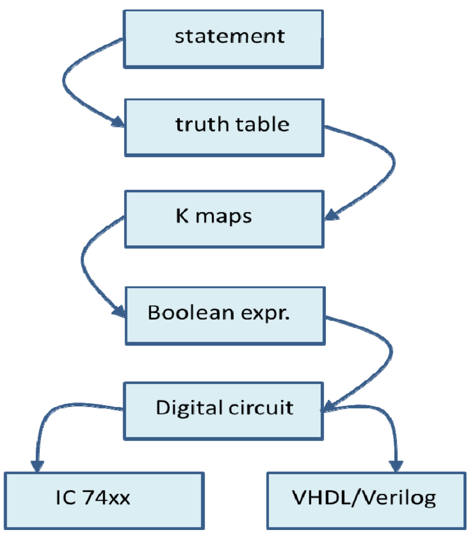


Fig. 2. Design process of a bit-level combinational circuit.

The process with bit-level sequential circuits is similar. Students will start by reading the problem statement and obtaining a FSM. After using an algorithm they will minimize that FSM. It will then be transformed into a truth table from which the K maps will be obtained. Based in the K maps, the minimized Boolean expressions will be obtained to be implemented with logic gates or in VHDL/Verilog.

Boole-Deusto focuses only on the design process. A student cannot use Boole-Deusto to see how a digital circuit evolves through time. Simulation is already covered in depth by tools such as Proteus, EWB, etc. Boole-Deusto helps freshmen in digital electronics to design and implement real and basic digital circuits. Boole-Deusto was developed as an Open Source project [11] by the University of Deusto after being unable to find an existing educational tool of this kind.

Since 2003, Boole-Deusto has been downloaded thousands of times [14]. Fig. 3 shows the download statistics from the official Boole-Deusto web page (since 2007 only – more download sources exist, so the full download count would be significantly higher).

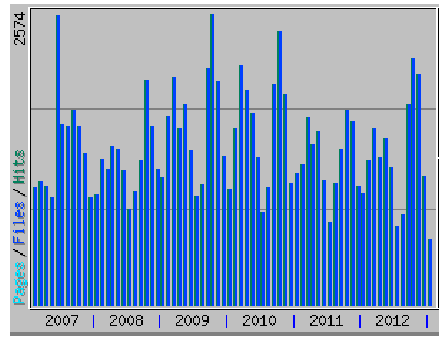


Fig. 3. Statistics of the Boole-Deusto downloads.

A. Combinational circuit example with Boole-Deusto

Figs 4-7 describe the design of a combinational circuit through its different representations. The description statement is: “Design the circuit that switches on a led if the four bits of the input are not a BCD combination”.

The combinational circuit has four inputs (BCD) and one output (LED).

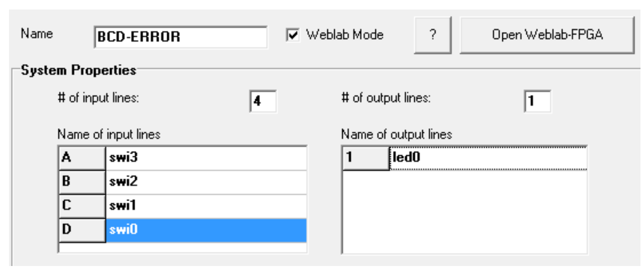


Fig. 4. Name, inputs and outputs of the example

The truth table in Fig.5 shows that the led must be on when the inputs are 1010 – 1111. 0000 – 1001 are proper BCD, so the led will be off.

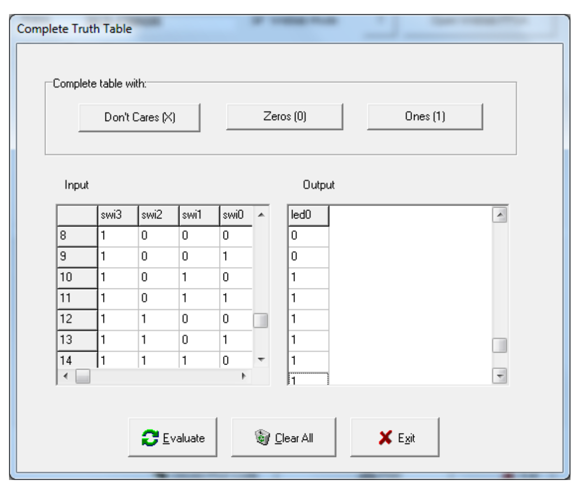


Fig. 5. Truth table of the system

When the student has filled the truth table, the Karnaugh map and the solved Karnaugh map become available. This map can be solved automatically by Boole-Deusto (Fig. 6), or the student can instead try to solve it manually using the Learning Mode.

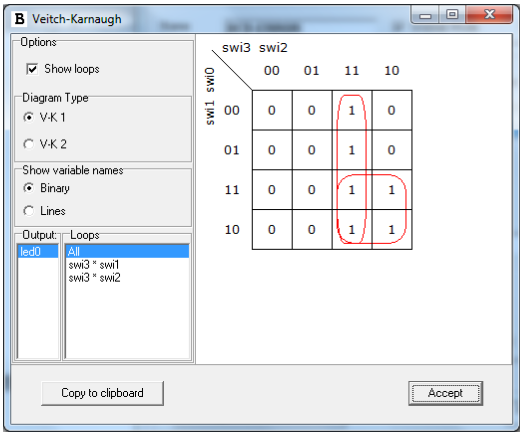


Fig. 6. Solved Karnaugh map for the BCD-ERROR problem

Finally, the student can obtain the matching digital circuit in both the AND-OR and the NAND/NOR versions.

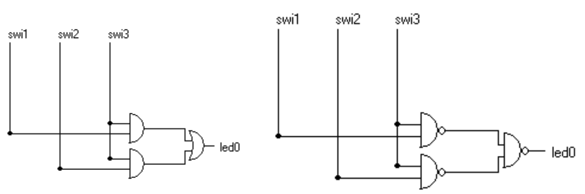


Fig. 7. AND/OR and NAND digital circuits

B. *Sequential circuit, Finite State Machine*

In this case, the student can draw the Moore or Mealy FSM using a graphical interface, displayed in Fig. 8.

The statement for this example is a sequence detector: “Design the FSM that switches on the led in the output, if three or more 1s are received in the input signal”

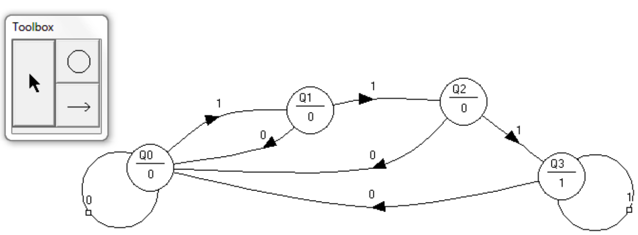


Fig. 8. Moore Finite State Machine

After drawing the FSM, the student can minimize it or obtain the truth tables (Fig. 9).

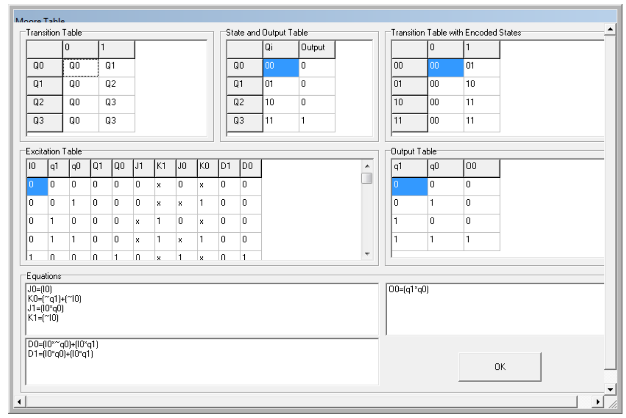


Fig. 9. FSM truth tables

The next step is to obtain the digital circuit (Fig. 10).

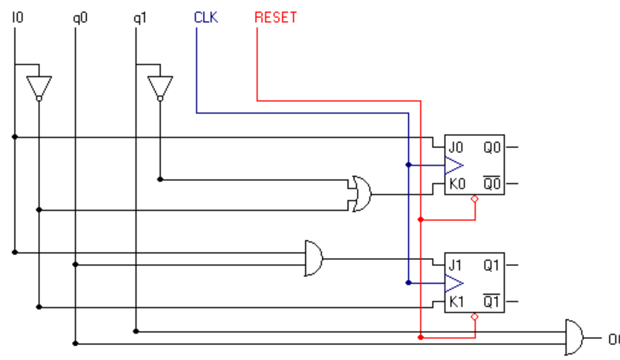


Fig. 10. FSM digital circuit with JK flip-flops

Finally, the student can obtain and download the VHDL program of the FSM.

C. *Boole-Deusto Characteristics*

Boole-Deusto allows the student to control the step-by-step design of bit-level digital circuits. The student will manage FSM, truth tables, K maps, digital circuits, VHDL code, etc.

When comparing Boole-Deusto with other software tools, the main difference is that Boole-Deusto takes the user through each step in the design process. Other tools focus only on the final result, neglecting aspects which are important from an educational perspective but not so much from a practical one. For instance, Proteus software, though certainly complete and professional, does not give students the opportunity of solving the Karnaugh maps themselves.

III. WebLab-Deusto Remote Lab

WebLab-Deusto is a remote lab created by the University of Deusto and released and developed as an Open Source project. A remote lab is a hardware & software platform that allows students to experiment remotely through the Internet as if they were in a classical lab.

WebLab-Deusto offers different remote experiments. Though it is a generic framework, currently the majority of them are related to electronics. There are also several which are connected to physics and biology (See Fig. 11).

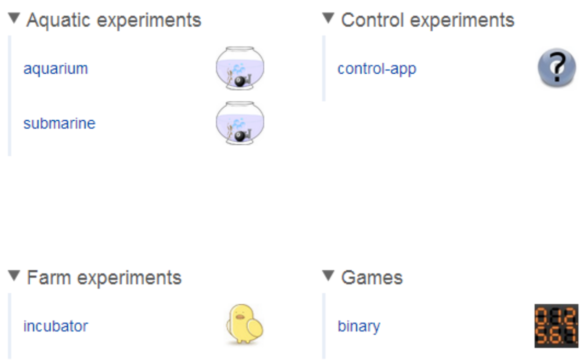


Fig. 11. WebLab-Deusto experiments (screenshot)

WebLab-Deusto supports several generic advanced capabilities [16], which are shared by all experiments. These include but are not limited to federation (experiments and hardware can be shared among different WebLab-Deusto instances, in different institutions and universities), escalation and load-balancing (the number of servers can be increased very easily) and optional integration with different technologies, such as Facebook or LMSs such as Moodle.

From a technical point of view, WebLab-Deusto experiments support any web browser (Chrome, Explorer, Mozilla, Opera, Safari…) in any OS (Linux, Windows…) and any device (tablet, laptop, smart phone…). Users do not need to install anything on their devices, and thus there are no local security issues. Some experiments are currently restricted and the user will require a user/password combination. For others, no registration is required.

A. *WebLab-Deusto-FPGA hardware description*

WebLab-Deusto offers different experiments. One of them is a FPGA:

- The experiment is based in a FPGA Digilent Board.
- The inputs (switches, buttons and clock) are controlled with a PIC Microcontroller of Microchip.
- A webcam and a lighting system are included to provide the user with a video stream of the behavior of the digital circuit.
- A FIT PC (small computer) and a modem are also included, on which the web service which interfaces with the remote laboratory framework is deployed.

All these parts are integrated in a compact, purpose-built professional box.

Fig. 12 shows the WebLab-Deusto-Box where the FPGA experiment is deployed. The same type of box is used to deploy other experiments, such as a CPLD. This WebLab-Deusto-Box was awarded in ICELIE/IECON 2009 for Best Educational Tool [15] has been deployed in different universities, including the MIT (USA).

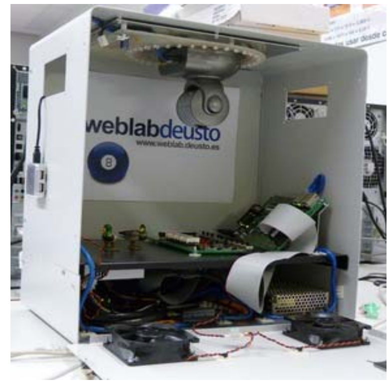


Fig. 12. WebLab-Deusto-Box for FPGA

IV. BOOLE-WEBLAB-DEUSTO

The main objective of this paper is to show readers the potential of the connection between Boole-Deusto and WebLab-Deusto. Fig. 13 shows the checkbox to tick when implementing in Boole-Deusto a system for WebLab-Deusto.

A. *Bit-level combinational circuits*

Fig. 13 shows the checkbox that should be checked by users when they wish to create a WebLab-compatible system easily.

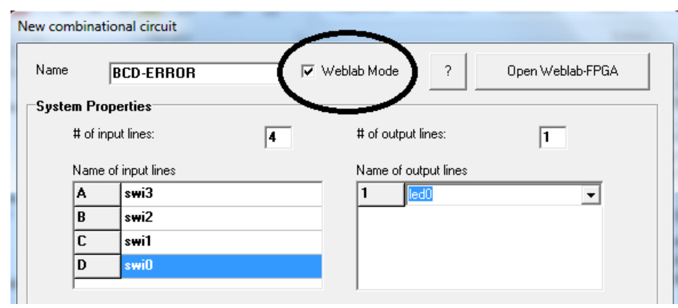


Fig. 13. WebLab Mode for combinational systems

When users are in *WebLab Mode* they may then assign, for instance, switches as inputs and leds or *seven_seg* (seven-segment displays) as outputs. After this, users should:

- Define the system: name, inputs and outputs (see Fig. 14).
- Describe the system using the truth table or the Karnaugh maps (or other means).
- Save the system to VHDL code.
- Click in “Open WebLab-FPGA” (see Fig. 13).

After this, Boole-Deusto will reach WebLab-Deusto through the Internet, directing your default web browser to the right WebLab-Deusto page. A user/pass combination for authentication is required, though it is only necessary to login once per session.

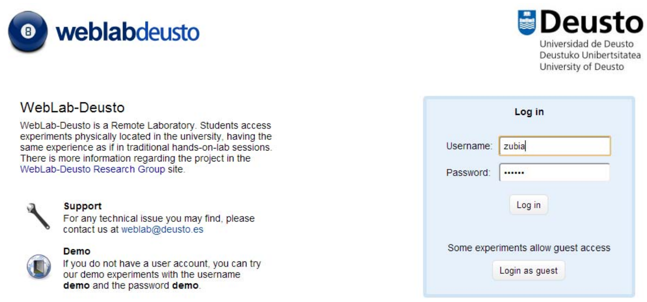


Fig. 14. WebLab-Deusto access web page

Comment for the reviewer: please use fie2013/fie2013 as the user/pass combination.

After accessing WebLab-Deusto by this means, users will be prompted to upload a file. This file should be the .VHD file they generated previously.

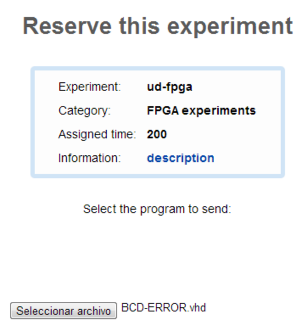


Fig. 15. Uploading the VHDL code to WebLab-Deusto

Then, WebLab-Deusto will synthesize the VHDL code with an internally provided UCF (User Constraints File) to obtain the BIT (BITSTREAM) file that will be loaded into the FPGA (see Section III.A). It is noteworthy that it generally does not matter for students if the designed system is implemented in a FPGA, a CPLD or even a microcontroller. What matters to students is to see the system running, with its inputs (switches and buttons) and outputs (leds and seven-segment displays).

During the uploading process, users will see a process bar as shown in Fig. 16.

Fig. 16. Synthesizing VHDL in WebLab-Deusto

When the process finishes, users will have full control of the switches, buttons and clock. Fig. 16 shows that with 0000 as input, the led output is off because 0000 is a BCD combination.

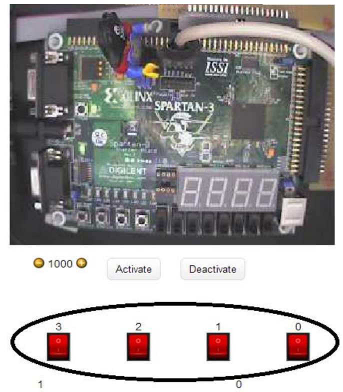


Fig. 17. BCD-ERROR system in the WebLab-Deusto

If the inputs are: 1010, then the led will be on because the combination 1010 is not BCD, as shown in Fig. 18.

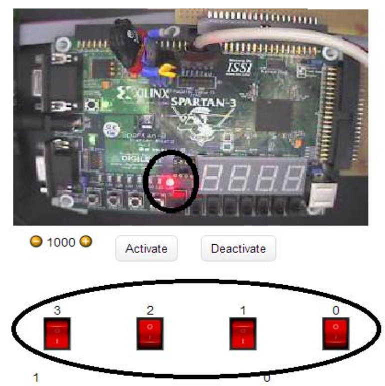
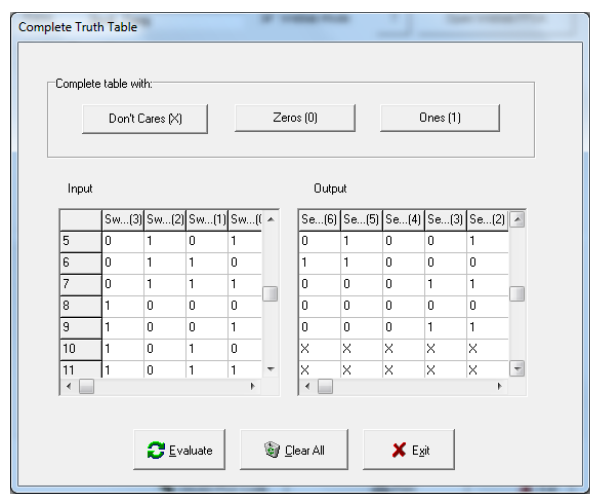


Fig. 18. BCD-ERROR system in the WebLab-Deusto

Figs. 19 and 20 show the truth table of a BCD-seven segment decoder and the remote experience with it for the input 0011.



	Sw...(3)	Sw...(2)	Sw...(1)	Sw...((	Se...(6)	Se...(5)	Se...(4)	Se...(3)	Se...(2)
5	0	1	0	1	0	1	0	0	1
6	0	1	1	0	1	1	0	0	0
7	0	1	1	1	0	0	0	1	1
8	1	0	0	0	0	0	0	0	0
9	1	0	0	1	0	0	0	1	1
10	1	0	1	0	X	X	X	X	X
11	1	0	1	1	X	X	X	X	X

Fig. 19. BCD to seven segment decoder truth table

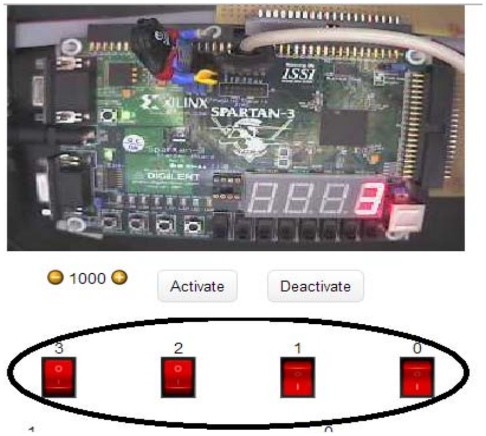


Fig. 20. BCD to seven segment decoder remote experimentation

Using this approach any basic combinational circuit can be designed and experimented with through a remote lab in just a few minutes.

B. *Bit-level sequential circuits: Finite State Machine*

With a sequential circuit, users start the process with a FSM (see Fig. 8). Then they must save the FSM to VHDL code. They can choose among four clocks (see Fig. 21):

- Internal clock. The FPGA will be controlled by its internal clock of 50 MHz.
- WebLab clock. The FPGA will be controlled by a clock offered in the web page. Its frequency can be specified within a range that goes from 100 Hz to 10 KHz.
- Switch and Button clock. The FPGA will be controlled by a clock connected to a switch (switch 9) or to a button (Button 3).

The first two options leave the system to run automatically, and the other two let the user control the speed of the system to witness its evolution in detail. The selection will depend on the particular needs of the student or teacher.

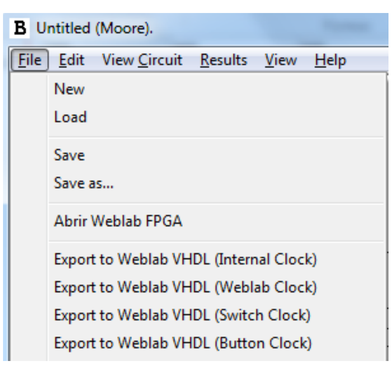


Fig. 21. Clock options

After saving the VHDL code, the user will repeat the process: Access to the WebLab-Deusto web page, upload the VHDL code, synthesize the VHDL, and finally load the bit file into the FPGA. After this, the user will interact with the system using the provided switches and buttons.

Fig. 23 shows the lit led after introducing four 1s in through the Switch 0.

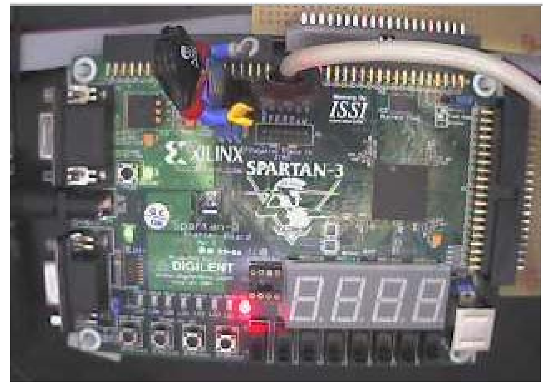


Fig. 22. FPGA board through the experiment's webcam

Other sequential systems can be designed and implemented in few minutes following the same order: FSM design, VHDL code generation, and WebLab-Deusto.

C. *Boole-Deusto and WebLab-Deusto Integration*

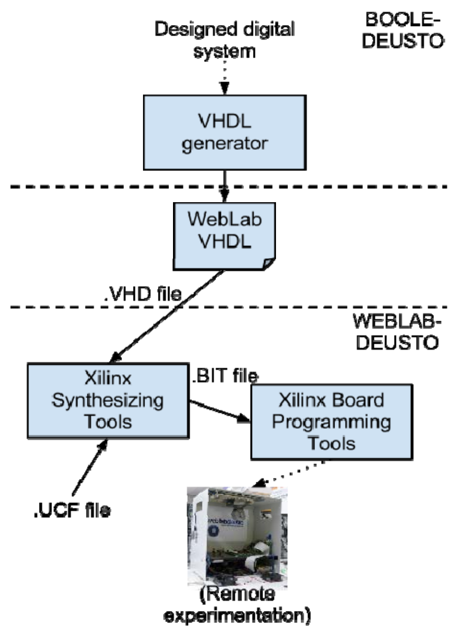


Fig. 23. Boole-Deusto and Weblab-Deusto integration

The aim has been to integrate WebLab-Deusto and Boole-Deusto in a single, mostly seamless workflow. Certain challenges had to be overcome. Fig. 23 shows how it has been implemented and deployed.

Back when Boole-Deusto was created, remote experimentation support was not an anticipated feature. Several additions to Boole-Deusto have been done. The most noteworthy is probably the capability to generate specialized VHDL code compatible with Weblab-Deusto.

Weblab-compatible VHDL code has certain requirements, such as a fixed set of inputs and outputs which matches the physical setup of Weblab-Deusto FPGA boards.

This match is described in UCF files (which, for security reasons, are fixed and located on the Weblab server itself). As fig. 23 shows, once the VHDL code for a certain design has been generated, eventually the VHDL file reaches the Xilinx Synthesizing Tools within the WebLab-Deusto servers.

Though WebLab-Deusto has long had the capability of experimenting with FPGA or CPLD boards remotely by providing a BIT file, this was not enough, due to several reasons. Firstly, obtaining a BIT file from VHDL is not a trivial process, especially for an inexperienced user. Specialized development software is required, and it has to be set up appropriately for the specific board that the remote experiment uses. And secondly, in order to obtain a BIT a UCF file is also required, linking the logical inputs and outputs to the physical ones.

Apart from an inconvenience, allowing users to provide their own UCF files can be a security issue. Misuse can lead to physical damage to the experiment's hardware board.

To prevent these issues the WebLab servers would have to be able to synthesize provided VHDL code themselves. This is done using the Xilinx Synthesizing command-line. The server also links it against the correct UCF file, which it chooses after finding (or not) certain specific preprocessor switches on the VHDL. If the process succeeds, a BIT file is obtained and programmed on the physical board.

As depicted on fig. 23, once the physical board has been programmed by the Xilinx board-programming tools, remote experimentation may begin. The board, which will be running the designed system, is now displayed and can be controlled.

V. CONCLUSIONS AND FUTURE WORK

Through the use of Boole-WebLab-Deusto students can design a bit-level digital circuit and test it in a real board straightaway.

Traditionally, this process often required hours, guidance, and access to a local laboratory with specialized equipment. Now only a few minutes and a standard Internet browser are required. Students do not need access to specialized hardware (FPGA boards) and they do not need specialized software (such as Xilinx ISE tools), as WebLab-Deusto provides both remotely.

Previous remote-lab approaches [16] did handle the hardware requirements, but they still required the user to install the software tools on their machines and to configure and synthesize the digital circuit logic themselves. Doing this was far from trivial, as the tools were several gigabytes big, required registrations and administrator privileges to install, and were significantly hard to configure appropriately.

Because Boole-WebLab-Deusto has made the process relatively simple, it does no longer need to be restricted to universities. We believe that it should be just as effective in secondary and high schools. Students can create and test their own designs easily, promoting creativity and autonomous work.

This does not mean that it is less useful for more advanced users, because Boole-WebLab-Deusto does not make the circuit design process itself different. Simply, teachers and students can now focus on the circuit design and testing itself. They do not need to dedicate their limited time to auxiliary activities which were previously required, such as reserving and moving to a laboratory, setting up the hardware, the development environment, etc. They may still want to dedicate some time to them, but it can now be done only at their discretion. They are no longer forced to.

Boole-WebLab-Deusto is now a reality, and the functionalities described here are already available [10][12]. It is expected that next year, several digital-electronics classes at the University of Deusto will start using it regularly.

In the future, one of our goals is to gather usage data from real students, to analyze the results, and to improve the system based on the findings. Another goal is to include augmented reality in remote experiments, so as to improve the learning experience of the student by improving the quality, interest, and variety of experiments in a cost-effective way. This would be done by allowing the student to use a real FPGA to control a virtual model.

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System Design:
A Novel, Project-Based Course
Connecting the Dots of the Electrical Engineering Curriculum

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***Abstract*— The four year curriculum of the Electrical Engineering program includes a fairly diverse set of classes covering topics including electronics, electromagnetics, signal processing, power & energy, digital systems, as well as communication and control systems. While these topics constitute the core components in the technical education of a future electrical engineer, a major missing component is the holistic, system understanding of these individual topics.**

This paper describes a class addressing the integration of the technical topics in addition to defining the overall architecture, the modularity of complex systems, as well as the interfaces between the different components to satisfy design requirements. The new class is a project-based, one credit-hour class with a single weekly meeting in a laboratory environment. The paper describes the assigned projects as well as their proposed solutions. The paper also includes assessment data including student feedback from the first class offering. Assessment shows a great student enthusiasm towards the class. It also shows that the class improved the student's conceptual knowledge, knowledge retention, and problem solving skills.

Keywords—EE curriculum; EE design; system integration; project-based learning;

I. Introduction

Analysis of engineering systems is an important step in the design process [1]. This topic has been addressed using artifact dissection, where a complex system is dissected into components. The interactions between different components of a system are then studied and if possible the system is put back together. A number of educators have used the dissection concepts into engineering education [2-4], some as early as a part of the freshman engineering experience [5-6]. System design concepts have been integrated in undergraduate curricula through a sequence of undergraduate engineering clinic/design courses spanning freshman to senior years [7-9]. To adapt these models would require a significant revision of the undergraduate curricula and may not be suitable for all programs.

The 4-year curriculum of the Electrical Engineering (EE) program includes a fairly diverse set of classes. Besides the general education requirements, the curriculum is usually front-loaded with a foundation of Math, Sciences, and Computer Programming classes, followed by the general engineering classes (Circuits, Statics, Material Sciences, etc.) The middle of the curriculum usually covers the core topics of the discipline including: Electronics, Electromagnetics, Signal Processing, Power & Energy, digital systems, as well as Communication and Control Systems. The final year of the program is mostly spent taking advanced (elective) classes to satisfy the depth requirement in the student's area of interest in addition to the capstone design project. Each of these classes covers the fundamental concepts as well as the analysis and the design of basic components in the respective subjects. None of these classes discusses the design of a whole system.

Some programs focus on a sequence of interrelated courses with a laboratory experience to enhance the topical depth and expand them to system related topics. Some of the examples include microprocessor and electronic interfacing [10], semiconductor materials [11], digital systems [13], and embedded systems [12]. Furse et al developed new laboratories at the University of Utah that integrate electrical engineering concepts from multiple classes throughout the ECE program [14-15]. These courses have improved students' understanding of system design and how various concepts they learn in their several classes fit together [15]. Nelson and Hung used the significant system design in their embedded systems course to assess their undergraduate program outcomes [13].

The electrical engineering program at Ohio Northern University tightly integrates the courses with laboratories. Although some of the laboratory experiments involve the knowledge learned from other classes, the emphasis of each lab is still to enhance the concepts learned in that particular course with hands-on experience. Although the electrical engineering students acquire a great deal of theoretical and practical knowledge over the course of their four year education and gain knowledge in many different areas, they never encounter many problems that require them to pull knowledge from multiple classes for one project. This is why a System Design class is important. The class addresses the integration of various areas in addition to defining the overall architecture, the modularity of complex systems, as well as the interfaces between the different components to satisfy the specified design requirements and create an effective electrical

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system. The class introduces a few new practical concepts that are not necessarily taught in classes, but are used a great deal by practicing engineers.

In this class, students are required to create common circuit configurations such as H-Bridge, relay circuits, and filters. These configurations may be conceptualized during various classes, but learning how to implement them can be essential in some occupations. System Design has a large emphasis on the design component. Students are given a project with some guidance, but must come up with their own design to implement during class time. Overall, it is believed that this class helped reinforce the topics learned in the electrical engineering classes and teaches students practical design concepts that will be invaluable in the workplace.

This paper provides a detailed description of the class format, the class contents, and the class assessment obtained from the first class offering in Fall 2012. The rest of the paper is organized as follows: section II describes the unorthodox class format. Sections III, IV, and V describe the various assignments in the class, together with their solutions. Section VI discusses the course assessment, and the paper is concluded with a summary in section

II. CLASS FORMAT

Considering the already saturated, concept-heavy, lecture-focused electrical engineering curriculum, the newly developed System Design class was designed to be a one credit-hour project-based class. In other words, the class met only once a week and in the laboratory room instead of a lecture hall. In every meeting, the instructor assigns a new for which the students are required to research and find a solution for. At the beginning of the following meeting, the instructor collects a design report before sharing one of the many possible solutions of the problem. The students then orally share their individual designs and compare them to the one suggested by the instructor in an informal discussion setting.

For the experimental projects, students spend the remaining time of the class creating a prototype of their favorite design working on individual work stations. The favorite design of a student can be their own design or another design suggested by the instructor or a fellow student, or even a hybrid combination of multiple designs. During this time, the instructor usually tries to supply the necessary components needed for the design and also helps debugging and/or troubleshooting any faulty setup. For the research projects, (non-experimental), students spend the remaining time of the class watching an audio visual presentation about the topic of the project. The presentation is followed by an informal discussion of the individual projects.

The overall student grade is the average of their grades in each of the various projects over the span of the semester. Each project's grade is a combination of the student performance in the pre-class research and their in-class prototype implementation or project discussion.

III. CONCEPTUAL PROJECTS

A total of three conceptual projects are included in the class. The topics of the three projects are system integration, Micro Electro Mechanical Systems (MEMS), and nano scale systems.

A. System Integration

This project discusses the hierarchical nature of complex engineering systems. The instructor explains how these complex systems are broken into a hierarchy of smaller subsystems that are designed and built by different groups or, in some cases, different industries. The instructor also explains the modularity of these subsystems and the importance of suitable interfaces between them.

As an example of a complex system, computers are used. A computer can be seen as a collection of hardware and software. The hardware includes the power supply, the processor, the memory, the storage devices, and the other peripherals that are all designed by different industries. Inside the processor, there is an ALU, registers, and other components. The ALU itself is made of a set of logic gates that are made of lower level semiconductor devices. Therefore, physics/chemists, electrical engineers, computer engineers, and computer scientists must work in harmony in order to design and build a computer. One can argue the need for mechanical engineers and artists to design the casing of the computer.

For their project, students are asked to individually create a detailed block diagram for a complex system of their choice and indicate the various skills/professions needed to create each block.

B. MEMS

This project discusses the design and the manufacturing processes of MEMS. Students watch a 42 minute video entitled Making Micro Machines: an overview of micro electro mechanical systems. This video, by Silicon Run [16], discusses the design, fabrication, testing, and packaging of some common MEMS devices.

In the video, MEMS devices are separated into three different categories, each of which is presented with a real life example: Microfluidic MEMS (Hewlett Packard's inkjet printheads), Optical MEMS, (Texas Instrument's digital micromirror devices), and Sensor MEMS (Freescale's Semiconductor pressure and inertial sensors).

For their project, students are asked to individually research a MEMS device and write a report describing its operation. The report should also describe the non MEMS alternative device and discuss the pros. and cons. of each technology.

C. Nanoscale Systems

This project introduces Nano scale engineering and Nano scale systems. In the class, students watch a 40 minute video entitled Nanotechnology: The world beyond micro. This video, also by Silicon Run [16], discusses engineered Nano materials and discusses their applications and their large scale productions.

The video starts by explaining how the property of materials changes at the Nano level and continues to describe the large-scale production of various Nano scale systems such as carbon nanotubes and polymers in Nano enhanced composites. The use of Nano scale technology in applications like tumor ablation and cancer biosensors fabrication, and integrated circuit fabrication are also discussed.

For their project, students are asked to individually research a certain device that is only realizable with Nano technology and Nano scale engineering. They submit a report that also describes the societal and economic impacts of the device and the technology.

IV. EXPERIMENTAL PROJECTS

Three experimental projects are included in the class. The topics of the projects are signal conditioning, sensor-actuator control, and analog filter design and implementation.

A. *Signal Conditioning*

In this project, the problem statement describes a position sensor used to achieve a closed loop control for an electric motor. The sensor output signal indicates the instantaneous angular position α of the rotor shown in Figure 1. Based on the position of the rotor [0˚ - 360˚], the sensor output can be seen as a sinusoidal signal in the range [-1.0–1.0V].

In order to digitally control the motor, the position signal must be digitized using an Analog to Digital Converter (ADC). The digital version of the sensor signal is then fed to a digital signal processor implementing to control algorithm. According to the data sheet of the ADC, it has an input range of [0.0–5.0V]. Therefore, the project assignment is to create a signal conditioning system that will map the sensor signal to be used at the input of the ADC from the range [-1.0–1.0V] to [0.0–5.0V] without any loss of information.

The signal conditioning system must be self-contained on a circuit board and must be easy to integrate with the rest of the system as shown in figure 2.

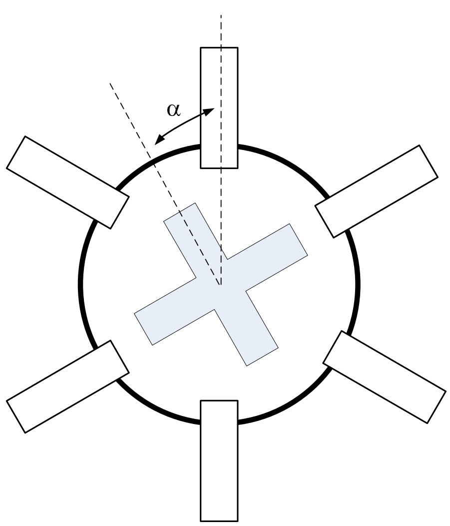

Figure 1. Rotor position in an electric motor.

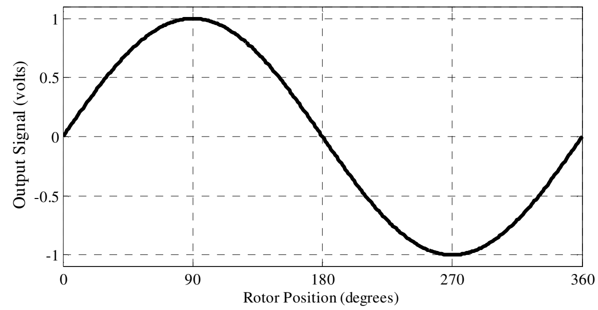

Figure 2. The output signal from the position sensor.

Solution: One of the many possible solutions to this project is to cascade two operational amplifier-based electronic circuits. The first circuit should be an analog adder that simply adds a 1.0 V to the signal to shift it to the range [0–2.0V] and the second should be an analog non-inverting amplifier with a gain of 2.5.

B. *Sensor-Actuator Control*

The problem statement of this project describes a 40V AC motor operated via a 3:1 step-down transformer that transforms the 120V, 60 Hz outlet signal to the appropriate 40V. The customer requests that the motor should be turning (electrically “on”) during the day and must stop turning (electrically “off”) at night.

The project assignment is to create a control system that automatically turns the motor on/off based on the available amount of light around it. The control system must be self-contained and easy to integrate with the whole system as shown in figure 3.

Solution: Any possible solutions to this project must include a light sensor. One of the solutions is to use a Light Dependent Resistor (LDR) in a voltage divider configuration. The voltage across the LDR, varying with the ambient light, must be enough to control a BJT switch circuit, which in turn trips an AC relay to turn the motor ON/OFF.

C. *Analog Filters*

The problem statement of this project describes an ADC where the sampling circuitry operates at 10,000 samples per second. The problem is that the ADC is generating aliased discrete-time signals in the sampling process. In other words, some of the signal components at the input are violating the Nyquist sampling criterion.

The student assignment is to create an analog filter that allows only the signal components with the appropriate frequencies to reach the sampling circuit as shown in figure 4.

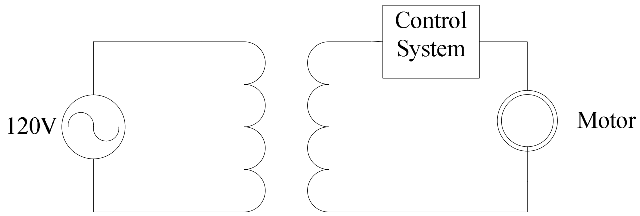

Figure 3. The AC motor setup with the integrated control system.

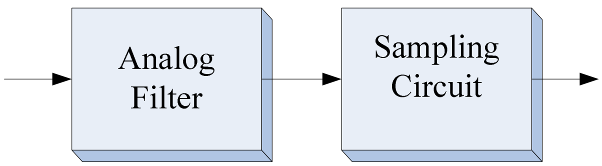

Figure 4. The anti-aliasing system.

In order to create this filter, students must determine the type of the filter to be designed (low pass, high pass, band pass, or band stop) and they also must determine its appropriate cutoff frequency/frequencies. Students are also instructed that the filter must be an active filter (use at least one operational amplifier) and that it must be an RC filter (no inductors used).

The design must be first tested using computer simulations using any available software package (Matlab, Spice, etc…) to show that the frequency response of the filter satisfies the design requirements. The project is then experimentally tested using a variable frequency signal generator and a digital oscilloscope.

This project can be extended for multiple weeks where students are asked to design and build a high pass, band pass, or band stop filters.

Solution: With a wide variety of possible solutions, the Sallen-Key filter configuration [17] is suggested for the implementations of second order filters.

V. Final Project

In the last few weeks of the semester, students still work on weekly projects. These projects, however, are designed to culminate together in a big system. The various weekly projects are described below.

A. H-Bridge

This project addresses the control and operation of a direct current (DC) motor. This type of motors, when appropriately controlled, can provide the motive power in both rotating directions. The goal of this project is to create a circuit that reads digital control signals (clockwise, counter-clockwise, and stop) and accordingly provide the appropriate voltages and currents to the motor without the need for any re-wiring or circuit modification.

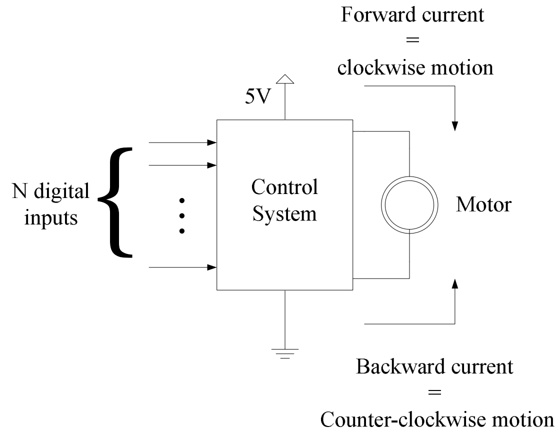

Figure 5. The control system configuration.

The system to be created must be designed to connect to a DC motor as shown in Figure 5. The system is to be powered by 5V DC and must have only digital inputs (logic on and logic off). The output of the control system is a two wire terminal that is connected to the DC motor. The output should be either +5V (forward current) to create a clockwise motion in the motor or -5V (backward current) to create a counter clockwise motion in it.

Solution: The solution of this project is the famous H-bridge circuit.

B. Signal Transmitter

In this project, students create a transmitting node in a communication network. This communication network will eventually include a combination of transmitting nodes and receiving nodes. In the problem statement, it is not enough for a receiving node to know what the transmitted signal is, but also which node transmitted it. This gives the network administrator the ability to set the receiving nodes to respond only to a subset of transmitters when needed.

The project assignment is to create a digital signal transmitter that has, in addition to the clock input port, 3 input push buttons (Forward, Backward, and Stop). A schematic diagram of this system is shown in Figure 6. When any of the three push buttons is pressed, the transmitter must generate a sequence of 7 bits. The first 4 bits designate the identity of the transmitting node (regardless of the pressed button) and the remaining three bits designate the action to be taken based on the input. A sample waveform out of the transmitting node is shown in Figure 7.

Solution: While students have the choice to select the details of implementing their system, Field Programmable Gate Arrays (FPGAs) are suggested as an adequate platform. In this platform, VHDL codes can be used to model a multiplexer that, based on the pressed input button, routes one of the hard-coded signals to the output port.

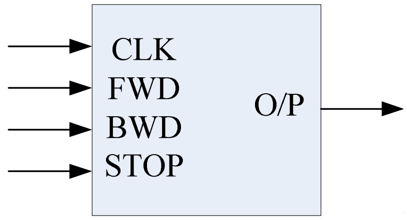

Figure 6. A schematic diagram of the transmitting node.

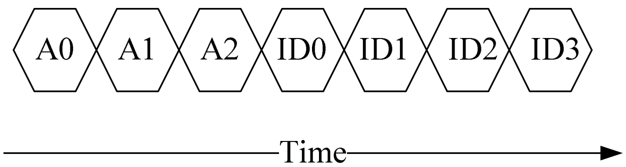

Figure 7. A sample waveform out of the transmitting node.

C. Signal Receiver

Along the same lines of creating a transmitting node, this project assignment is to create a digital signal receiving node that can detect and decode transmitted signals sent by the "recognized" transmitting nodes. The system must have a clock and receiving input ports. The receiver should also have a single output port consisting of 3 bits corresponding to the three functionalities (Forward, Backward, and Stop).

Inside the block, pattern recognition systems must be created to identify a signal transmitted by a "significant" transmitting node and decode the command.

Solution: Just like the transmitter, FPGAs are suggested as an adequate platform. In this project, VHDL codes are used to model a pattern recognition Finite State Machine (FSM). The FSM looks for the pre-determined ID pattern. When a positive ID is detected, the 3 following bits are read to decode the transmitted command.

D. System Integration

The rest of the semester will be used to integrate the various components of the final projects together to create the overall system. With different students creating different transmitting/receiving nodes, the group will get the chance to test which nodes are capable to control the operation of the DC motor and which ones are not.

VI. Course Assessment

In the inaugural offering of the class, a total of six senior level electrical engineering students were enrolled. At the end of the semester, these students participated in the evaluation of the class. The evaluation included both numerical evaluations as well as a subjective evaluation section where students can write any comments/concerns about the class.

The numerical evaluations included questions for which students had to pick one of five answers, namely: strongly agree (5), agree (4), neutral (3) disagree (2), or strongly disagree (1). Table I below shows the average value of the six different students' submissions for each survey question.

Looking at the table, one can clearly see that students appreciate the value of the course and they strongly feel that it helps their problem solving and their independent/creative thinking abilities. Students also seem to enjoy the homework & lab structure of the class. The only problem, however, is the workload of the class as many students felt that it exceeded the norm they would expect in a single credit course.

On the subjective/comments side of the course assessment, the following comments were received:

- The course did a good job of having students review material that had been learned over the years
- This course also simulated some real-life situations
- The course should be worth at least 2 credits
- I learned a lot and it helped me remember many of the past topics we learned as an underclassman
- The class was a needed addition to the Electrical Engineering schedule
- This class was the first only-lab class we have had

VII. Summary

In this paper, we discussed the inaugural offering of a novel, project-based, single credit-hour course in the Electrical Engineering program. The projects and the assignments in the class are designed in a way to combine two or more subjects from the EE topics and integrate various components in a big-picture complex system.

Assessment results showed that students appreciated a project-based class that simulated real-life situations and help them remember and integrate material from different classes. Results also showed a great satisfaction with the format of the class.

TABLE I. The numerical class evaluations

Question	Avg
This course enhanced my problem solving abilities	4.7
The homework helped my understanding of the material	4.0
The laboratory assignments facilitated my learning experience	4.5
The laboratory assignments and course material reinforced one another	4.4
The professor encouraged independent/creative thinking	4.5
The professor used teaching methods that helped me learn	3.8
The workload for this course in relation to other courses of equal credit was as expected	1.8
Overall, I had a quality learning experience	3.7

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An Approach for Teaching Logic Programming based on Real-world Applications

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***Abstract*—In this paper the authors describe their approach towards motivating students in the learning of logic programming is given. The focus here of the authors is on real world applications. Nowadays, where internet applications are still a hot topic, the development of projects related to internet applications are quite strongly motivated. Unfortunately, many of the resources used in logic programming that help us to explore the development of programs for internet purposes are not so freely available. The authors therefore had to develop much of the material used in order to be understood by first year university students, who were in fact the target group. Preliminary results showed an augmented interest in the learning of such concepts and as a result an increase in the pass rate was achieved.**

I. Introduction

Logic programming (LP) is an important programming paradigm in Computer Science. It is for this reason many Computer Science and Computer Engineering programs include logic programming in their curricula. Logic programming presents some concepts that are not present in procedural programming, which is predominant in the majority of the courses. Many students have trouble in learning the concepts of logic programming. As a result, many students fail in achieving a pass grade. This is not the only problem. Unfortunately, there is the erroneous idea that logic programming is only for academic purposes and for this reason is not utilized by the software industry. Therefore, the instructor finds that extra work and effort is needed in order to motivate students. We, the authors believe that an innovative methodology along with motivating resources should be developed to help students with the learning of logic programming. In this paper the authors describe their proposal and resources that they themselves have developed over the last years that aid students in the development of real-world applications. This is by no means an easy task as students who take a logic programming course at our university are first year university students and the development of real-world applications requires many concepts that are the content of subsequent future courses.

In order to develop our approach it was perceived that it is possible to achieve internship reports and monographs written by students in their final year. Actually, for some degrees related to Computer Science and Computer Engineering internships and monographs are mandatory and their reports are made publicly available. The authors investigated some of these reports and observed that most of them are part of actual projects addressed to companies. In general these projects consist of developing internet applications, which require tools for web development and database management. Unfortunately, there do not exist books that cover such features in prolog, a representative programming language of the logic programming paradigm. For instance, "Prolog Programming for Artificial Intelligence" [1] [2] [3] [4], which is a well known book for the learning of prolog and artificial intelligence, has no reference for internet applications. As a result, the authors developed teaching aids in order that web development and database management could be carried out in prolog. During the course, projects are proposed based on internship reports and monographs mentioned earlier. The project to be developed is a simplified version of the project described in the reports.

In order to compare our approach with that previous, the authors developed a questionnaire that was submitted to the students. The compilation of the answers led us to conclude that it was incremental in terms of learning and motivation the use of the methodology and resources developed by the authors. We believe that our approach can be used successfully for any course towards logic programming.

The rest of the paper is organized as follows. Section II describes related work. Section III provides evidence on the lack of knowledge currently available for prolog applications. A panorama of logic programming from within our institution appears in section IV. Section V describes the motivation for our approach. A description of our approach for motivating students for the learning of logic programming appears in section VI. The evaluation procedure of our approach is described in section VII. Section VIII discusses the results of our evaluation. Finally, section IX relates our conclusion.

II. Related Work

Several projects have been developed, which aim at motivating students for the learning of logic programming. Many projects are targeted at developing games and solving puzzles based on the use of artificial intelligent (AI) techniques. Examples include Robocup, Sudoku, and Ataxx.

RoboCup [5] is an international scientific initiative with the goal of advancing the state of the art of intelligent robots. When established in 1997, the original mission was to field a team of robots capable of beating the human soccer World

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Cup champions by 2050. Robots equipped with AI strategies can be used to motivate students.

Another motivation for students to learn logic programming are logic games. There are several puzzles available which are fascinating. Some of these problems can be solved effortless in prolog [6].

Ribeiro et al. [7] developed a sophisticated competition framework based on ataxx, which involved prolog programmed contenders and game servers, including an appealing GUI. Ataxx is played on a grid board by two opponents that take turns to play, each one playing with pieces of a different color. Although using very simple rules, Ataxx provides a rich and interesting environment for gameplay. The authors reported that the response obtained from students was impressive, surpassing their most optimistic expectations.

Linck and Schubert [6] understand that computer students should learn more than one programming paradigm. Each paradigm is unique and influences in the way a person reasons when solving problems. The authors argue that logic programming should be one these paradigms. In order to motivate the student, the authors suggest the use of practical applications. Moreover, the authors present a didactic plan for the learning of logic programming.

Different from previous projects, our approach relies on developing interesting applications for the software industry, where is a growing demand for internet applications. Actually, most of the students that achieved their degrees are employed by companies that develop internet applications. Therefore, the authors aim at proposing projects that consist in developing internet applications using prolog. For this reason, the authors understand that projects based on this feature are quite motivating.

Our observation is in agreement with Selby [8] findings that describes four different approaches to teaching programming. One of this is named full systems approach where the learners design a solution for a non-trivial problem, often a representatite of real life. They are immersed in the full use of language constructs and tools. The essential concepts are introduced to learners only when the solution to the problem requires their application. Selby also describes four different studies reporting success in using a full systems approach.

III. Logic Programming in the Real World

In this section we provide evidence that goes some way to explain why prolog might be considered just a programming language for academic purposes with no application in the software industry. Howevever, the authors do not consider this to be a fact and provide proof that shows the use of logic programming in several important applications.

A. *Is Prolog used only for Academic Purposes?*

It is not difficult to find some questions related to the use of prolog in the development of real applications. Next, we describe some quotations related to this issue.

“Many study Prolog in college, but I have personally not come in contact with it professionally. The traditional examples given are AI and expert system applications, but what have you used it for and what made Prolog a suitable language for the task?” [9]

“I am trying to research the use of Prolog now, outside of Academia and am struggling. I was hoping somebody could point me to some real- world applications.” [10]

Therefore, there is some evidence that the use of prolog in the software industry is not well known. Actually, there is some debate on this issue as one can see in the following quotations.

“I’ve heard that before: that many companies using Prolog commercially want to hide (or at least not openly state) that they use the language.” [10]

“Quite a few commercial users do not admit they use Prolog openly. These users are likely to have good reasons for that, but for the LP community this is an unfortunate situation. ” [10]

In fact the lack of knowledge of prolog applications contributes to the erroneous idea that LP is only useful for academic purposes and as a consequence does not help to motivate students to the learning of the paradigm.

B. *Applications of Prolog in the Real World*

Despite the lack of knowledge related to prolog applications, there are many examples of the use of prolog in the ”Real World”. Below there some quotations that show the use of prolog in the development of serious applications.

“We implemented a Prolog-based system to write a mobile phone email configuration tool. It was used by several of the world’s largest mobile phone makers as a web-based support service.” [9]

“Remember a particular project about 3 years back. For an insurance firm they used this software called GraphTalk. It has a nice OOP architecture. The programming language used was Prolog.” [9]

“The IBM Tivoli Enterprise Console is an event management system that uses a dialect of Prolog for its event processing rules.” [9]

“I am working on a Prolog and C based application for Airlines Fares processing in Travel domain. This is fares engine with around one million line of code in prolog and 1/2 million line of code in C. This application was developed by Galileo (now Travelport) and EDS (now HP) around 10 years back. Now this is in maintenance and enhancement mode. A number of airlines are hosted on this. Other than above two SITA also use this application for pricing their itineraries. This application was started in 1998 to remove the dependencies on IBM mainframe which cost for each transaction. This is using SICStus prolog. If you are interested in working in above application please let me know, I am working on this application for past 7 years and leading a team of 40 people” [9]

IV. A Panorama of Logic Programming in our University

The Computer Science degree offered by our department at Federal University of Uberlandia has a curriculum in which logic programming is offered in the first year. In terms of programming abilities, a procedural programming course is informally required before attending the LP Course. Knowledge related to building internet applications and databases management is offered in subsequent courses during the following years.

In our university special attention is given to the use of free software. Based mainly on this feature, our department decided on the use of SWI-Prolog, a well known prolog implementation [11].

Students have taken the logic programming Course over the last twenty years. Unfortunately, students have trouble in achieving a pass grade. As we stated before, many students have trouble in grasping the concepts of logic programming. This is not the only problem. Also in our university there is the erroneous idea that logic programming is only for academic purposes and for this reason is not utilized by the software industry.

V. Motivating Students: developing internet applications

In Brazil there are some degrees related to computer science. The curriculum of each one is established based on guidelines approved by the government. In most of them internships and monographs are mandatory or optional. Even when it is optional, it is a fact that most students will submit it. There is this feeling that they are quite important for completing the graduation.

Most of the programs make publicly available the work developed by students in their internships and monographs in their final year. In this way, anyone has access to them. It is possible to download all of them if someone wants to. For instance, the Information Systems Program at University of Blumenau keeps all the monographs on its web page [12]. In general, students in their final year have to write a monograph in order to receive a degree. Many monographs are result of the development of a system to solve a real problem for the business industry.

The authors downloaded some reports available in several universities. In most of the reports we found evidence that the work was related to a project developed for a real company and it was to be developed as an internet application. For instance, Rocha [13] describes the entire development of a system called Winepad, which was developed for the iOS platform. Basically this system allows establishments to show their wine list to their customers in a fast, simple and original manner. The user can choose a wine in a practical and fun way. Also, it is possible to perform a filtering by price and type of grape.

For accomplishing a job in a company, the student is trained in how to use the tools required to develop internet applications, such as:

- editors for HTML [14] [15], PHP [16], JavaScript [17] e CSS [14]. Dreamweaver [18], EasyPhp, and Netbeans [19] are widely used tools for development.
- database management tools. In many of the reports we found references for InterBase, MySQL [20], PostgreSQL [21], and DBDesigner.

The examination of reports helped us to confirm that the development of internet applications is still a hot topic today. Informally, in conversation with students, we were told that Internet is a topic that everyone is interested in working with.

VI. Details of our Approach

In this section the authors provide details about their approach. Essentially, there is a project assignment that consists of developing an internet application. In order to accomplish the task, the student has to go through some phases making use of the material we have developed.

During the course students, organized in groups, have to develop a project. Such a project is based on internship reports/monographs available in other institutions. As already mentioned, it is not difficult to find those reports/monographs. The instructor is responsible for allocating an internship report/monograph for each group of students.

The project is composed of three phases:

1) Development of the html pages.
2) Development of some features using a prolog server and management of files based on prolog predicates.
3) Integrate the application with a database manager.

There are few references that help students in developing Internet applications using SWI-Prolog. Actually, one is expected to build internet applications through the use of the manual. Even worse we have found no material aimed at developing internet applications for first year students. As a result, we had to plan and develop the required resources.

In the first phase of the project development we provide material for helping the students in the design of html pages. We showed how it is possible to construct html pages using prolog. Emphasis is given to HTLM5. It was not our goal that students become HTML programmers. Basically, the material we have developed contains the following:

- Elements of HTML5: menus and forms. The reason for giving emphasis to these two components is explained by the internship reports. Essentially, we can develop a simplified version of the application by using these two elements. We describe basic information that allows the inclusion of styles in HTML pages. Also, a basic introduction to CSS is provided.
- Description of tools for creating and visualizing html pages. We describe how to visualize html pages making use of internet browsers. Also, we emphasize that the material we released is a basic introduction to HTML. It is necessary to read more to gain a better understanding in designing HTML pages. Also, we inform that there are tools that allow the user to develop HTML pages quickly.

In the second phase we present information related to:

- Basic concepts on networks and internet. We describe the process that allows communication among computers. We show how a web page stored on a computer can be viewed through another computer. There are different types of content that can be viewed on the Internet. We focus on text and html because we illustrate prolog code that allows the dynamic creation of answers based on these two kinds of content.

- Set up a web server in prolog. We show how to create a web server in Prolog. Also, we provide examples for serving text and html. We also show at this point how to create dynamically an html page. It is interesting to note that the SWI-Prolog page is served by a prolog server.
- Interacting with prolog server by means of HTML pages and saving information in files. By means of a menu and form, it is possible to establish an interaction between an user and the internet. This interaction may involve reading data from the form and saving it in a file using predicates prolog. We provide an example showing how to implement such an interaction. This a good example because it is a motivation for the learning of input/outputs predicates.

Finally we provide instructions for integrating prolog with a database management tool. Based on the requirements for the applications described in the reports/monographs we provide the following information:

- Instructions for installing a database manager. We provide instructions for installing SQLite on windows and linux.
- a template for creating a database. We provide instructions for creating a database file and tables based on information described in the internship reports.
- a template for inserting, updating and recovering information in the database.

The material released to the students contains an example that illustrates how to use the templates. More details of databases management were omitted. The students were told that more information would be given in subsequent courses. Again, we have just provided basic information for accomplishing the requirements existing in the monographs. With the above information the students were capable of developing a project.

VII. Evaluation

The approach used earlier in the course consisted of developing projects based on XPCE. XPCE is a toolkit for developing graphical applications in prolog and other interactive and dynamically typed languages. The XPCE GUI system for dynamically typed languages has been part of SWI-Prolog for a long time. It aims at a high-productive development environment for graphical applications based on prolog. In order to compare both approaches, the one using XPCE and the other using HTML, we developed a questionnaire. A hard copy questionnaire was sent to every student who had the opportunity to work with HTML and XPCE.

In the cover letter the purpose of the questionnaire was clearly described by means of a short text. It was signed by the department head. The cover letter also contained a clear set of instructions explaining how to complete the survey and where to return it. Students had to return the questionnaire to the secretary of the department. Furthermore, emphasis was given on making clear that respondents must not provide their names.

The questionnaire was composed by 13 intensity questions based on the Likert-type answer scale. We also provided in some questions space in which answers could be written in their own words. Special attention was given to a small number of short questions with a simple language. The questions were related to the following issues:

- how easy is it to integrate HTML and prolog
- preferences between HTML and XPCE
- Preferences between saving and recovering data using management of files in prolog and a database management tool.

VIII. Discussion

Students have provided excellent feedback. All the questionnaires were returned. Based on their answers, it was possible to make an analysis on some of the strengths and weaknesses of our approach.

With respect to the material we released for working with HTML, the majority of the students understood the objective, which was to give a brief introduction on the topic. Also, they know there are many other materials to complement the learning in greater depth.

Respondents also preferred to develop a graphical interface using HTML instead of XPCE. Given that internet applications are quite motivating, we really believe that HTML is a good choice.

However, respondents showed preference in manipulating files in prolog rather than using a database manager. We believe that providing information for first year students on this topic is not an easy task. An extra effort should be made to improve the material. Some prolog instructors might like this result because working with a database manager requires less effort in learning the prolog language with respect to input/output of data. However, it is not good for our purposes as we want to develop applications that use most of the technology that companies employ to develop their products, in particular internet applications.

Figure 1 depicts that the pass rate increased with the application of our methodology. In this figure we show the pass rate in the semester before the application of our approach (label *before method*) and the average pass rate after the application of our approach (label *after method*)

IX. Conclusion

Logic programming is an important programming paradigm. In this way, efforts should be made to make its understanding easier. The development of real applications should be pursued in order to motivate students, practitioners and organizations. In this paper we made a contribution toward to this end.

Preliminary results showed an increase with respect to learning and motivation. However, it is necessary to keep monitoring the progress of students in order to verify the consistency of the results.

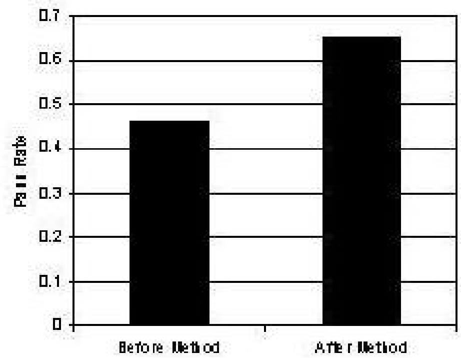

Fig. 1. Pass Rate before and after the application of our methodology

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Enhancing Microelectronics Education using Online Semiconductor Technology CAD Laboratory

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***Abstract* — Currently, semiconductor devices, VLSI circuit design and fabrication are specialized fields in electrical engineering curricula. Teaching microelectronics technology is dependent on the availability of resources and is mainly being taught at universities where a fabrication facility is available. As such, microelectronics engineering education is in transition. New thoughts are being given to topics such as what constitutes microelectronics process design fundamentals, how to shrink the gap between industrial and academic perspectives on process design and how to help students gain more experience and knowledge. This paper proposes and discusses an efficient teaching methodology for micro- and nano-electronics education. A Technology CAD (TCAD) course integrated with an online simulation laboratory at undergraduate/graduate level. The aims of the course are the development of theoretical and practical skills in semiconductor manufacturing using virtual wafer fabrication. It is expected that the students shall have increased affinity towards semiconductor fabrication, improved academic skills, abilities and knowledge. The impact of the proposed teaching methodology on the learning process will be presented.**

Keywords— remote laboratories; microelectronics education; TCAD; semiconductor fabrication; online learning

I. Introduction

Currently, micro- and nanoelectronic device, circuit design and integrated circuits fabrication are specialized fields in electrical engineering curricula. Due to very high cost, microelectronic fabrication facilities are available only in a few educational institutions. As such, microelectronics technology is mainly being taught at universities where a fabrication facility is available and the microelectronics engineering education now is in transition [1]. New thoughts are being given to topics such as what constitutes microelectronic process design fundamentals, how to shrink the gap between industrial and academic perspectives on process design, and how to help students gain more experience and knowledge [2].

To extend microelectronics engineering education, various approaches are being made such as, teaming with semiconductor industry partners who are willing to share their facilities with the students by providing remote access to their expensive facilities on the internet. The remote access has additional advantage of students need not physically entering the facility. Another possible solution towards microelectronic education is to use virtual laboratories [3].

Technology computer aided design is commonly used for developing semiconductor technologies. TCAD has now become an important component of modern semiconductor manufacturing and a new framework is needed for advanced microelectronics education. To meet the goal, integrated measurement-based microelectronics and VLSI engineering laboratory with simulation-based technology CAD laboratory has been reported [4].

Learning environment is continuously evolving and it is all the more important to change the present "teacher centered methods" to "student centered methods". Now-a-days, the trend in education strategies goes in the direction of learner centric learning. In learner centric learning, learners are expected to participate more actively in the learning process to improve their own learning. The objectives for the integrated technology CAD laboratory is to introduce the students to the basic and advanced processing technologies that are being used in semiconductor fabrication. This paper will discuss an efficient teaching methodology for a TCAD course integrated with a simulation laboratory at final year undergraduate and graduate levels. The main aim of the course is the development of theoretical and practical skills in semiconductor manufacturing via virtual wafer fabrication. Both laboratory and simulation experiments are used in the learning process.

II. Methodology

Laboratory courses are integral part of engineering education. Simulation is a popular teaching technique amongst educators. Simulation helps student to understand a situation, a process and the replication of real situation activities. In semiconductor manufacturing context, computer simulation brings in the real situation on the computer screen. With the capability of technology CAD tools, now-a-days, students can use softwares such as, Silvaco and Synopsys Suites to observe process detailed effects in a space through animation, just like in a real situation. Currently available commercial softwares suites are predictive which increase student understanding of the semiconductor process.

The advantages of computer simulation in designing microelectronic process are that it can boost designers' capabilities towards quickly evaluating the quality of process. If computer simulation is integrated in learning process, it is predicted that students can be more creative. It is obvious that process and device simulations are very dynamic fields and are developing rapidly, which makes them difficult even for technologists actively involved in this area to keep abreast of developments. To maintain rapid advancement, device and process designers are increasingly turning towards computer simulations of the process, design of electronic devices and circuits for solutions [5].

Advancements made in methods of communication and research is beginning to change the traditional scenarios of the classroom. The exponential growth of the Internet has promoted opportunities for new ways of teaching and learning. The Internet has now become a valuable source of information that breaks down many of the barriers associated with a traditional classroom teaching. Despite the radical changes in the context of communication, university curricula have been slow to adapt the changes. In particular, microelectronics educational programs still focus almost exclusively on teaching traditional technical skills and the students receive little explicit training in how to apply these skills in circuit design [6].

Current TCAD use is mostly limited to process and device simulations; however, it may be extended for the development of compact models, suitable for circuit and system level analysis. Compact model generally include SPICE-like parameters obtained from the device electrical behavior. Also, variations of SPICE-like parameters need to be carefully estimated to achieve acceptable model predictivity, including process yield evaluation. This paper proposes and discusses an efficient teaching methodology for microelectronics courses when "integrated" with an online technology CAD laboratory [7].The purpose of this research is to examine the effects of integrating the SPICE parameter extraction tools in technology CAD course as a subject for the design of integrated circuits.

A. Research Purposes

The dynamics of teaching and learning usually involves three entities: the teacher, domain of knowledge, and the student. The Internet has today become the fourth entity. Learning environment is continuously evolving and it is all the more important to change the present "Teacher centered methods" to "Student centered methods." The purposes of the research are as follows: (i) to identify the interest of the students in microelectronic circuit design through process/device simulations, device characterization, SPICE parameter extraction, and finally the circuit design, (ii) to study the effect of integrating Technology CAD laboratory for use in developing the circuit design process via simulation, and (iii) to study the effect of integrating class room teaching (theory) with the online technology CAD laboratory.

B. Technology CAD

Before the 1980s, numerical simulation was not considered seriously for electronic device development. Instead, the device structures and fabrication steps were modified following a set simple guideline (scaling laws). However, as the channel length is scaled below 1000 A, scaling laws no longer can accurately predict the operation of the devices due to the increasing structural complexity and small geometry effects. TCAD has become the principal tool for virtual characterization of technology development and uses computer simulation to model semiconductor process and device operation. In the deep sub-100nm regime, the increase of feature complexity and scaled geometry make it more challenging for TCAD to predict the characteristics of the devices. The design for manufacturing solution when incorporated in TCAD provides a bidirectional link between manufacturing and design. TCAD bridges the gap between the world of technology and that of circuit and system design. Conventional (core) TCAD is currently used for process and device simulations. It uses process recipe and layout information to simulate the several fabrication process steps (e.g. oxidation, implantation, lithography, deposition, etc). Originally, these tools were used as individual units to simulate individual fabrication process steps.

With increasing computer power, TCAD is being used more and more efficiently to explore new device architectures and optimize process flows. TCAD is being increasingly used in manufacturing for advanced process control and parametric yield improvement. Extended TCAD modules include the characterization (measurement) of the devices and extraction of SPICE parameters [5]. The aims of the TCAD course are the development of theoretical and practical skills in microelectronics. Both laboratory and simulated experiments are used in the learning process. Our approach addresses these issues by way of an internet accessible simulation laboratory which uses the world-wide web and the trend towards network-based computing. A typical TCAD flow for microelectronics circuit fabrication is shown in Figure 1.

C. TCAD Tools

Availability of TCAD softwares has made possible accurate multidimensional simulation of realistic device structures and processes. Advanced set of TCAD tools is available from universities and from TCAD vendors. Commercial TCAD vendors (Silvaco and Synopsys) provide an excellent collection of TCAD suites. Commercial TCAD tools may be used to show students the link between physical and electrical simulation through the mixed TCAD and electrical simulation abilities of Silvaco and Synopsys tools. Advanced TCAD suites include process simulation, device simulation, compact models parameter extraction and circuit simulation suites, interconnect simulation, and optimization to other technology CAD requirements. However, the use and maintenance of coupled TCAD tools becomes difficult and requires a significant level of user experience. Historically, all the TCAD tools developed were available on various UNIX-based platforms. Attempts have also been made for Windows versions of TCAD tools, but the use of Windows versions are very limited, as the software packages are distributed and supported by third-party vendors. Current TCAD tools accelerate advanced technology development with Process and Device modeling capabilities.

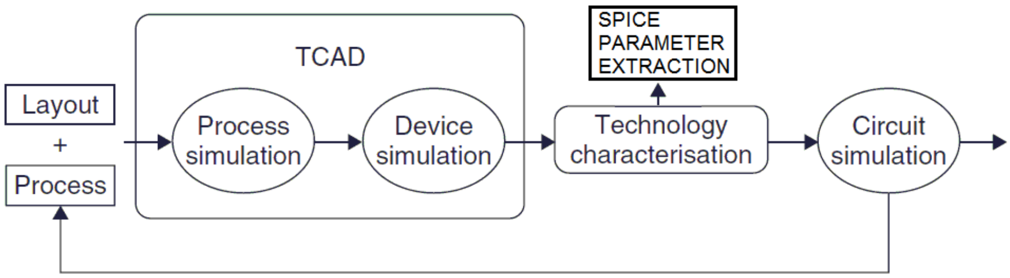

Figure 1. TCAD flow in semiconductor circuit fabrication.

D. Technology CAD laboratory

In an earlier paper [7], we have described an approach and methodology and addressed the issues arising in combining virtual device fabrication, remote electrical measurements, modeling and TCAD simulations of basic semiconductor devices. Integrated measurement-based online microelectronics laboratories with simulation-based technology CAD laboratory have been described [8]. For a TCAD course, the associated Technology CAD laboratory may include (among others) the following experiments:

1. BJT: Gummel plot
2. BJT: Output characteristics
3. SPICE Model parameters extraction for BJTs
4. MOSFET: output characteristics
5. SPICE Model parameters extraction for MOSFETs.

III. CASE STUDY: LABORATORY SESSION

Each laboratory session (duration 3 hours) generally consists of three parts. In the first, students characterize one or more electronic devices such as a bipolar transistor (BJT) or a MOSFET using the experimental setup shown in Figure 2. In the second part, they extract the SPICE model parameters from the dc characteristics obtained in first part. Finally, they are asked to prepare a short independent report that includes a brief description of the experiment, comparisons between experimental measurements, and extracted SPICE parameters.

A. SPICE parameter extraction: NPN BJT

With the extreme scaling down of devices in high volume manufacturing, it is imperative to develop TCAD based methodologies encompassing process design to device simulation, and characterization for SPICE parameter extraction. SPICE parameters are essential in integrated circuit design and the accuracy of circuit simulation depends on the accuracy of the transistor model. The four most widely used silicon bipolar transistor compact models are:

- SPICE Gummel-Poon (SGP)
- Most EXquisite TRAnsistor Model (MEXTRAM)
- HIgh CUrrent Model (HICUM)
- Vertical Bipolar Inter-Company (VBIC)

During teaching of TCAD subject, the students are taught on these bipolar device models. The accuracy of compact models in circuit simulation depends not only on the correct physical description of various physical phenomena in the device but also on a reliable, robust, and unambiguous extraction methodology for model parameters. An automated measurement system capable of accurately measuring the various characteristics of a device and extracting parameters is very important. General requirements for parameter extraction methodologies are:

- well-defined, simple, fast and reliable procedures
- standard measurement equipment
- modular - implementation enabling quick adaption to process and model evolution
- model implementation in CAD systems

Bipolar junction transistor (BJT) is one of the most widely used semiconductor devices in integrated circuits. Because of its superior speed performance, such a device has found wide applications in high speed switching and digital electronics systems. In this experiment, students characterize the current-voltage characteristics of an NPN bipolar junction transistor using the IIT-Kharagpur Lab-on-Demand [8].This experiment involves three parts: (i) measurement of current-voltage characteristics (both Gummel and output characteristics) and their plotting, (ii) SPICE model parameter extraction, and (iii) comparison of SPICE model with measurements. Main objective of this experiment is to expand students' knowledge of bipolar junction transistor devices.

In the following, SPICE Gummel-Poon (SGP) model parameter extraction techniques is illustrated. Specifically, the extraction of current gain and related compact model parameters is described. The current gain may be obtained from the Gummel plot and also the output characteristics of the bipolar transistor. An automated measurement setup that may be used for the extraction of device parameters is shown in Figure 2. An Agilent 4156C-based or equivalent system is chosen as it has the capability to measure dc characteristics of semiconductor devices. As device characteristics evaluation is the prime objective, the controller is commonly used to collect the measured data and transmit the data to the host computer for post-processing. In order to extract the model parameters, several measurements are performed at different biasing conditions at room temperature.

As a first step, the forward Gummel plot is measured. In order to measure the forward Gummel characteristics of the transistor, the Agilent 4156C is programmed as a voltage or current source. For measuring the Gummel characteristics, the instrument is programmed to sweep emitter-base voltage from 0 to 1 V. Both the base and collector currents are measured. The forward current gain is plotted as the ratio of the measured collector current to the base current. The output characteristics of the BJTs are measured using either forced base-emitter voltage (kept constant), or a forced base-current (kept constant). In the measurement collector-emitter voltage is swept and the collector current is measured. Figure 3 is a screenshot showing the Gummel plot and the extracted SPICE parameters; the current gain and other associated parameters for a NPN BJT.

The next step is the inclusion of the finite base, collector, and emitter resistances in the model. The emitter resistance is determined by stimulating the base with a current in strong saturation and measuring the collector-emitter voltage. The collector current is kept small (typically less than 1 microAmp) and the applied base current is swept up to 10 mA. The inverse of the gradient of characteristics can then be used to obtain emitter resistance. The measurement of the collector resistance is similar to the emitter resistance. Here, current is applied to the base and collector, and the collector-emitter voltage is measured. The base current vs. base-collector voltage characteristics for two collector current values is measured and the collector resistance is determined from the ratio of collector-emitter voltage difference to collector current difference. Figure 4 is a screenshot showing the output characteristics and extracted SPICE parameters; the Early voltage and collector resistance for a NPN BJT.

B. SPICE parameter extraction: MOSFET

The main objective of this experiment is to expand students' knowledge of MOSFET devices. We use modeling and simulation tools to gain deep understanding of device physics and process effects on MOSFET performance. The four most widely used MOSFET compact models are:

- Charge-Based MOSFET Models, such as BSIMx
- Surface-Potential Based MOSFET Models, such as HiSIM
- MOS Model 11
- EKV Model

The outline of this laboratory exercise is similar to the BJT experiment described in detail above. The students study the current-voltage (output) characteristics of MOSFETs using similar measurement system. From the output characteristics, the related SPICE parameter such as, channel length modulation and the source-drain resistances are extracted. Figures 5 shows the screenshot of output characteristics along with the SPICE parameters extracted for a MOSFET.

C. Student Performance Evaluation

For each laboratory session, students need to submit a project report (written report) related to the experiment and appear in an oral presentation. Although it is recommended that students work individually on each experiment, but it is also allowed to be in a group of two students for collaborative study. The written report needs to focus on the experimental/modeling results including a short description of the techniques that were used. The oral presentation should focus on presenting the results of the study. Also difficulties especially for measuring equipment and techniques need to be focused. The grade was set according to the output of each

Figure 2. Experimental setup for semiconductor device characterization. BJT output characteristics is visible on the instrument's screen.

student in these three components as mentioned above. The final assessment included the evaluation of the all the experiments performed by the student during the semester.

D. *Effectiveness Evaluation of Online Laboratory*

To understand the effectiveness of these online simulation experiments (especially the SPICE parameter extraction part) towards students' learning was to examine what motivated the students to take the online TCAD laboratory course and to assess their interest in receiving services online. The impact of the proposed teaching method on the learning process was investigated by analyzing the data collected through a online survey designed specifically for this study. In our study, student's grades were also monitored to evaluate their academic performance. Our evaluation showed that the use of online simulation experiments available in the TCAD laboratory was beneficial for the students. The authors believe that the improved students' academic performance and their positive attitude towards the course are mainly due to the integration of simulation tools in microelectronics teaching.

E. *Limitations*

This study is also not without some limitations. First, the students (learners) participating were first-time to this online laboratory. It is possible that more experienced students might have different needs than the first-time user counterparts. Second, data were collected from students enrolled in a single institution. Students using this online laboratory from other institutions may have motivations for taking online courses and may like to see different academic needs. Overall, this study provided some useful insights into the needs of learners who wish to take online microelectronics course when integrated with a TCAD laboratory.

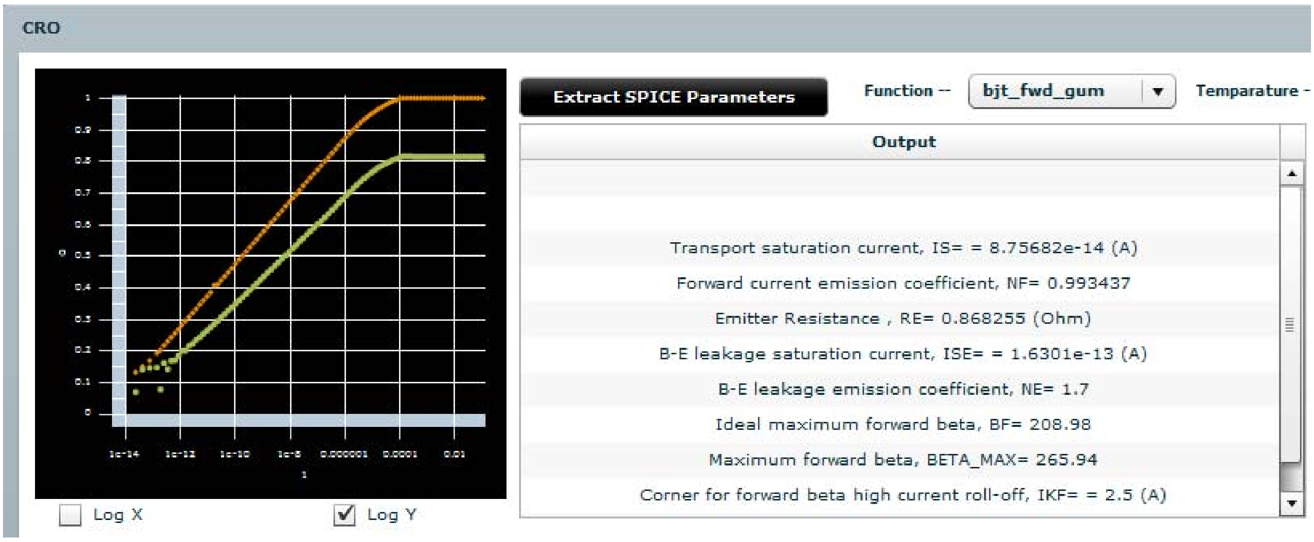

Figure 3. Screenshot showing the BJT forward Gummel plot and extracted SPICE parameters.

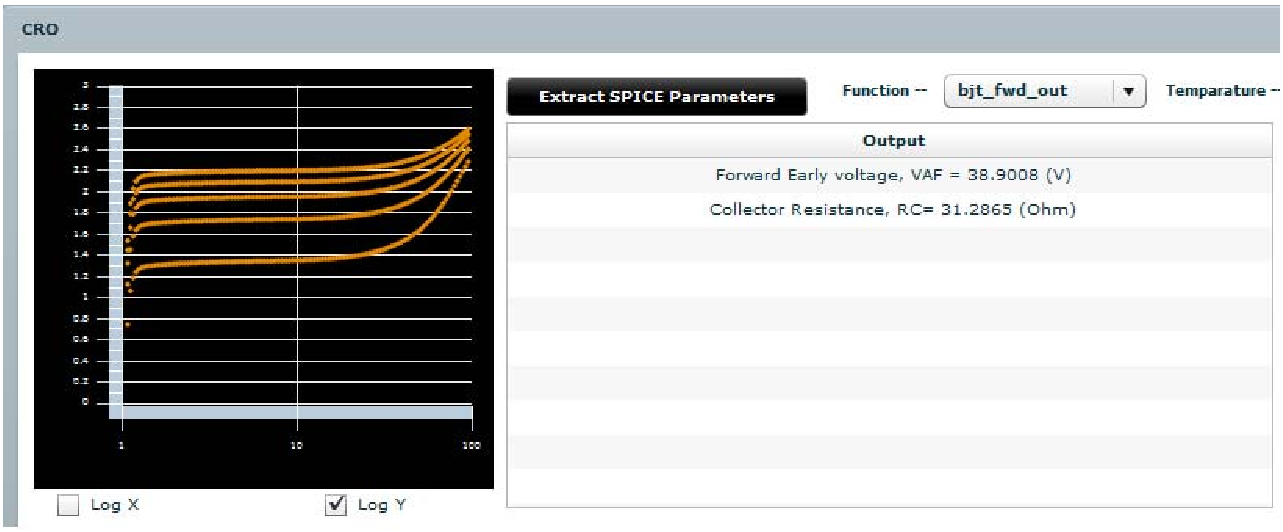

Figure 4. Screenshot showing the BJT forward output characteristics and extracted SPICE parameters.

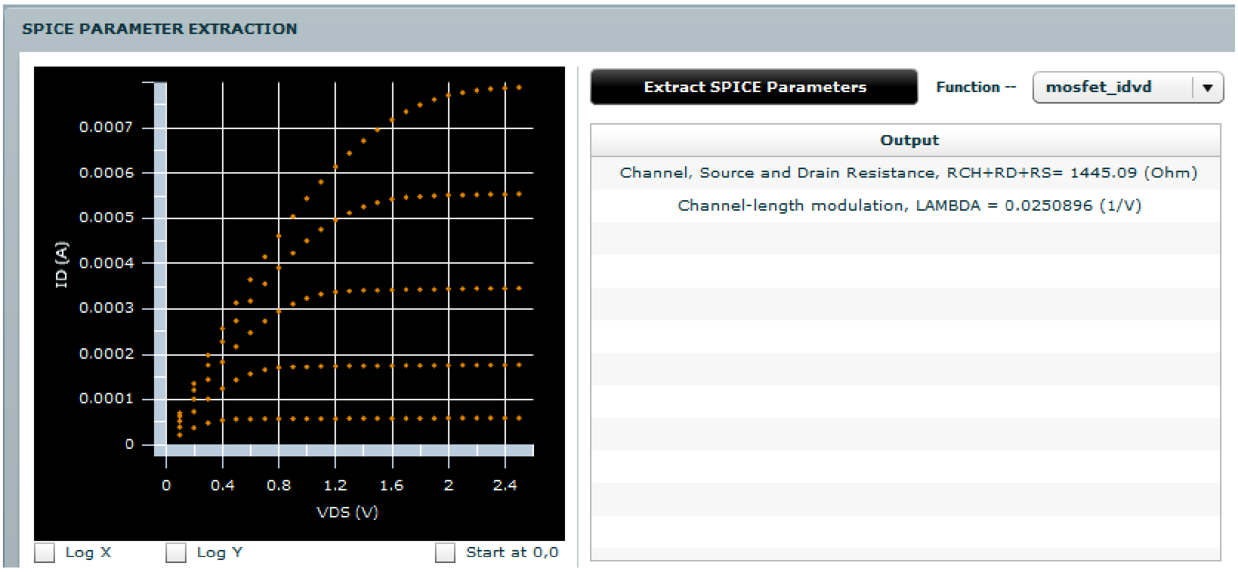

Figure 5. Screenshot showing MOSFET output characteristics and extracted SPICE parameters.

CONCLUSION

This paper described a project that introduces university students to the high technology fields of microelectronics through the use of web-based "hands-on" experiments. It is expected that the outcomes of this study shall have significant impact on the future practices in teaching microelectronics in distance education mode. The proposed methodology allows students to explore microelectronics course starting from underlying science, to device physics, to process and extract SPICE model parameters essential for the circuit design. This research contributes to the development of an interactive Technology CAD course using "online" TCAD laboratory and conventional class room teaching. The new technology CAD course integration with the virtual wafer fabrication (VWF) in designing microelectronic devices, process and circuit simulation is shown to enhance student's interest. The authors believe that the improved students' academic performance and their positive attitude towards the TCAD course are mainly due to the integration of simulation tools in teaching.

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Insights for Curriculum Design from Design Research

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***Abstract*—The paper considers how research in product/process design methodologies can be used to design engineering curricula. Following the Function-Behavior-Structure (FBS) framework for product design, we show how the curriculum design task can be separated into functionality of the curriculum, student behaviors and course structures. We then describe possible ways in which such a design could help us explore the possibilities of designing different types of curricula with the same functionality so that we could develop flexible, fault tolerant, scalable curricula that *evolves* with changing circumstances. These requirements are not generally included as curriculum design criteria and an approach that highlights the role of "robustness" would be useful.**

Keywords—curriculum design; design; flexibility; fault tolerant; function-behavior-structure framework; robustness

I. Introduction

Although program faculty across the world design and redesign their curricula, the authors have not read many papers on curricular design processes that apply research on product/process design methodologies. The paper intends to highlight findings from research on design methodologies, as well as observations on some important trends in education, and consider how these findings and observations are and are not applied in curriculum design processes. As a starting point in the exploration, the authors consider three very different curricula, all of which generally intend to achieve similar student learning outcomes, because the various organizations that accredit engineering programs in different global regions articular similar student outcomes.

II. Starting Point

First, consider the mechanical engineering (ME) curriculum in Fig. 1, which begins in the sophomore year, because this is often where various engineering curricula differentiate. While specific details, e.g., course names, specific course content, detailed order of courses, etc., of the curriculum in Fig. 1 differ from other ME curricula, overall the curriculum is similar to many other ME curricula in major universities around the US.

In contrast to the curriculum shown in Fig. 1, engineering students in the General Engineering program at the Iron Range Engineering (IRE) program take 15 one-credit courses in each semester of the last two years of their four-year engineering program, having completed their first two years at another institution. Over the last four semesters, IRE students complete 60 credit courses (32 technical credits and 28 professional development credits); however, they earn the majority of these credits while working on four industry-sponsored projects (one per semester) [1]. For breadth, "when the technical learning cannot be in the context of the project, another deep learning activity is chosen and executed. Typical activities include: (a) design or execution of Model Eliciting Activities (MEA); (b) student designed, conducted, and analyzed experiments; or (c) construction of an advanced computer program, e.g., expert system or simulation program" [1].

Finally, at Maastricht University the knowledge engineering program is built from blocks, 6 blocks per year. In the first two years, two of the six blocks are projects and parts of the other four blocks are projects. In the last year, two of the blocks are for a bachelor thesis, another block is project work, and a project is incorporated into another two blocks. So, the Maastricht program is "designed around the Project-Centred Learning (PCL) teaching method. It resembles the Problem Based Learning style, which Maastricht is well-known for. The PCL educational model is small-scale and student-oriented. You work in small groups on complex and challenging projects that require you to develop a variety of skills" [2]. ABET accreditation criteria would be used to evaluate the ME program and IRE program while Engineers Australia criteria would be used to evaluate the Maastricht program.

All three programs: the ME curriculum, the IRE General Engineering curriculum, and the Maastricht Knowledge Engineering curriculum are very different implementations, but all are intended to achieve roughly similar student learning outcomes. Methodologies that foster creation of very different embodiments to achieve the same desired outcomes are a focus of research on design methodologies [3-5]. The paper intends to highlight some findings from the research on design methodologies and consider how these findings are applied in

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curriculum design. The approach has elements in common with [6] who has considered a systems design approach to instructional design but differs from it in the adoption of a Function-Behavior-Structure approach [7].

For concreteness, the paper will, at times, focus on ME curricula, although many observations will be relevant to any engineering curriculum. Also, there is another set of issues, relevant to curriculum design and change, which will not be explored in this paper. Once an engineering curriculum that is different from the existing curriculum has been designed, questions arise about how transition to the new curriculum will be accomplished. Transition introduces many logistical issues, e.g., which curriculum requirements will apply to which students during the transition. Also, course content and/or instructional strategies may be different once transition to the new curriculum is complete. Issues related to these changes may draw on research related to organizational change. However, issues that are related to curriculum and organizational change are not the focus of this paper.

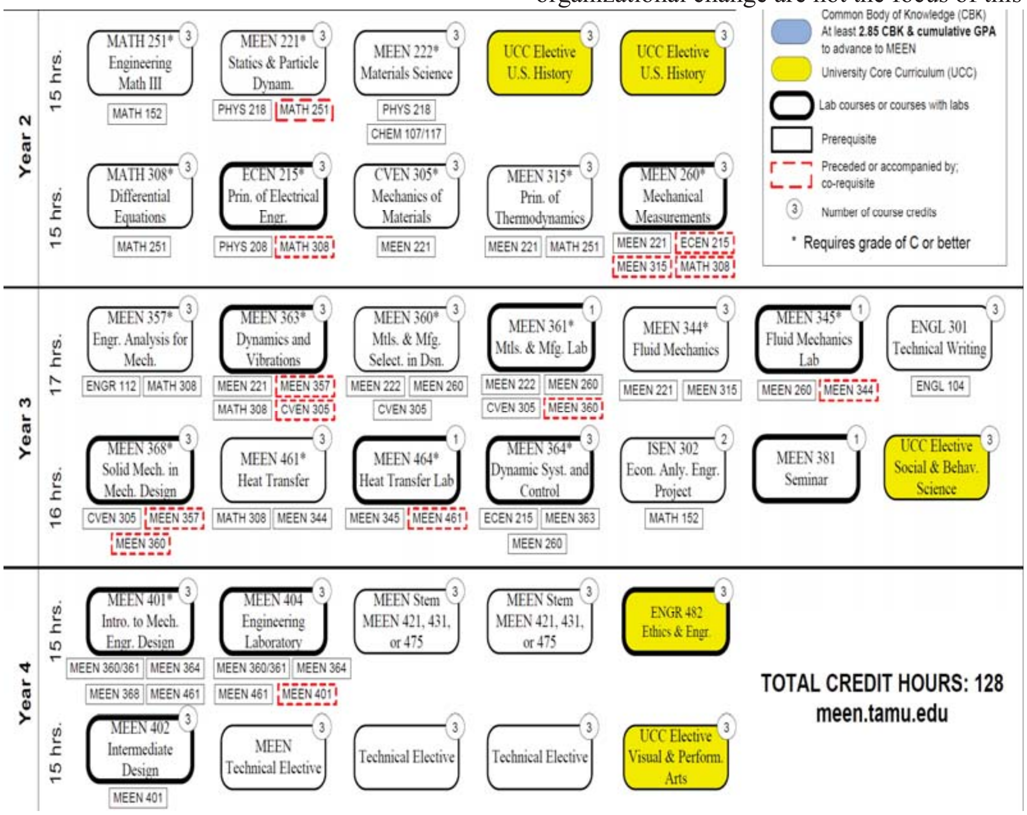

Fig. 1. A mechanical engineering curriculum (from sophomore on) together with the prerequisites.

III. Traditional Curriculum Design

Observations in this section summarize the authors' observations of engineering curriculum design. They are not results from rigorous analysis of systematically collected empirical data captured from multiple curriculum design processes at multiple institutions. Instead, they are offered to differentiate current curriculum design processes from process that might draw from design methodology research. In practice, curriculum design processes appear to draw from combinations of three curriculum design approaches:

Design by Experience: This is the de-facto craftsperson approach where the focus is on course content and faculty members fashion their curriculum design decisions or instructional approaches based on personal experience and selected empirical evidence of what appears to be useful.

Design by Trial and Imitation: Recently, more emphasis has been placed on "benchmarking", imitating "best practices", and drawing on ideas from other programs. Here, innovative faculty members became acquainted with approaches at other institutions and are inclined to try something they have observed, often based on a combination of "gut" feeling of "what works" and their sense of what could be adapted to their course, beliefs, and personality. If results from initial trial are encouraging, then they may stick with it. Later, others may choose to imitate or adapt it with varying degrees of success.

Approaches based on Research on Learning and Education: The next category is that which is based on a scientific discovery approach to curriculum design; here the system to be studied is a group of students and various hypotheses (based on discoveries made by innovators) are tested and the results are disseminated. In many cases, results show [8-10] that initial hopes for great improvement are not borne out. However, evidence on research and education does not appear to cause significant changes in how curricula are modified [8-10]. Reasons for resistance to change include: (a) research results appear to contradict the years of experience built up [8, 9] and (b) the scientific approach tends to engage critical/analytical aspects of the instructors thought process rather than collaborative, innovative aspects. It is therefore not surprising that approach (2) based on trial and imitation seems to be more successful than approach (3) in changing the hearts, minds and behaviors of instructors, i.e., curriculum designers.

A. *Observations about Traditional Curriculum Design Approaches*

All three approaches are bottom-up and based on the following underlying assumptions:

a) The basic building block of curricula is the course. Instructors bring with them all of their assumptions and experiences that accompany thinking in terms of courses.

b) Instructors and students know what a course is, they know what each course is intended to achieve, and they how it relates to overall curriculum objectives.

c) Curricula are built by assembling courses. If each course achieves its objectives, then the curriculum is successful

As a result, faculty members engaged in curriculum design expend a vast amount of effort in deciding which courses are necessary and which are not, and then modifying and optimizing courses that are selected. In this scenario, the overall curricular goals are “emergent behavior” and there is no guarantee that the requirements will be met [11].

B. *Importance of Flexibility, Fault Tolerance, and Scalability*

While curricula are intended to achieve learning outcomes, other characteristics such as flexibility or adaptability to changing external conditions, fault tolerance, and scalability are also desirable characteristics and should also be design criteria. Inability of curricula to be adaptable and scalable has been the focus of recent, widespread media attention.

A case study in flexibility, fault tolerance and adaptability , is the development of the worldwide web: While many computing technologies stagnated after a while, the web grows and evolves at an amazing rate, from simple computer sharing in the 1970s to the internet of things in 2010 [12]. This has occurred in spite of competition. Several features are noteworthy and contribute to robustness of the web:

1) **Flexibility:** The original idea for the web was not presented as a “finished product” but as a “work in progress” that invited people to contribute with open protocols and low barriers to entry.

2) By allowing web designers access to the source code, the dominant idea was to “copy and edit” not reinvention.

3) Parallelism inherent in flexible open systems enables greater exploration of the space of possibilities. But it comes at the cost of efficiency. In other words, the web sacrificed optimality of performance for robustness, openness and flexibility.

4) **Fault Tolerance:** Unlike earlier implementations of hypertext, where there was a central database of links and link failures were not tolerated, the web is based on loose coupling and decentralized service, leading to greater fault tolerance.

5) The web was able to recruit thousands of people to contribute content---this eventually overpowered proprietary corporate networks. You did not have to ask anyone to do something interesting. There was no pre-screening for access.

6) **Scalability:** Scalability is achieved through gradual learning and investment possibilities.

So, questions may be raised about how curriculum design could be done to enhance (a) robustness and fault tolerance, (b) flexibility with low barriers to entry (which result in very different metrics than retention and time to degree), and (c) scalability. Design methodologies, which are explored in the next section, can provide a framework that allows us to explore these ideas and see to what extent this could be done in curriculum design.

IV. Conceptual Design Methodology

Findings from research on design methodologies that will the focus of this paper are drawn from the Function-Behavior-Structure (FBS) approach [7]. An overview of the FBS approach, at least for the work in this paper on curriculum design, is summarized in Fig. 2.

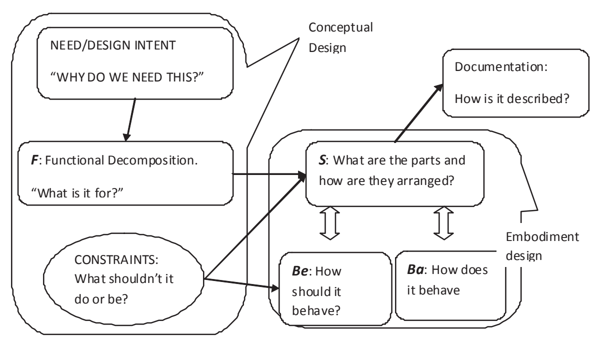

Fig. 2: Core elements of a conceptual design process. Arrows represent flow of the processes.

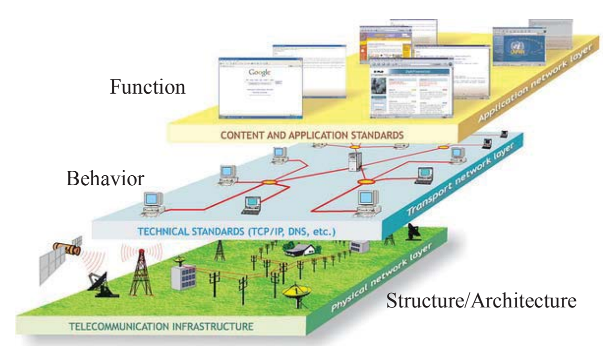

Fig. 3: The three layered architecture of the web showing FBS framework.

Function, behavior, and structure are often referred to a layers, although their interdependent relationships are often more complex than the word suggests. Interestingly the web itself has three identifiable layers that can be mapped to the three elements of conceptual design: (i) Function (Content and

Application Standards), (ii) Behavior (Technical Standards: TCP/IP, DNS, etc.), and (iii) Structure/Architecture (Telecommunication Infrastructure).

Further, although listed in a sequence below, steps in the FBS framework are implemented in complex, iterative combinations that are highly dependent on results that emerge from a particular step. However, for simplicity, steps in the FBS framework are described as:

1) **Need Analysis:** This is the highest level of the function layer development and describes desired input-output behavior of the whole system. Designers and their clients work together to identify principal client needs and constraints that restrict the range of feasible alternatives. Then, designers convert needs and constraints into an abstract, high level specification listing inputs, outputs, and transformations required to convert inputs to outputs. Each transformation is described as a functional requirement.
2) **Functional Decomposition:** Functions are hierarchically/recursively decomposed into a sequence of subfunctions (each with their own input-to-output transformations). The process stops when realizable behaviors or components are reached.

The first two steps are usually referred to as conceptual design and several systematic ways to do this have been described in the literature. At the end of a conceptual design process, clients and designers should have a clear answer to the question: "What needs to be done?"

3) The third step is to list possible alternative behaviors that could satisfy the functions in the function hierarchy that emerges from step 2. These list the expected behavior of the system. This is also the stage where the constraints imposed on the system can be made explicit.
4) This step develops potential structures intended realize behaviors from step 3 while meeting the constraints.
5) This step documents the structure, its actual behavior, and the resulting functionality.
6) Next is the evaluation/assessment step (this is akin to the sensing function in a feedback loop system). We evaluate the structure of the component or system and evaluate its actual behavior and compare with the expected behavior.
7) This is the redesign or modification step:
   a) First if there is a significant discrepancy between expected and actual behavior, then the structure or expected behavior needs to be modified.
   b) If the expected and actual functionality is different, then the behavior and/or functional hierarchy must be re-examined and modified as required.
   c) If client needs and constraints are not met, needs and constraints are re-evaluated. Also, design intent/need is re-evaluated.

Initial focus on the conceptual design process is extremely useful in capturing the current state of design intent without mandating "how it could be done". Clear, explicit description of design intent allows for greater exploration of different possible embodiments, although time is spent on conceptual design may initially appear to delay implementation or waste resources.

Example: Smartphone Input System

The FBS framework in Fig. 2 and the seven steps are stated very abstractly. Before examining implications of the FBS framework for curriculum design, a concrete illustration may help elaborate the nature of the framework and design steps.

Before 9 June 2007, smartphone designers asked the following question with respect to user data input: "How can the designer include a keypad in the phone so that it is compact, but still useful?" Phones such as the Motorola Razr or various sliding, folding, or flipping phones were considered innovative solutions to the question. However, when Apple introduced the iPhone in 2007 (along with the Samsung 700), it became apparent that the question could be framed differently, "How can a user communicate their intent to a smartphone?" If functional requirements are framed this way, then many behaviors are possible, e.g., eye-tracking. Further, a keyboard becomes only one possible embodiment (a tangible or visible form of an idea, quality, or feeling) to realize behaviors that achieve the stated function. By framing user intent differently, Apple designed a phone with no keyboard. Rather, it offered an entirely new embodiment with combinations of behavior, e.g., tapping, swiping, etc., that achieved the desired intent.

Functional/conceptual design: For example, in the phone input system example stated above, a simplistic description of the function layer would be: (i) Input: User intent; (ii) Output: Phone actions; and (iii) Function: Transform user intent into phone actions.

Behavior Layer: With this functional description of intent, it may be observed many behaviors may achieve the same functionality [13]. For example

1) Touching the screen causes it to translate and make physical contact with a circuit board completing a circuit (keyboard structure)
2) Touching the screen causes it to deform thus changing the capacitance causing a change in electric current (capacitive touch screen of iPhone)
3) Touching the screen creates a radio frequency resonant vibration which is detected using electromagnetic circuits (Wacom tablet)
4) Touching the screen causes the deformation of a layer under it whose resistivity changes which can be detected. (resistive touch screen)

Each of these behaviors results in the same primary functionality but leads to different possible structures. However, there are secondary behaviors that result that may be beneficial or not. For example the capacitive touch behavior cannot be caused by stimuli from a simple plastic stylus. So a design needs to consider these effects and then decide what changes need to be made.

With the iPhone, the behavior layer would be that physical contact with the phone surface should lead to an electrical signal that will activate certain programs in the phone to perform certain actions. The structure layer would be the keyboard layout or arrangement of the conductive layers on the phone surface. Each kind of behavior may strongly influence the structure and the combination is usually called an embodiment.

V. Mapping FBS Framework into Curriculum Design

With the preceding description of the FBS framework and process, implications for curriculum design processes can now be explored. Table 1 maps steps in the FBS design process to analogous elements in the curriculum design process.

Table 1. Mapping between FBS Design and Curriculum Design Steps

FBS design	Curriculum Design
Need/design intent	What are sources of design intent: mission statement? Capstone course learning outcomes?
Functional decomposition	Program learning outcomes, i.e., student capabilities at program completion
Expected behavior	Student activities in the classroom (attending lectures, doing homework or individual or group projects etc.)
Structure	Weekly Course outline, scheduled classroom activities
Documentation	Course catalogue, Syllabus, website etc.
Evaluation of expected vs. actual behaviors	Student Assessment, internal meetings with different groups, student evaluations etc, research into course outcomes etc.
Evaluation of expected vs. actual functionality	ABET, SEC or other external bodies.
Evaluation of overall intent and functionality	Society, Various governing boards, market survey etc.
Redesign	Usually focused on course topic redesign and occasionally course structure redesign

A. Where might curriculum designers look for design intent?

How well do department mission statements illuminate curriculum design intent? Consider, since the authors are familiar with it, the mission statement of the Department of Mechanical Engineering at Texas A&M University. Analysis of the mission statement reveals program clients are broadly described as "students, the state of Texas and the nation," and within this broad population, the mission statement highlights three subgroups: industry, government and academia. Core functions can be extracted from the mission statement: (i) preparing students for leadership positions and successful careers in industry, government and academia, (ii) advancing knowledge in mechanical engineering, (iii) spawn new economic development in Texas, and (iv) provide professional development activities. However, from an undergraduate ME curriculum perspective, these core functions do not offer anything substantive. An informal survey of mission statements of other leading ME departments around the country provides similar findings. Therefore, curriculum designers need to look for other sources for design intent, needs, and constraints.

If the endpoint of the undergraduate ME curriculum is taken as attributes of students who complete the senior capstone courses, then the learning outcomes/objectives of these courses could be used as the output of the transformation that the ME is intended to achieve. At Texas A&M, the objective of the capstone design course is: "At the end of this course, students should be able to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability."

As stated, the course objective is specific enough for further steps. Also, it addresses part (3) of the mission statement directly and partially addresses part (1) of the mission statement. Unfortunately, if only the learning objective for the capstone design course is used as the design outcome, the outcome does not distinguish a ME curriculum from graduates of other engineering curricula. At this point, the design process is challenged because curriculum designs lack solid descriptions of ME-specific outcomes for ME curriculum design. Likely these outcomes will be related to four design and analysis streams in many ME curricula: structure, thermal systems, materials and manufacturing processes, and control systems. Course outcomes of courses in these four streams might be analyzed to determine ME-curricula-specific outcomes, but the detail involved for this analysis is beyond the scope of the paper.

Conceptual design also requires characterization of the inputs. For ME-specific curricula, i.e., the last three years, the inputs are the course learning outcomes of key first-year courses. For engineering curricula, these key courses include second-semester calculus, second-semester physics (often electricity and magnetism), and chemistry. At Texas A&M, these course outcomes can be found [14].

B. Conceptual Design: Behaviors and Functions

In the FBS framework, a core distinction must be made between "behaviors" and "functions." As described above, course learning outcomes can provide valuable starting points for extracting outcomes and inputs. However, course learning outcomes are mix behaviors and functions. For conceptual design, emphasis needs to be placed on functions. In the context of curriculum design, behaviors refer to activities and responses of the students in the course while functions correspond to student capabilities upon course completion.

For example, if one considers the course learning outcomes for ME capstone design course [14, p. 27], they are listed as a mix of behaviors and functions. Careful analysis of these course outcomes using the above distinction between functions and behaviors yields the following list of functions:

F1: Analyze client/sponsor requests in order to produce quantitative design requirements

F2: Evaluate concepts and select the most viable

F3: Analyze and address risks associated with a concept

F4: Identify the visceral, behavioral, and reflective aesthetic components of designs

F5: Assess risk in a project and assign appropriate contingency

The other course learning outcomes for the capstone design course are behavioral outcomes, since they are related to specific patterns of behavior during the course, not functional outcomes expected to be achieved upon course completion:

B1: Describe activities that occur during each stage of a design process, and distinguish among products of each stage

B2: Develop a functional representation of a design solution based on design requirements

B3: Describe differences among various logical and intuitive innovation methods

B4: Apply prescribed innovation methods to generate conceptual design solutions

B5: Identify sources of design information and differentiate among them to determine their usefulness

B6: Record all project-related activities in a design notebook

B7: Recognize ever-present roles of design in human activity

B8: Formulate methods to improve the predicted reliability of a concept

B9: Design a suitable work breakdown structure for completing a project

B10: Employ software tools to manage projects

B11: Assess project performance though a project tracking method

Learning outcomes for other courses in the curriculum can also be separated into behavioral and functional features. If behavioral outcomes are included in formulation of the conceptual design, then the conceptual design over constrains the remaining design process by mandating behaviors during the course as functional requirements. For example, it is an unacknowledged fact that actual delivery of a course may deviate significantly from the written syllabus (behavioral requirement) and the way most faculty member have taught the course, but that the functional outcomes are achieved. Undergraduate advisors in large-enrollment programs know differences in behaviors or structural embodiments, e.g., which faculty members teach different sections of the same course, and offer advice on which faculty members to pick. Students often elect to postpone a course until their senior year, even though the curriculum in the published catalog (structural embodiment) recommends taking the course in the sophomore year. So, in some ways, engineering curricula can be viewed as fault tolerant or flexible (depending on your perspective), even though fault tolerance or flexibility were not intended functional requirements. Two points are worth noting. First, flexibility and fault tolerance are rarely functional requirements for engineering curricula, even though the examples of Iron Range Engineering and Maastricht University suggest that significant flexibility is possible. Second, separation of functions and behaviors (as well as structural embodiments) in curriculum design should promote achievement of greater robustness, flexibility and fault tolerance.

VI. Inputs and Outputs of an ME Curriculum

Examination of the inputs to a ME curriculum, i.e., outcomes of key first-year courses mentioned above, and outcomes of the curriculum, which may be described at the outcomes of the senior capstone course reveals that [15-17] ME curricula take students who are able to:

I1: Isolate bodies and represent the forces on them (at a novice level)

I2: Describe and apply the rules of geometry and calculus to obtain quantities (such as velocity and acceleration) related to the motion of particles

I3: Describe and apply the conservation laws of physics to particle systems

I4: Represent the laws of physics (especially the laws of statics) in mathematical form and solve the resulting equations (typically algebraic equations)

I5: Apply their knowledge of mathematics to analyze various special problems in mathematics

I6: Explain relevance of molecular structure and properties to a wide variety of real technological problems

I7: Describe the modern model of atomic structure and its origins in quantum mechanics

I8: Apply concepts of thermodynamics to evaluate compounds as fuels or energy sources

I9: Describe connections between chemical bonding and material properties like electrical conductivity

I10: Predict or explain properties of elements (atomic size, ionization energy, chemical reactivity, etc.) in terms of electron configurations;

and transform them into students who are capable of

O1: Identify societal needs and constraints

O2: Design systems, components, or processes that satisfy (O1)

O3: Developing multiple viable alternative designs

O4: Evaluate the alternatives to see how well they meet the requirements and what are the risks to society from these design.

Thus, a significant transformation is expected in three years.

VII. Designing For Robustness

Design rules or guidelines [18] are useful for avoiding some obvious pitfalls in the course behavior and structure design. Design experience has suggested that the following guidelines are useful for robust designs:

R1: **Provide short and direct paths**: In curriculum design, one implication is “don’t layer multiple prerequisites” or “ensure prerequisite content occurs in close temporal proximity to courses expecting prerequisite content.” Teaching content that will not be applied within a short period of time violates the rule of short, direct paths and reduces robustness.

R2: **Avoid steep gradients in properties**: This relates to interfaces. In curriculum design, one implication would be “make sure that the content and presentation of the prerequisite content is similar to that of the following class.” This helps avoid failure to apply requisite content because far transfer is required instead of near transfer.

R3: **Do not over constrain**: For curriculum design, one implication is to “avoid unnecessary prerequisites.” This is directly related to flexibility and adaptability of the curriculum.

R4: **Exploit symmetry/similarity**: Curriculum design implications include teaching different content streams or threads similarly, e.g., consistent use of conservation laws or solution tricks are avoid or similar.

R5: **Separate functions**: Component designer try to avoid optimizing a component for two different criteria. In curriculum design, one implication is to focus a module on one function instead of trying to accomplish too many things at once. ***This design rule is directly related to fault tolerance and loose coupling and is a key to evolution of the design by changes being made by the actors based on their own assessments.***

When literature on how novices approach product design is studied [19, 20], analogies with novice curriculum designers present themselves:

A1: Novices in both the fields lock into to a trial and error mode early in the design process without considering the functionality or the design strategy [20].

A2: Novices in both fields persist with a single structure without frequent evaluations (comparisons with required functionality). They do not develop multiple alternatives, since they do not carry out frequent evaluations, i.e., they do not show metacognitive behavior. [19] showed that experts generated roughly 3 times more alternatives than novices.

A3: Novices indulge in structure-up sequential design, instead of function-led hierarchical design. They tend to think of the artifact as a sequence of connected parts, instead of a purposeful holistic design. As a result, designs are cluttered, not clean. In curricular design, this behavior can be seen in the packing of individual course content to meet different detailed needs rather than course contributions to overall functional requirements.

A4: Novices also tend to develop functionality at too concrete a level ("where should we put the keypad, rather than "how do we sense user intent") and hence eliminate many interesting designs. Examine most course learning outcomes for concreteness versus functionality.

A5: Design experts realize that interfaces (user interfaces, connection between parts, etc.) can make or break a design. Novices frequently ignore interfaces or consider them as an afterthought. Studies of statics and dynamics at Texas A&M [14, 15] have shown the extent of the misalignment between first-year course content and student success in the engineering courses. Careful consideration of interfaces between different curriculum segments is essential for smooth functioning.

VIII. Potential Implications of Curricula Design using a FBS Approach

Finally, a FBS approach to curriculum design might lead to "out of the box" engineering curricula. Consider the following implications:

- Sources of curriculum design intent are limited.
- Courses may disappear from curricula because viewing "the course" as a fundamental unit of a curriculum is simply a particular embodiment. However, the particular embodiment is such a pervasive dogma that MOOCs and other novel instructional strategies methods still apply it.
- A second dogma appears prevalent: "every student should exhibit the same behavior". As was learned from the iPhone example, different behaviors can engender the same functionality. For example, a student could meet functionality of senior capstone design by choosing an internship or research project provided assessment approaches have been implemented to evaluate achievement of required functionality.
- Instead of courses being used as prerequisites, specific functional learning objectives could be used. This may directly impact time to graduation.
- Finally, instead of using course grades, a student may be able to develop a capabilities portfolio and use that as a means for advancement in the program.

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Using Backwards Design Process for the Design and Implementation of Computer Science (CS) Principles: a Case Study of a Colombian Elementary and Secondary Teacher Development Program

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Abstract—**This paper describes the outcomes of a three-day teacher professional development workshop aimed at introducing concepts, principles and practices of computational thinking. The guiding research question for this study was: How teachers implement the backwards design process embodying elements of CS Principles (i.e., computational thinking big ideas and computational thinking practices) in the context of their classrooms? The participants of this study included 15 elementary, high school and college level teachers who are also graduate students from a master program in engineering. As part of the workshop participants developed a learning activity that included a set of learning objectives, the design of computational thinking related activities considering appropriate pedagogical strategies, and the integration of mechanisms to evaluate students' performance. Here we describe (a) how participants embodied the CS Principles in the design of learning activities to be integrated into their classrooms, (b) how they used the backwards design process as a tool to implement elements of the CS Principles and (c) what is teachers' performance in integrating CS Principles to the design of learning activities as evidenced by their peer evaluations. Finally, we propose the use of backwards design process together with the CS Principles as a framework for the design of computing learning activities and the development of teacher professional development programs in computing education.**

Keywords—Computing science; education; lesson plan; backwards design

I. INTRODUCTION

Computing has become an essential tool for international competitiveness in supporting scientific and engineering developments. For instance, the use of computational tools to solve complex problems that are not solvable neither through theoretical nor experimental approaches is increasingly common [1-3]. In spite of this trend, there is a lack of well-prepared workforce with computing skills that empower them to solve these complex interdisciplinary problems. Developing countries, such as Colombia, are not the exception. Specifically, Colombia faces the threat of falling behind if it does not keep up with new technological advances [4] and the appropriate training of its future workforce.

Three decades ago the Colombian government began working on initiatives aimed at improving informatics and computing knowledge among its people [4, 6]. For this purpose, Alianza Futuro Digital Medellin (AFDM) [7], a partnership between educational institutions and the private sector, was created in order to support the transformation of technician and professional technology education through teacher professional development. Eight institutions are part of AFDM and their major goal is to provide adequate training to high school teachers. Their ultimate goal is that once high school teachers are well equipped with pedagogical content knowledge to introduce computing at the pre-college level, then these will be able to prepare high school students capable of enrolling in software-programming degrees or training courses in higher education.

One of the AFDM's strategies to accomplish their goals is by means of a teacher professional development program that supports elementary and middle school educators to complete a master of engineering degree at Universidad Eafit. This master program is focused on the area of educational technologies. As part of this program, a course called Advanced Topics is a required course to all participants. Among other topics explored, the course included a three-day workshop to introduce computational thinking concepts, practices and perspectives [20]. Along with this workshop we conducted a research study to identify how this group of teachers adopted and adapted the CS Principles [21] to the design of a learning activity guided by the backwards design process [10].

The guiding research question for this study was:

How teachers implement the backwards design process embodying elements of CS Principles (i.e., computational thinking big ideas and computational thinking practices) in the context of their classrooms?

Corresponding derived research questions are:

- What elements of CS Principles have teachers implemented in the design of their learning activities?
- How they used the backwards design process as a tool to implement elements of CS Principles?

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- What are teachers' performances when integrating CS Principles to the design of learning activities as evidenced by their peer evaluations?

II. Theoretical Framework

Action research was used as the theoretical framework that guided this investigation. Action research has been defined as a qualitative model of inquiry in which all individuals involved in a specific situation take an active role in the process of the research study [8]. We have identified action research as an appropriate theoretical framework to approach our research question because it has the primary intent to provide a framework for qualitative investigations by teachers in conjunction with researchers in complex working classroom situations [9]. Part of the goal of the workshop was to also introduce the participants to a systematic process of evaluation and refinement of their learning experiences. The ultimate goal is for the participating teachers to be able to formulate a research plan, carry out the intervention and data collection, evaluate the outcomes, and design/re-design further strategies in an iterative fashion [10].

Action research methods informed this investigation firstly by having the researchers model the research experience to the teachers by means of this study. Specifically, the researchers designed and introduced the three-day workshop utilizing the Backwards Design process [11, 12] and then conducted a systematic assessment by identifying research questions, developing data collection instruments and collecting, analyzing and reporting the data and findings. Then, participating teachers followed the same procedure by designing their own learning experience, implementing it in their classrooms and collecting and analyzing the corresponding data. The scope of this paper focuses on the first stage of the study where teachers' designed their educational modules and then conducted peer assessment. .

III. Organizational Framework

Backwards Design [11, 12] constituted the organizational framework for the workshop and was also used to make sense of our own findings. We used this framework for the design of the study because it encompasses all elements that should be involved in any instructional intervention. We also utilized this framework as a tool for the participating teachers to develop the design of their learning activities. Also known as understanding by design, this process it is a way of thinking about curricular design and implementation of curricular innovations. It emphasizes a set of tools and practices using three main stages: (a) identifying the desired learning outcomes (the content of the lesson), (b) determining the acceptable evidence of learning (the method of assessing learning), and (c) planning the experiences and instructional approach (or pedagogy).

IV. The Learning Experience

A three-day workshop was designed to introduce relevant challenges in computer education in different contexts. For instance, we discussed topics such as the decrease in number of students who pursue computing-related degrees, the lack of female representation in these fields, and the lack of formally introducing computing related concepts at the K-12 level. We also discussed initiatives started in the U.S. aiming at addressing those challenges. For instance, we discussed the CS10K effort, aiming to have 10,000 high school teachers capable of teaching some AP-level computer science class in 10,000 US high schools by the year 2016.

In the following sections we describe in more detail the goals and content of the workshop and how we also applied the Backwards Design process to the design of the learning experience.

A. General Context

The course Advanced Topics is a graduate level course from an educational technologies master program. It intends to explore relevant topics in students' areas of interests. The format of the course is as a research seminar, which allows students to interact with experts to deepen their knowledge in diverse topics. During the spring semester of 2012, the course focused on topics such as Engineering Education, History in Engineering Education, Service Learning, STEM competences, Computational Thinking, and Computing Engineering Competences.

B. Structure of the Workshop

As mentioned earlier, we used Backwards Design process to guide the design of the workshop. These elements were instantiated as follows:

Content: The learning objective for the workshop was for the participants to identify the several available approaches to integrate CS Principles in educational contexts and to use the Backwards Design process to the design of computing learning activities. Another objective was for participants to integrate the use of Scratch to support their lesson designs and to introduce computing concepts, practices and perspectives [20] in their classrooms. Therefore, the course objectives were for the teachers to develop learning experiences aimed at introducing to their students to programming and fundamental concepts of computing.

As part of this effort, teachers described Learning Objectives and Evidence Statements grouped by Big Ideas and Key Concepts informed by the CS Principles (presented in Table I). CS Principles are part of a U.S initiative aimed at developing or supporting existing AP courses. The CS Principles were designed by the College Board through a NSF grant in 2009. Due to the lack of general agreement on a common definition of computational thinking among the computer science education community, the workshop was prepared to show different computational thinking perspectives and some examples of their application areas.

The workshop started by exploring the contributions of Seymour Papert [19] and how those are related to computational thinking. Contributions from Jeanette Wing were also discussed, particularly her major role in popularizing the term defining it as: "computational thinking represents a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use." [18] Other visions were also explored such as the ones from the Women in Computer Science Alliance, the International

Society for Technology in Education, the Center for Computational thinking at Carnegie Mellon and Google.

TABLE I. CS PRINCIPLES' BIG IDEAS AND KEY CONCEPTS [21]

Big Idea	Key Concept
Creativity	A. Computing fosters the creation of artifacts. B.Computing fosters creative expression C.Programming is a creative process.
Abstraction	A. A combination of abstractions built upon binary sequences can be used to represent all digital data B. Multiple levels of abstraction are used in computation. C. Models and simulations use abstraction to raise and answer questions.
Data	A. People use computer programs to process information to gain insight and knowledge. B. Computing facilitates exploration and the discovery of connections in information. C. Computational manipulation of information requires consideration of representation, storage, security, and transmission.
Algorithms	A. An algorithm is a precise sequence of instructions for a process that can be executed by a computer. B. Algorithms are expressed using languages C. Algorithms can solve many, but not all problems. D. Algorithms are evaluated analytically and empirically.
Programming	A. Programs are written to execute algorithms B. Programming is facilitated by appropriate abstractions. C. Programs are developed and used by people. D. Programming uses mathematical and logical concepts.
Internet	A. The Internet is a network of autonomous systems. B. Characteristics of the Internet and the systems built on it influence their use. C. Cybersecurity is an important concern for the Internet and systems built on it.
Impact	A. Computing affects communication, interaction, and cognition. B. Computing enables innovation in nearly every field. C. Computing has both beneficial and harmful effects.

The three main steps of the Backwards Design process [10] were then introduced. Workshop instructors facilitated the implementation of this three-step process and guided the teachers in the design of their learning experiences. Finally, we also discussed some of the technological learning environments and tools that can support the integration of computational thinking activities such as WISE (http://wise.berkeley.edu), Scratch (http://scratch.mit.edu), and Whyville (http://www.whyville.net).

Assessment: The participants then designed and presented a lesson plan based on at least one of the CS Principles' learning objectives presented on Table 1. Peer assessment was then conducted using a rubric designed by the workshop instructors. The detailed rubric is presented in Section V.

Pedagogy: The three-day workshop combined lecture format with active and cooperative learning pedagogies. First, a lecture session with two speakers – one through videoconference and the other one on-site – was carried out. During that session, the speakers introduced the topics of the workshop, facilitated the discussion of the topics, and guided the application of the backwards design process for the design of computational thinking related activities.

Then, during a second session participants were introduced to the Scratch software (http://scratch.mit.edu/) and to the ScratchEd community (http://scratched.media.mit.edu/). Scratch software was introduced through hands-on activities where participants explored the Scratch development environment to carry out a series of structured tasks. Then, participants implemented an exercise where they had an opportunity to use several Scratch controls such as: object movement, audio for playing or recording sound, and sensors to interact with the mouse and screen borders. The software was presented with a set of worked examples.

The ScratchEd community was introduced as a resource of tools and lesson plans for the design of learning activities. During the presentation and demonstration of these resources and its capabilities it was emphasized how Scratch can be used to the development of computational thinking learning activities and how the ScratchEd community is currently working towards that goal.

Finally, participants working in dyads had two weeks of guided independent work to develop their projects. After the two-week period participants presented their projects to the entire group. During a third session participants conducted a ten-minute presentation of their designs and each of them received feedback from their peer instructors on their implementations.

V. METHODS

This section presents the findings of a case study describing how participants made sense of the CS Principles and embodied them in a learning activity with Scratch. A case study can be defined as "an empirical inquiry approach that investigates a contemporary issue in depth within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident." [13, p.18].

A. Participants

The participants of this study were 15 graduate students from a Master in Engineering Program with an emphasis in Educational Technologies who are also professors of informatics at different educational levels. Table II displays the teaching levels and disciplines for each of the participants along with other demographic information.

TABLE II. PARTICIPANTS TEACHING LEVELS AND DISCIPLINE

Discipline	Gender		Level[a]		
	Male	*Female*	*E*	*H-T*	*C*
Informatics & Technology	7	6	0	11	3
All the areas	0	2	2	0	0

a. **E**: Elementary – **H-T**: High school/Technician - **C**: College Level. Some of the participants teach in both Elementary and College level

B. Procedures

At the end of the three-day workshop the participants worked in dyads to create a learning experience. The requirements for the learning experience were that they should use Backwards Design and Scratch to implement one of the CS Principles in the design of their lesson. They had two weeks to prepare the lesson plan. At the end of the two-week period participants gave a ten minute presentation, which included a description of the learning objectives, methodology, assessment, support tools and materials, and reflection.

The presentation took place in the classroom two weeks after the workshop ended and each one of the nine dyads had the opportunity to present and discuss their lesson plans with the rest of the group.

C. Data Collection Method

As part of the assessment process, a rubric was designed using the elements of Backwards Design process as elements to be assessed. The three established stages (desired results, acceptable evidence and learning experiences) were mapped to a specific assessment criterion: Learning Objectives, Assessment, Pedagogy and Materials/Resources.

Participants were required to include at least one of the CS Principles' learning objectives into the design of their lesson plans. As shown on Table III, an assessment criterion was centered on identifying the relationship between the presented lesson plan and the selected learning objective. In addition, Reflection and Coherence/Order and Presentation were also included as part of the rubric. The rubric included four levels of achievement being 1 the lowest and 4 the highest. Because of space constraints, Table III only indicates the lowest and highest levels of achievement.

TABLE III. ASSESSMENT RUBRIC (MIN AND MAX GRADES ONLY)

Criteria	1	4
Learning Objectives	The design has no relation with the chosen learning objective.	The design completely covers the chosen objective and some others.
Assessment	The assessment method for the students is not clear.	The assessment method for the students is clearly defined and is authentic. It can also be used by an expert and peer or self-assessment
Pedagogy	The selected didactic strategies are not well suited to accomplish the learning objectives	All strategies are appropriate for learning outcomes. The strategies are based on a combination of practical experience, theory, research and documented best practices
Reflection	The reflection is not realized or the answers are not coherent with the responses	Reflection is complete and it presents some examples that demonstrate clearly the results, challenges and opportunities of experience
Materials Resources and Technology	The resources and material list is not clear. The use of technology is out of context	All the materials and resources needed to complete the lesson are listed. The use of technology is relevant and clear. It also offers advantages that make it necessary
Coherence / Order and Presentation	The design is presented in an unorganized way. Every element is isolated from each other	All the design elements are aligned with each other to achieve the learning objective in students. All these elements are presented in an organized way

D. Scoring and Data Analysis

The scoring method used for the developed learning experiences was through peer evaluation. Together with the experts, the participants used the rubric to assess their peers' presentations and their own designs. Ten scores, including the ones by the experts, were averaged to determine the final score.

The artifacts produced by the participants were also analyzed qualitatively by the researchers to identify patterns in their design decisions. For this purpose we conducted a categorical analysis of participants' selected big ideas and their selected ways to implement the components of the backwards design process.

VI. RESULTS

A. What elements of CS Principles have teachers implemented in the design of their learning activities?

Most of the dyads selected the big idea "Creativity: Computing is a creative activity" to design their lesson plan. Their designs were intended to engage and empower students with CS Principles through the development of a creative project in Scratch such as a Storyteller, an Interactive Multimedia or a Traffic Light Simulator. Table IV lists the number of projects developed for each big idea and practice.

TABLE IV. SELECTED BIG IDEAS AND PRACTICES

Bid Idea	Practice	#
Creativity: Computing is a creative activity	Developing computational artifacts	4
	Programming is a creative process	1
Algorithms: Algorithms are used to develop and express solutions to computational problems	Communicating & Abstracting	2
Abstraction: Abstraction reduces information and detail to facilitate focus on relevant concepts.	Communicating & Abstracting	1

B. How teachers used the backwards design process as a tool to implement elements of the CS Principles?

Several learning outcomes and strategies were chosen by the participants for development of their projects including the combination of two or three of them in a single lesson plan. Also, all designs utilized the development of a Scratch artifact as the acceptable evidence of the learning. Most of the assessment mechanisms were designed to be conducted either by the teacher or by the students and the mechanism employed was an assessment rubric.

Based on the Backward Design process, Table V describes the most frequently chosen learning objectives, assessment mechanisms and pedagogical practices.

For example, a dyad selected the learning outcome "The student can use computing tools and techniques for creative expression." Based on this selection they defined project-based learning and collaborative learning as the pedagogical approaches to implement the chosen learning goal. They also developed a rubric including criteria such as the use of meaningful naming and convention of objects, functional compliance of the developed artifacts and number and variety of Scratch controls used.

TABLE V. COMPONENTS OF PARTICIPANTS' DESIGNS

Item	Practice	#
Learning Outcomes	The student can use computing tools and techniques for creative expression	3
	The student can express an algorithm in a language	2
	The student can use computing tools and techniques to create artifacts.	1
	The student can use programming as a creative tool.	1
	The student can explain how binary sequences are used to represent digital data.	1
Acceptable Evidence of the Learning	Rubric (including Peer and Self-assessment)	6
	Categorical Analysis	1
	Performance Indicators	1
Learning Experiences and Pedagogical Approach	Project-based learning	4
	Problem-based learning	4
	Collaborative learning	3
	Game-based learning	1
	Constructivism	1
	Critical and societal.	1
	Discovery learning	1
	Creation-based learning	1
	Trial and error learning	1

Another example can be described for the learning outcome "The student can express an algorithm in a language" where participants used three components for their assessments: cognitive (knowing), procedural (knowing-doing), and attitudinal (being), and evaluated those performance indicators through peer-assessment. The learning experience for this particular learning goal was problem-based learning, taking into account the design challenges students were presented with and how those were solved by using Scratch.

C. *What are theachers' performances in integrating CS Principles to the design of learning activities as evidenced from their peer evaluations?*

Overall, all projects obtained relatively high scores from all the workshop participants. The obtained grades were over 84% while the mean was over 90%. Table VI depicts means and standard deviations for all the assessment criteria:

TABLE VI. ASSESSMENTS RESULTS

Criteria	Mean (%)	Standard Deviation (%)
Learning Objectives	94.14	7.67
Assessment	89.07	16.57
Pedagogy	89.94	9.98
Reflection	86.67	10.12
Materials, resources and technology	91.11	10.05
Coherence / Order and Presentation	91.30	9.21
Total	90.37	7.23

The best evaluated projects were named "numbers eater" and "English names". The first one consisted of building a Scratch application with the goal of having the final user walk through a labyrinth while he/she answers math's questions. Hence, the computational thinking aspect for this project included the use of loops and conditionals while students were building their own math games.

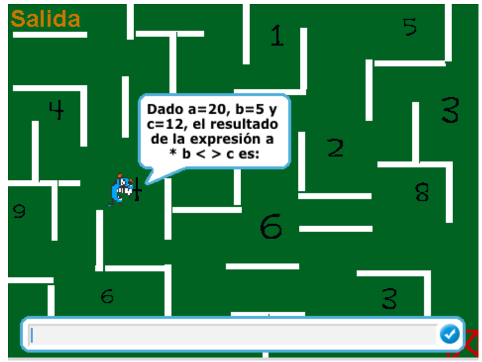

Fig. 1. Numbers eater project

The second project consisted of having students draw geometric figures, paint them with the primary colors, and write and pronounce their names in English (for elementary school-Spanish speakers). This activity was also designed to learn non-computational concepts i.e., English language, while students also learned how to program using Scratch. Both projects focused on the big idea: Creativity: Computing is a creative activity. Screen shots of each of the projects are shown in Fig 1 and Fig 2 respectively.

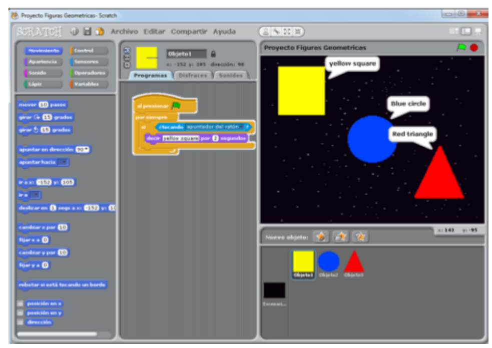

Fig. 2. English names project

At the end of the workshop participants were asked to do a final reflection of their learning experience. In their descriptions participants highlighted the advantages of integrating Scratch and the Backward Design process into computing education activities. Participants enjoyed the process and they believed that their lesson plans will help their students in problem solving, creative thinking and systematic reasoning. Other participants mentioned benefits such as collaboration, research and creativity, as well as motivation and engagement. They also indicated a high interest in having the opportunity to teach these concepts coupled with non-technology subject topics. Finally, participants emphasized their need or desire to learn more about computational thinking.

VII. DISCUSSION

The design of lesson plans using the CS Principles and guided by the Backwards Design process resulted to be a productive activity through the three-day workshop. Using the College Board CS Principles as a scaffolding method for the design of learning materials was useful for these teachers by providing them with relevant content. However, this approach may have a constraint: most dyads focused on selecting the same big idea (computing as a creative activity) even though they had other seven ideas to choose from. Participants' rationale for the selection of this big idea is unknown. We speculate that the reason why most participants selected "computing as a creative activity" as the big idea to guide their designs is the fact that it is very flexible and open to different forms of interpretation. It therefore becomes important for future workshops to promote the random assignment of different learning objectives in order to provide a whole vision for all participants of how CS Principles can be implemented and coupled with Scratch. This random assignment can provide participants with a wider view of the Backwards Design process and novel ideas about how to integrate each of the CS Principles in their curriculum.

Also, Scratch was used as the main tool for the activity but some of the projects did not limit their design to it. Participants used other tools such as Google docs, storybooks, web pages, among others. Participants also took advantage of their networks and academic settings and coupled their projects with ongoing social projects in their own schools, such as projects related to the importance of recycling and garbage separation.

Finally, further analysis of the peer assessments can be done in order to identify potential explanations for the large standard deviation. Possible reasons that can explain this result are the variety and background diversity of the target audiences. Specifically, the participants' backgrounds and areas of specialty included elementary, secondary and college level education. Also, some of the participants were focused on technology lessons while some others were focused on software development lessons. Another potential explanation could be that participants misunderstood the rubrics or specific evaluation criteria designed by their peers for their own lesson plans. Future workshops will emphasize the creation of effective and appropriate assessment mechanisms for demonstrating computational thinking including some notions of validity and reliability of assessment instruments.

VIII. IMPLICATIONS

The implications of this study relate to the use of Backwards Design process not only as a tool to develop lessons related to computational thinking, but also as a framework for the advancement of effective methods for teacher professional development in computing.

We identified that Backwards Design was proven to be helpful for these participants on a macro level, allowing the identification and alignment between content, assessment and pedagogy. However, other aspects at a smaller or micro level need to be considered as well. For instance, what are teachers' knowledge about computing in general and computational thinking in specific? How are teachers comfortable with integrating new technologies into their classroom such as Scratch? What are the most effective pedagogies to be integrated with computational thinking? And how computing content knowledge can be properly orchestrated with technology knowledge and pedagogical knowledge?

A framework that can support the design of effective professional development programs at this level of detail can be guided by the use of Technological Pedagogical Content Knowledge (TPCK) [14-16]. TPCK can serve as a framework to the design of learning experiences for teachers to help them acquire computing content knowledge and transform it into a more conceptually understandable version for their students by blending it with technological and pedagogical methods [14-16].

We believe that the acquisition of TPCK is especially needed for computing teachers to be able to effectively integrate technological and digital tools such as Scratch to facilitate proper instruction and to support the improvement of students' computational thinking. TPCK can be used for teacher professional development programs to connect their understanding of computing concepts, practices and tools and their integration with their subject domain. TPCK can also be utilized for assessment purposes on the effectiveness of professional development programs to track data on instructors' cognition [17] and their current educational practices and beliefs for integrating computational thinking.

IX. CONCLUSION AND FUTURE WORK

We believe that through the activities described in this study, which took part during the three-day workshop, computational thinking concepts and ideas became clearer to all participants. The workshop offered the participants with an opportunity to not only get to know the several existing approaches to computational thinking but also it allowed them to explore how they could integrate these concepts and practices into their classrooms. Finally, we believe that sharing their experiences with their peers enriched their learning processes through discussions and peer-evaluations.

Most of the participants are currently implementing or are planning to implement and then evaluate their developed lessons into their own classrooms during this academic year. Findings from an initial classroom implementation with fifth graders suggest that students showed a high performance and engagement when using Scratch to complete an assignment related to "computing as a creative activity." Students also found Scratch software useful and easy to use. Additionally, the corresponding teacher reported the intention to continue implementing this kind of activities at other elementary and secondary levels [22].

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Understanding the Motivation of Instructors to Get Involved in Service-Learning Environments

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***Abstract*—Professional associations of engineering have recommended Service Learning environments to cultivate professional engineering skills. However, a report from ASEE published in 2012 showed that faculty did not consider these learning environments to be important. This study aims to understand the motivation of instructors of Service-Learning programs in engineering. The results can be used to propose campaigns to attract faculty toward these effective engineering learning environments.**

Keywords—Service learning, motivation, student-centered environments

I. Introduction

Experts in the field of engineering education have called for an "urgent" change in the way engineering schools prepare engineers for industry and for the future challenges ahead [1–4]. Engineering also needs not only to encourage high school students to choose engineering over other professions but it also requires to retain, engage current students understanding [5] and teach them for deeper understanding or transfer, and for long-life learning [6–9]. Chances of succeeding in making the profession more attractive, improving retention, engaging students, and preparing them for the future challenges [10] are less likely to happen if the educational model in engineering education remains the same.

A growing movement trying to change the teacher-centered pedagogies that have ruled engineering education have emerged, especially since 2005 when the Steering Committee of engineering education defined five areas of research[11]. The area of engineering learning systems seeks understanding of "the instructional culture, the institutional infrastructure and the epistemology of engineering educators" [11]. Instructional theories have shown benefits of student-centered pedagogies to reach the changes that are expected in engineering education [1], [3].

Current efforts in moving forward engineering education are focus on preparing and encouraging faculty to adopt student-centered pedagogies. The proportion of faculty members who have adopted this approach is increasing. In an study from ASEE [12], engineering faculty committees from different universities of the US were asked about the use of active and engagement pedagogies. Long standing learning environments, like labs, internships and research were reported with a high rate of adoption whereas international programs, entrepreneurship and service learning were reported with lower frequency [12].

Service learning have shown its effectiveness to prepare engineering students for professional practice, and its incorporation in the engineering curriculum is highly recommended by engineering education experts [12–14]. The big question that will be addressed in current and future studies is: "what strategy should be followed to promote the adoption of service learning by a higher number of faculty members?"

One of the phases defined to answer that question is presented in this study. This phase look to answer the following sub-question: why instructors (faculty members, staff and industry practitioners) are motivated to get involved in service learning?

II. Method

Participants

The design experiences provided by the Engineering Projects in Community Service – EPICS program are well-known and recognized in the engineering community. Instructors, or advisors, from this program will be the group of participants that will be studied. Currently, the scope is limited to the advisors of different EPICS teams in a mid-western university.

Data collection

A qualitative methodology will be used to guide the research. To reach validity the same phenomena will be observed from three different perspectives, each of those will be interpreted as phases of the study.

A. Open ended surveys

In order to have a first sight of the factors that describe the motivation of advisors (instructors) to get involved in EPICS, we will conduct an open ended survey composed of questions related to their motivation to get involved first, and a subsequent question asking why they are still involved. In addition, we will ask if their participation is related to their professional goals and if they receive any rewards for their involvement. This data will be analyzed following the principles of grounded theory, in which the data collected are read trying to find common topics and possible relationships between them to establish a theory grounded in the data.

The survey has been already piloted with the 29% of the population of advisors.

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B. Literature review

Once the first phase is finished, we will revise the literature about motivation from different perspectives so we can compare the results from the open-ended survey with what other studies have said about motivation to get involved in similar activities than those performed by advisors in EPICS. Preliminary literature has been collected after analyzing the data that was gathered in the pilot of the open-ended surveys.

C. Semi-structured interviews

The third phase of the study will validate the findings from the open ended survey and from the literature review using semi-structured interviews. The literature will be revised every time a new issue related to motivation emerges in the conversations. The interview protocol will include questions beyond the experience advisors have had in EPICS. Since motivation could be explained by intrinsic and extrinsic factors, the interview protocol will include questions that help to disclose if the advisor's motivation to be involved in service learning is intrinsic or extrinsic. Intrinsic motivation will be identify by asking to the interviewee for the kind of activities that he/she enjoyed when he/she was a child and in high school. The interview protocol also includes questions asking for meaning of life. Answers to this kind of question will be helpful to create connections with the sources of the motivation for the activities they currently do. Besides, the interview protocol will include questions to assess the value that the interviewee gives to extrinsic motivational factors. For example, one of the questions asked for the ideal job and another for the ideal compensation package.

III. Preliminary Results

The data from the pilot survey have shown that the main source of motivation of EPICS advisor is intrinsic. Some factors that were identified as source of their motivation are social interest (interviewee expressed his/her concern about others), professional growing (interviewee expressed his/ her interest in creating opportunities for employment and connection), cognitive interest (interest of advisors in learning), and personal satisfaction (the activity makes them feel better).

Some of the previous findings in the literature explain that sources of motivation could be in the interest and concerned for others (social interest) [15], in the nature of the interaction with elements of the environment [16], in their need to volunteer to improve the conditions of a community [17], and specific studies addressing the motivation to get involved in service learning in general [18].

At the FIE conference, we will present the theory that resulted after analyzing the preliminary data collected with the pilot of the open-ended survey and interview protocol. In addition, we will present a comparison between the theory that was generated by data and the existing theory in motivation.

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Instructional Module Development (IMOD^{TM}) System: Building Faculty Expertise in Outcome-based Course design

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***Abstract*— A well-designed and constructed course plan or curriculum is an integral part of the foundation of effective STEM instruction. This paper presents a framework for outcome-based course design process and its translation into a semantic web-based tool; i.e., the IMOD^{TM} system. This system guides STEM educators through the complex task of curriculum design, ensures tight alignment between various components of a course (i.e., learning objectives, content, assessments, and pedagogy), and provides relevant information about research-based pedagogical and assessment strategies. The theoretical framework is presented, along with descriptions and screenshots of the implementation of key features.**

Keywords—course design, instructional module, learning objectives, outcome-based education, semantic web application.

I. INTRODUCTION

At many colleges and universities, engagement in scholarly teaching is becoming a minimum expectation of faculty who are held accountable for the quality of the learning experienced by students enrolled in their course(s). These expectations are even greater for Science, Technology, Engineering, and Mathematics (STEM) faculty given the national demands for a well-trained STEM workforce [1]. Since education training is not typically included in the plan of study of most STEM programs, faculty who graduate with STEM degrees gain their teaching expertise post-appointment and "on-the-job". In the absence of formal training, most faculty can take as much as five years to truly become proficient teachers, and during that period, it is the students who are most affected [2].

There is a growing demand and interest in faculty professional development in areas such as outcome-based education (OBE), curriculum design, and pedagogical and assessment strategies. In response to this demand, a number of universities have established teaching and learning centers to provide institution-wide, and sometimes program specific support. This paper describes the development of the Instructional Module Development (IMOD) System, which further supports these ventures and broadens the impact and reach of professional development in the scholarship of teaching and learning, particularly to STEM faculty. The IMOD system is an open-source web-based course design software that:

- Guides individual or collaborating users, step-by-step, through an outcome-based education process as they define learning objectives, select content to be covered, develop an instruction and assessment plan, and define the learning environment and context for their course(s)
- Contains a repository of current best pedagogical and assessment practices, and based on selections the user makes when defining the learning objectives of the course, the system will present options for assessment and instruction that align with the type/level of student learning desired
- Generates documentation of course designs. In the same manner that an architect's blueprint articulates the plans for a structure, the IMOD course design documentation will present an unequivocal statement as to what to expect when the course is delivered
- Provides just-in-time help to the user. The system will provide explanations to the user on how to perform course design tasks efficiently and accurately. When the user explores a given functionality, related explanations will be made available
- Provides feedback to the user on the fidelity of the course design. This will be assessed in terms of the cohesiveness of the alignment of the course design components (i.e., content, assessment, and pedagogy) around the defined course objectives.

II. THEORETICAL FRAMEWORK

Many of the leaders in faculty development programs have identified facilitation by experts as a key ingredient in increasing the effectiveness of instructional development programs [3]. For the IMOD system, which will provide professional development with the use of an online tool, expert facilitation is embedded within its design, through the application of a framework that is informed by research in the area of instructional development for STEM disciplines. This framework translates the scholarship into a software platform that supports the development of a rich, meaningful knowledge structure that can be queried to: (1) identify omissions in a course design; (2) identify inconsistencies in the relationships between the elements of the course being designed; (3) identify relevant strategies for instruction and/or assessments; (4) provide just-in-time guidance to the user on the design process. The structure of the framework and its implementation in the IMOD™ system are discussed in the subsequent sections.

A. Previous Models of Outcome-Based Course Design

Outcome-based education (OBE) is an approach where the product defines the process, i.e., the outcomes that specify what students should be able to demonstrate upon leaving the system are defined first, and drive decisions about the content and how it is organized, the educational strategies, the teaching methods, the assessment procedures and the educational environment [4]–[6]. This is a contrast to the preceding "input-based" model that placed emphasis on the means as opposed to the end of instruction. OBE was used as the principal guide for the development of the IMOD framework. It was chosen for the following reasons: 1) Win-for-all solution – OBE is shown to improve student success, provides a structure to educators for designing instruction, and facilitates reporting to external stakeholders in an accountability education climate; 2) It supports the How People Learn framework for designing learning environments [7]; 3) Growing adoption of outcome-based program accreditation – Accreditation boards such as ABET, have moved to an outcome focused model (what students learned) to assess the quality of programs in Applied Science, Computing, Engineering, and Engineering Technology; 4) Alignment with other models that are meant to increase innovation in STEM education – OBE dictates the end and not the means thereby allowing innovation in instruction. It also provides an empirical structure to track impact and identify shortcomings.

A number of models have been developed to represent the application of OBE in the design of effective courses. Four key models widely discussed in the engineering education literature are: 1) the Effective Course Model by Felder & Brent [8]; 2) Integrated Course Design by Fink [9]; 3) Understanding by Design Model [10]; 4) Content Assessment Pedagogy Model by Streveler, Smith, & Pilotte [11]. All of these models either directly or indirectly identify four main elements that must be tightly aligned when defining a course design, i.e., course objectives, content, assessments, and pedagogy. Therefore, one of the main challenges in adhering to an outcome-based approach is maintaining the alignment between course elements. Inconsistencies in the interrelation of these elements can lead to the overall incoherence of the course.

One approach for achieving alignment among course elements is through a "backward-looking" design process where the desired results are identified first, and then assessments are designed to verify that these results have been achieved. The learning experiences and instruction are then formulated around the desired results and the assessments. The use of this approach forms the basis of the Understanding by Design model, and it is also applied by the other models. One of the key functions the IMOD system is expected to perform is the evaluation of the fidelity of the course design. To achieve this, the IMOD framework must include machine processable constructs that can be used to make inferences on the inconsistencies in the relationships between the elements of the course being designed. While the backward-looking process dictates an ideal sequencing of tasks, it is limited in its ability to support automated inferencing on course element coherence. The IMOD framework, therefore, expands on the current models with the inclusion of new constructs.

B. IMOD Framework

The IMOD framework adheres strongly to the OBE approach and treats the course objective as the spine of the structure. New constructs (not included in the models previously discussed) are incorporated to add further definition to the objective. The work of Robert Mager [12] informs the IMOD definition of the objective. Mager identifies three defining characteristics of a learning objective: Performance – description of what the learner is expected to be able to do; Conditions – description of the conditions under which the performance is expected to occur; and the Criterion – a description of the level of competence that must be reached or surpassed. For use in the IMOD framework an additional characteristic was included, i.e., the Content to be learned – description of the factual, procedural, conceptual or meta-cognitive knowledge; skill; or behavior related to the discipline. The resulting IMOD definition of the objective is referred to as the PC^3 model.

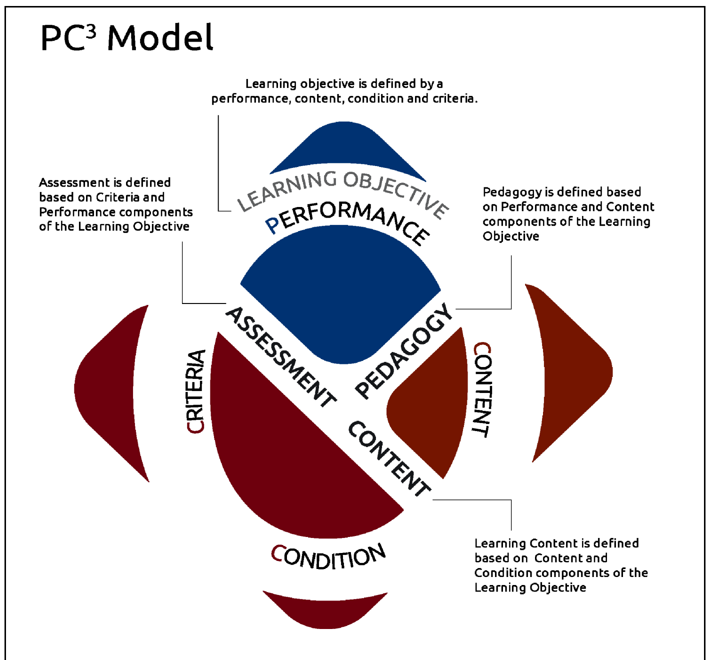

Figure 1: PC^3 Model

The other course design elements (i.e., Content, Pedagogy, and Assessment) are incorporated into the IMOD framework through interactions with two of the PC^3 characteristics. Course-Content is linked to the content and condition components of the objective. The condition component is often stated in terms of pre-cursor disciplinary knowledge, skills or behaviors. This information, together with the content defined in the objective, can be used to generate or validate the list of course topics. Course-Pedagogy is linked to the performance

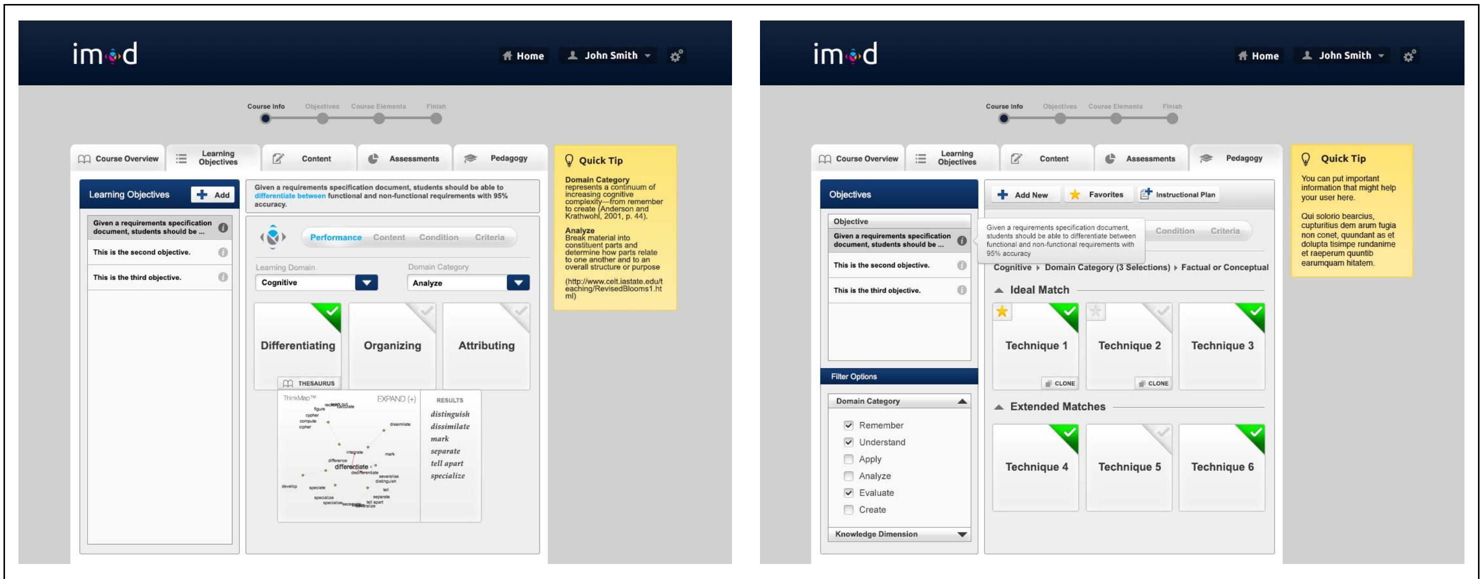

Figure 2: Screenshots of Learning Objective and Pedagogy tabs of the IMOD™ system

and content components of the objective. The types of instructional approaches or learning activities used in a course should correspond to the level of learning expected and the disciplinary knowledge, skills or behaviors to be learned. The content and performance can be used to validate pedagogical choices. Course-Assessment is linked to the performance and criteria components of the objective. This affiliation can be used to test the suitability of the assessment strategies since an effective assessment, at the very least, must be able to determine whether the learner's performance constitutes competency. Figure 1 shows a visual representation of the IMOD framework.

III. Implementation of IMOD™ System

The implementation of the IMOD system shown in Figure 2, consists of five features described below. 1) *Course Overview* – a feature used to capture information on the learning environment (e.g., type of course, meeting days and times, instructor(s) information, course policies, etc.). 2) *Learning Objectives* – a feature used to guide the user through the creation of learning objective statements that conform to the PC^3 model. Revised Bloom's taxonomy of learning objectives [13] was also used in this feature to help the user describe performance characteristics. 3) *Content* – a feature used to capture information on the course topics. The content prioritizing model by Wiggins and McTighe [10] and the Knowledge Dimension from Anderson and Krathwohl version of Bloom's taxonomy [13] are also used in this feature. 4) *Assessment* - features used to suggest relevant assessment techniques based on the type of learning and evaluation criteria specified in the learning objectives. 5) *Pedagogy* - features used to suggest relevant instructional techniques based on the type of learning and knowledge specified in the learning objectives.

IV. Future Work

The design of the IMOD system is still ongoing, and will be further described in future publications. Some of the implementation has already underway. Once the first version is completed, user testing will be conducted to test for effectiveness, efficiency and usability.

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IMA-Tool: A Tool for Modeling and Automatic Generation of Educational Content

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***Abstract*—In this paper we discuss the establishment and application of $\mathcal{IMA}$ *Tool* – a web-based tool for the modeling and automatic generation of educational content. The tool is based on $\mathcal{IMA}-\mathcal{CID}$ – an approach for modeling educational content, capable of addressing conceptual, instructional and didactic issues altogether, in an integrated way. $\mathcal{IMA}-\mathcal{CID}$ and $\mathcal{IMA}$ *Tool* have been applied in the development of an educational module for software testing. The preliminary results indicate the effectiveness of such mechanisms for modeling and generating content.**

Keywords*—*content modeling, automatic content generation, supporting tool, educational module.

I. Introduction

Several initiatives involving the use of computing resources have been investigated in order to ease the learning processes in general. It is the case of educational modules – concise units of study, composed by theoretical and practical content, which are delivered to learners by using innovative technologies and computing resources [1], [2].

The construction of educational modules is a complex task however, involving both pedagogical and developmental issues. Content modeling, for instance, plays a significant role in the development of such modules. Basically, it helps the author to determine the concepts to be taught, providing a systematic way to structure the relevant parts of the knowledge domain [3], [4].

Despite its relevance, there are few approaches for modeling the educational content, each one of them considering different perspectives, which can be suitable for a specific learning setting, but inadequate for others. Motivated by this scenario, we proposed $\mathcal{IMA}-\mathcal{CID}$, an integrated approach for modeling educational content [4]. In short, $\mathcal{IMA}-\mathcal{CID}$ is composed of a set of models, each one considering specific aspects of the development of educational content.

Although the results obtained so far reveal the feasibility of the practical use of $\mathcal{IMA}-\mathcal{CID}$, applying it without an automated support can be a time-consuming and an error-prone activity. In this perspective, we have worked on the specification and development of $\mathcal{IMA}$ *Tool* – a supporting tool for content modeling, particularly for constructing the $\mathcal{IMA}-\mathcal{CID}$ models. Issues of content generation and ontologies adoption have also been addressed. To illustrate our ideas, we have applied $\mathcal{IMA}-\mathcal{CID}$ and $\mathcal{IMA}$ *Tool* in the development of an educational module for software testing. The preliminary results achieved suggest the effectiveness of adopting such mechanisms in the modeling and automatic generation of educational content.

This paper is organized as follows. In Section II we present an overview of $\mathcal{IMA}-\mathcal{CID}$ approach, focusing on the construction of its associated models. In Section III we describe the main characteristics of $\mathcal{IMA}$ *Tool*, illustrating its application in the modeling and content generation of an educational module for software testing. Our conclusions and perspectives for further work are presented in Section IV.

II. IMA-CID: A Content Modeling Approach

$\mathcal{IMA}-\mathcal{CID}$ (Integrated Modeling Approach – Conceptual, Instructional and Didactic) [4] is composed of a set of models, each one addressing specific issues to structure and represent the educational content. The *Conceptual Model* consists of a high-level description of the knowledge domain, representing its main concepts and the relations among them. Two classes of relations are defined. Structural relations (e.g., *type-of* and *part-of*) are useful to set up taxonomies among concepts and make inferences about the domain, being applicable to any kind of domain. Domain-specific relations are user-defined and have their meaning associated to a particular subject, carrying their own semantics.

The *Instructional Model* aims at defining the additional information to be related with the concepts previously identified. Thus, besides concepts, *information items* and *instructional elements* should be represented as part of the domain. As instructional items, the model specifies [5]: (i) *facts*, logically associated pieces of information; (ii) *procedures*, set of ordered steps to solve a problem or accomplish a goal; and (iii) *principles*, explanations or predictions on why something happens in a particular way.

Similarly, instructional elements are also specified in different categories: (i) *explanatory elements* deal with the complementary information used for explaining a given topic; (ii) *exploratory elements* allow the learner to navigate through the domain, practicing the concepts and relevant information; and (iii) *evaluative elements* allow assessing the learner's proficiency on the domain.

Finally, the *Didactic Model* is responsible for the establishment of prerequisites and sequences of presentation among the elements of the conceptual and instructional models. Particularly, the model introduces the idea of *open specifications*, which provides support for the definition of dynamic contexts of learning. According to aspects such as audience, learning goals and course length, distinct ways for presenting the same content can be required.

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A. An Example in the Software Testing Domain

Next we summarize the *IMA−CID* application in the development of an educational module for Mutation Analysis [6], a fault-based testing criterion. Shortly, this criterion is based on the assumption that a program will be well tested if all “simple faults” are detected and removed. Simple faults are introduced into the program by creating different versions of the program, known as *mutants*, each of which containing a simple syntactic change. Simple faults are modeled by a set of *mutant operators* applied to the program under testing. The goal is to find a test case that causes a mutant to generate a different output from that of the original program (*dead mutant*). A mutant is *equivalent* if no such test case exists. The *mutation score* measures the adequacy of the test set, being the ratio of the number of dead mutants to the number of non-equivalent mutants.

Figure 1 shows the didactic model of *IMA−CID* for the Mutation Analysis criterion. Consider, for instance, the `MutationAnalysis General` state. It represents an OR state, composed of two substates: `MutationAnalysis` and `MutationAnalysisDetails`. `Mutation Analysis` represents an AND state, which is composed of: one concept (`MA:concept:text`), one fact (`MA:fact:text`) and two principles (`CompetentProgrammer:principle:text` and `CouplingEffect:principle:text`). All of these elements are specified as text.

Exploratory elements are specified as well. `Mutant:example:figure`, for instance, complements `Mut: concept:text`. This example is also related to another explanatory element, `IdentifierImplementation:complementary: figure`, which provides complementary information for it.

Finally, the idea of *DD*-states is defined in order to address the navigation issues. Consider the `MutationAnalysisDetails` state. Its sub-states (OR_{DD} states) are all connected to each other by implicit transitions. That is, from `MutantOperator` we can get to the states `MutantGeneral`, `MutationScore`, `Application` and `ApproachesGeneral`, and so on for all other combinations of states of `MutationAnalysisDetails`. The same reasoning should be applied to the other *DD*-states.

IMA−CID has been successfully applied for modeling educational content in different domains. However, despite the promising results obtained, applying the approach without an automated support can be a time-consuming and error-prone activity. In this perspective, we have worked on the specification and development of *IMA Tool*, described next.

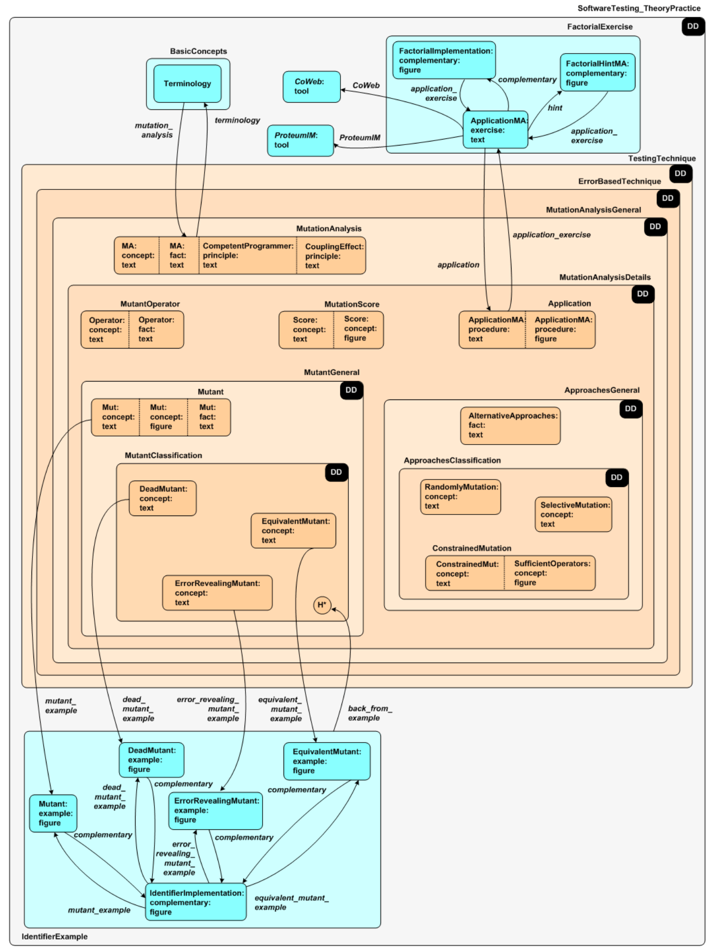

Fig. 1: Didactic Model for the Mutation Analysis Criterion

III. IMA-Tool: Main Characteristics

IMA Tool is a web-based tool designed to help the construction of the *IMA−CID* models. The modeling process starts with the definition of the main concepts and relationships in the subject domain. *IMA Tool* provides two ways to support the development of the conceptual model: (i) inserting both concepts and relations manually; or (ii) using concepts and relations defined in an ontology (i.e., importing an OWL file).

In the case of mutation analysis, the conceptual model was constructed based on an ontology of testing, referred to as *OntoTest* [7]. *OntoTest* addresses the main testing concepts and relations, such as: testing process, testing steps, testing strategies and procedures, and testing resources. Mutation analysis concepts and relations, in particular, are addressed in details in the testing strategies and procedures sub-ontology.

The next step is the construction of the instructional model. Using *IMA Tool*, the author is able to register and choose different elements to be associated to a given concept: information items and instructional elements. Media elements, classified according to the ALOCoM ontology [8], should be associated to the objects modeled as well.

Besides that, issues of hierarchical decomposition must be addressed. That is, it is necessary to define the states that compose the corresponding statechart of the model. In this direction, *IMA Tool* supports the specification of AND and OR states. Shortly, AND states are used to group information that has to be presented simultaneously whereas OR states are used to gather information of a same group but that is never presented concurrently. For instance, information related to *Constrained Mutation* (an alternative approach for applying Mutation Analysis) was defined as an AND state (Figure 2(a)); information regarding the classification of mutants (*Dead Mutant*, *Equivalent Mutant* and *Error Revealing Mutant*) was defined as an OR state (Figure 2(b)).

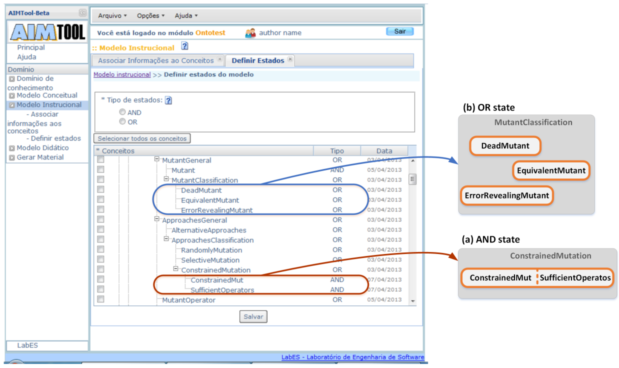

Fig. 2: Instructional Model: AND and OR states.

Regarding the didactic model, IMA *Tool* allows the author to create different sequences for presenting the same content. Basically, the concepts that will compose the educational content can be selected through the IMA *Tool* interface. The tool returns all the elements related to the concepts selected and the author is responsible for choosing the complementary information to be considered for each concept.

After the modeling phase is completed, the educational content can be automatically generated through IMA *Tool*. Based on the elements modeled according to IMA−CID, IMA *Tool* generates an SCXML file, which corresponds to the statechart of the didactic model. From the SCXML file, AIM *Tool* is able to generate and package the content (PDF-Latex and/or HTML). Figure 3 shows some slides (PDF-Latex) for mutation analysis, automatically generated by IMA *Tool*.

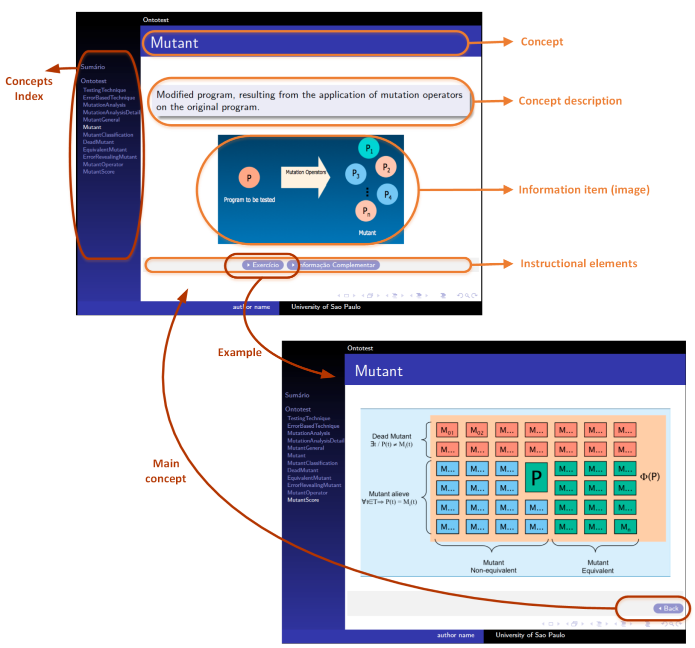

Fig. 3: Content Automatically Generated by IMA *Tool*.

The resulting content of software testing has been applied both in graduate and undergraduate courses at ICMC/USP. In general, good results regarding the learning effectiveness provided by the module have been observed in terms of the students' ability in generating test cases, covering the test requirements and detecting the existing faults in the programs under testing.

IV. Conclusions and Future Work

In this paper we discussed the establishment and application of IMA *Tool*. In general, the results achieved so far provide preliminary evidences on the practical use of the tool as an effective mechanism to support the modeling and automatic generation of content. The authors' attitudes toward the usage of the tool highlight the possibility of keeping all relevant information of a given domain in a single place, at the same time of being able to structure and generate different versions of the same content according to aspects such as audience, course length, learning goals, among others. More experienced authors (knowledge specialists) also point out the adoption of ontologies as a positive aspect in order to provide a better comprehension of the domain as well as to ease the knowledge sharing and reuse among authors/designers. Usability issues were identified as points to be improved in the next versions of the tool.

As a further work, we highlight the need of conducting more formal experiments to evaluate both IMA *Tool* and the educational content it generates. Indeed, systematic and controlled experiments have been planned and should be performed in short term. We also intend to investigate the integration of IMA *Tool* with learning environments, such as Moodle and Sakai.

Acknowledgment

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Data Base Development for School-Related Research

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Abstract— **During 2008, the Institute for P-12 Engineering Research and Learning (INSPIRE) began a research project that started with 19 teachers and more than 200 students who were educated, interviewed, and assessed for STEM learning. This longitudinal study grew fast, gathering numerous pieces of data from 168 teachers and more than 3,000 students during the five-year treatment. This information growth led to a need for data management improvement. However, there are few database structures available for gathering school-related research. This paper presents lessons learned during the process of database construction and improvement for supporting project data consolidation. The process of construction and development included structural changes to provide an organization commensurate with schools' clusters, domains, and strata, all of which occur organically in the school setting. The database construction also included program development for uploading and cleaning large amounts of information; application analysis for defining an appropriate tool; and improvements for user information visualization. The analysis of lessons learned includes a discussion of major changes within the database and benefits of creating program codes within this tool. The discussion ends addressing the implications of having a structured and automatized yet flexible database tool designed for school settings.**

Keywords—database; STEM education; K-12 education; data cleaning; data consolidation

I. Introduction

In 2006, the Institute for P-12 Engineering Research and Learning (INSPIRE) was created with the intention of improving methods of approaching STEM education at the pre-college levels. During 2008, INSPIRE began a research project focused on integrating engineering into the elementary science curriculum of a south-central United States school district. Researchers collected general data about the participants including gender, ethnicity, school, and grade. Information related to the teachers' prior experience, background, and project-related experience was gathered. Likewise, information concerning students' knowledge and perceptions was collected via pre- and post-assessments each year. The large amount of information collected drove the need for a data management system to consolidate results and outcomes. A database was needed to manage research information about the effects of STEM education in K-12 settings where the majority of the stakeholders (e.g., K-12 researchers) have little expertise in computer science or database technicalities. This context requires applications that provide user-friendly tools for organizing and accessing data. The process of designing the Research and Assessment of Students and Teachers Results and Outcomes (RASTRO) database provided experiences that led to reflections about data consolidation, visualization, and requirements used for structural and automation improvements.

II. Rising Numbers in K-12 STEM Education

A recent increase in research concerning STEM education advocacy has been identified by stakeholders such as the Academic Competitiveness Council [1], the President's Council of Advisors on Science and Technology [2], and the U.S. Congress [3]. During the last several decades, since the publication of A Nation at Risk [4, 5], the United States has focused on improving STEM education and ultimately increasing the number of professionals in STEM-related fields. Several proponents of this objective support this sense of urgency by claiming that STEM education is needed to ensure that the United States maintains a sustainable economic competitiveness in the global market [3]. For instance, the PCAST report [6] suggested that one million STEM professionals are needed to maintain the national reputation in science and technology, while the National Academy of Science [7, 8] stated that income growth in the U.S. is fundamentally due to technology change.

These analyses led to an increase in the invested budget for STEM education (e.g., the America COMPETES act [3] or the GAO report [9]) and regulation development (e.g., the new framework for K-12 Science Education [10] or the Next Generation Science Standards [11]). This heightened involvement in STEM education guided the creation of programs designed to address the gap in STEM education. More than 200 programs have been administered by 13 agencies, and more than 3 billion dollars are expected to be invested [9]. According to the GAO report, for the STEM education investment, the diversity of initiatives has not been realized due to insufficient coordination of data that has led to considerable overlap in the programs. Tools for data management specialized in these types of projects may provide a timely evaluation and reporting of outcomes that identification of new projects that complement rather than replicate existing projects.

Tools are needed at the project level that can better store and manage data and facilitate data analysis, so that data and results can be better shared and coordinated at the national level.

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III. NEED FOR INFORMATION CONSOLIDATION FOR K-12 PROJECTS

This need for coordination particularly applies to K-12 STEM education where a large number of separate projects are addressing similar goals, areas of study, subjects, and strategies. These projects are unifying efforts to promote STEM education and increase the number of people pursuing STEM-related careers, but it is not yet clear how these efforts build upon each other, because of a lack of evaluation and reported outcomes [9]. Consolidating tools that allow summarizing project-impact (e.g., through number of schools in the project, ethnographic distribution, teacher background statistics) and project-efficacy (e.g., through changes in students' perceptions and knowledge of STEM) are needed for better coordination of efforts. However, there are few applications that facilitate the documentation and analysis of data.

Some existing tools offer basic organizational structures (e.g., Hep Inc. [12], Maponics [13], SAS Institute Inc. [14]), which include generic forms to describe people (e.g., customers) or products (e.g., refrigerator parts). Other existing tools are already filled with data and serve as examples but are not available as tools for others to use (e.g., ERIN Project [15], COMPASS [16]). This is problematic for K-12 research projects because of the uniqueness of school structures, which differ from industry and corporate organizations.

There are some applications in which more flexible types of data can be gathered and analyzed. This flexibility creates a level of complexity that requires trained technicians to manipulate the information. If the unique elements that exist in K-12 formal settings are acknowledged and supported by tool design, STEM education may be positively influenced, and therefore U.S. competitiveness will be promoted through innovation as suggested by the National Governors Association [17].

IV. DATA STRUCTURE AND PREPARATION FOR K-12 SCHOOL SETTINGS

Before analysis of data gathered from students, teachers, and other participants in K-12 interventions, it is important to prepare the data. Assuring data quality leads to accurate reporting and therefore advancements in school interventions. Data cleaning and integration is the first step in data mining no matter the context of the data [18, 19].

Data cleaning is a process that comprises data extraction, transformation, and loading (ETL) [18, 20, 21]; although other stages may be included in this process as well [22]. This paper focuses on the first stage (E) in which discrepancy detection and transformation occurs [21]. Discrepancies or glitches [19] are caused by human errors such as, but not limited to, misspelling, coding errors (where wrong identification numbers may be assign to a participant, low-structured entry) forms that may lead to inconsistencies, or data decay that produces errors due to outdated information. To prevent or mitigate these problems some procedures may be followed [18]. For instance, validating information during its entry and using rules and linked registries will help prevent errors when entering years, codes, or grade levels, this means ensuring data integrity and referential integrity.

Since this cleaning process is likely to take a considerable amount of time (to ensure data integrity and referential integrity) and programming [21], it should be automatized and customized for K-12 school settings to save time and resources. Although automation of data cleaning may provide assurance of data quality, school-data managers must be capable of working with these processes. Therefore, it should have user-friendly interfaces for non-technical experts who manage and analyze educational data.

V. NEED FOR A PLATFORM FOR DATA AND ANALYSIS DOCUMENTATION

The scarcity of tools addressing the unique characteristics of K-12 formal education also hinders the process of data management within some STEM education projects. For instance, INSPIRE researchers started to collect large amounts of data for a five-year project to improve STEM teaching and learning at the elementary level. Researchers needed the data to understand how the intervention designed for teaching science through engineering affected STEM education at the elementary levels. Did perceptions about engineering change? Did understanding and belief in stereotypes change? Without a suitable data management method to support answering these questions, research took far more time than expected.

This five-year longitudinal project started with 19 teachers and more than 200 students at 6 schools in one district in south-central U.S. Participants were taught, interviewed, and assessed for their STEM learning. During the second year, a considerable sample size increase (15 schools, 62 teachers, and more than 800 students) led to a need for structural growth in the project database and for increasing flexibility for data storage and management. In response to this need, researchers started to develop programs for automating tasks such as uploading information and creating records for new participants. In the fifth and final year of data collection, the project ended with a total of 168 teachers and more than 3000 students at 15 schools in the same district. Since the first automation was created, researchers continued the development of more features and systematic procedures for data management. The process has been dynamic but also challenging. Each year, new requirements were addressed while minimizing uploading-time and data-error.

VI. LEAVING OUR TRAIL FOR UNDERSTANDING K-12 STEM EDUCATION

Since its first version, the Research and Assessment of Students and Teachers Results and Outcomes (RASTRO) database has been adapted to consolidate the growth of information related to the project. The current version of the database comprises several tables linked together with information related to schools, teachers, and students for several periods of time.

In Fig. 1, tables 1–3 gather permanent data for students (gender and ethnicity), teachers (gender, ethnicity, and date of birth), and schools (school name). Fig. 1 tables 4–7 hold information that change every year for each cohort. For students, the information that varies every year is related to the academic year, existence of consent and ascent forms, tracking (i.e. student's information was updated and tests and interviews were collected), and teacher. For teachers, data that changes every year includes academic year, existence of consent form, tracking (i.e. teacher's information was updated and surveys and interviews were collected), school, grade taught, status as engineering teacher in their classroom, background, experience, teaching style, and engineering perceptions. School's information varying every year is related to the treatment (if the school was included in the engineering training program or not) and Title 1 eligibility and designation.

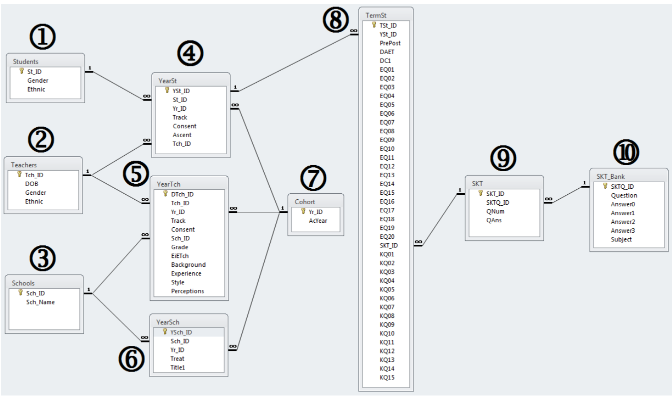

Fig. 1. RASTO structure.

Fig. 1 tables 8–10 store information that varies by semester, which is related to pre (Fall) and post (Spring) assessments for students in the engineering program. Table 8 includes the students' responses to the assessments, and the pre or post designation. Students performed three different assessments each semester; one concerns students' engineering identity development [23], a second assesses students' engineering and science knowledge [24], and the third concerns students' drawings of an engineer at work [25-27]. Table 9 holds information about the version and answer key of the knowledge test because questions changed according to grade level and term in which the test was conducted. Finally, table 10 holds the bank of items included in each of the knowledge versions with the subject assessing (engineering, technology, or science). One example of a student-registry is shown in Fig. 2.

ID	Type	Hom	Gen	Eth
10001	1	0	1	4

Sch	T1
101	1

Yr	Co	As	Trck
1	1	1	1

Tch	EiE	Gr
10007	10007	2

Trm	DAET	EQ1	–	EQ20	KQ1	–	KQ15
Pre	C:\Tests\DAET_Fall08\101_2_T10007_S10001_f08.jpg	1	...	3	1	...	0

Fig. 2. De-Identified Student-Registry

The development of RASTRO can be described as existing in three stages: its creation, its stabilization, and its improvement. The first stage of development, the creation, started during the first year of the project when the database was built. The tools were built parallel to the project development, which led to a database structure based on time of data collection instead of the system, which in this case is the school setting which includes school districts, schools within the district, grade levels, classrooms, students, and assessments. This caused a low level of data consolidation where specific test information was fractionated and a general overview of participants was difficult to capture. For the first year, development was focused on constructing an initial version of the database, learning how to systematize the process of uploading the data and how to present the information to the user. During the second year, the first automation processes were developed in open-source software for engineering and scientific applications. This upgrade was very useful for improving efficiency in a significant manner; however, automation codes were running in a separate application, which made uploading and updating data complex procedures. Between the first and second cohorts, the rapidly increasing amount of data (see Fig. 3) caused another obstacle: the database created during the first year did not fit into the application. This led to a division in the database structure, and therefore retrieving data become more complex as the amount of data in the system increased.

In the second stage of the project, stabilizing the database was the focus. This stabilization process was needed because the longitudinal data that was gathered changed during the five years of the project. A large percentage of the data gathered was highly dynamic; some project changes were related to inclusion of new schools, teachers and students, while changes within the data were caused by student name changes, inclusion of new students during the academic calendar, changes in school policies, and increasing teacher experience, among other issues. Name changes were common because of the use of a second last name (a common practice in the Hispanic community), legal status changes (using maiden or family names), or use of nicknames within rosters (e.g. Andy instead of Andrew, Andres, Andreas, etc.). Inclusion of new students during the academic year was also an issue because new entries were required within the database; often there was not enough information to identify whether the participant was new to the project, new to the school but a returning student, or was an existing student who changed classrooms. School information was also changing. For instance, some schools that were Title 1 changed their eligibility during the project. Another example of the high level of dynamism within the data was related to teacher experience. Years teaching STEM, years teaching at the elementary level, teacher assessments, and other information changed over the course of the project. Some information such as teacher experience within the project or age was easily stabilized by changing the data collected from age to birth date or from years within the project to dummy variables tracking teacher involvement year by year. Teachers updated some of their data periodically (e.g., teacher assessments or years teaching STEM); these types of information could not be stabilized.

The automations were migrated to the main application that was developed as an Excel file. Visual basic macros were created to accomplish the previously programmed-tasks for uploading data and identifying if a participant was new to the project. These tasks were improved with more flexible capabilities that allowed the program to handle a small amount of human error. Likewise, new macros were designed to complete new procedures such as double-checking old information against new information, correcting the entry of assessment responses, homogenizing assessment versions, and checking for the existence of homonyms for assigning identification numbers and uploading information for the correct participant. Another aspect of stabilization was consolidation of similar types of data within the same table, and creating links between tables with related data but different typology.

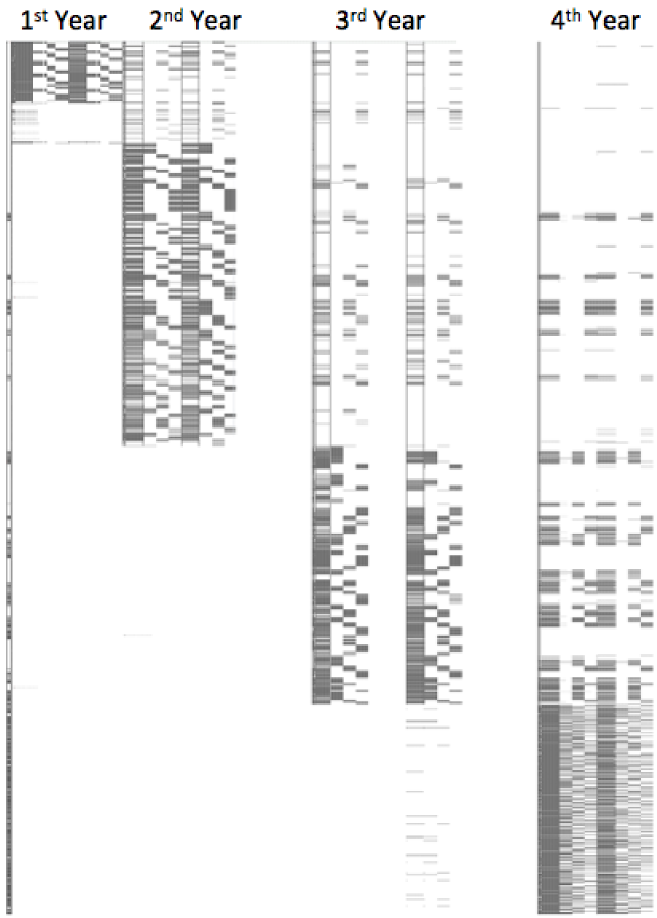

Fig. 3. Data growth between 2008 and 2012

The third stage of RASTRO improvement is currently in progress and is informed by the experiential knowledge gained during the first two stages. This stage includes more consolidation and automation advances for the database. The central goal is to increase the application robustness. This is explained in more detail in the following sections.

VII. Data Analysis

The first two stages of RASTRO database development provided an opportunity for reflection about what has worked and what needs to be improved for data analysis and reporting to happen in a timely manner. In the following three sections, the main areas of database improvement for data cleaning are discussed in relation to the unique characteristics of the K-12 setting.

A. Data and Process Consolidation

Recording data in a study is not as simple as just copying the information into a shared space where researchers can look for information. It is far more complex than that, and requires an understanding of how the data is collected, if is quantitative or qualitative, and if the collection occurs through clusters, strata, or domains. It also requires an understanding of how different types of data are connected [18, 21]. After almost five years of data collection, cleaning, and analysis, several conclusions were drawn based on what has or has not worked for this and other K-12 projects within INSPIRE.

All school settings are highly similar, no matter the state or school district involved. States, counties, and school districts function as clusters where characteristics between subjects within the same cluster are more similar than not. Likewise, classrooms may be identified as clusters on a smaller scale. Grade levels (corresponding to age ranges) between schools may be perceived as strata in which one or several levels may be studied. Lastly, gender, ethnicity, and experience (among other demographic characteristics) may be studied as domains. Therefore, it is possible to design a database structure that fits the school setting and its particular needs, taking into account how to link and validate information entered.

The research design for diverse K-12 studies may have some similarities where, impact of an intervention or improvement of an assessment tool, are common research topics. This means that pre and post data may be collected for each participant (e.g., student, teacher, administrator, parent, or community member involved in the school). In these types of studies, the information gathered could be qualitative or quantitative; however, within RASTRO only quantitative information can be gathered. Other research designs such as ethnography or case studies are common performed in school-related research; this type of information can be fit into RASTRO structure when it is coded.

The process of data digitization and entry should be systematized. This organized procedure facilitates optimizing the quality of the data gathered and therefore minimizes the time needed for crosschecking and cleaning [18, 20]. High quality data was the objective for the INSPIRE project, where data collection was arranged with teachers and administrators and collected by part of the research group twice each year. As soon as data arrived at INSPIRE, a sub-group of researchers started to digitize the information using predefined formats for each type of data. During this process different persons created the template, entered the data, and double-checked the information. After the data was double-checked, another researcher consolidated and introduced the data into the database. This process was highly automatized, which assured high upload speeds, error identification through data crosschecking, homonym identification assuring a correct link between students and their data, and auto-correction of some of the assessment response entries.

B. Usage of Appropriate Applications

Understanding the requirements for the database was not an easy task. The process of introducing data, expanding the database structure, and addressing the different challenges as they arose changed each year. Database managers needed to prevent problems related to application limitations, and they needed to anticipate potential problems with further growth in the database (e.g., researchers working with a identification scheme that would run out possible character during the third year of data collection). The technical knowledge gained from this five-year project has helped to document other K-12 projects within INSPIRE, but there were several technological challenges along the way.

The first technical problem was having the data in one application and the automatized programs in another application. The second application was more specialized; therefore, new people had to be trained before they could use it. Also, having two different applications made data-sharing more complex, leaving some room for incompatibility problems. Taking this risk into account, we decided to migrate all automation programs into the same application where the data was stored. The application where the data was being stored was chosen because it was much simpler than the application where the automatized programs where running; it was flexible and programmable, but user-friendly. Since individuals with a wide range of technology aptitudes and backgrounds constitute the research group (e.g., engineers, educators, psychologists, biologists), the decision of having RASTRO developed in a general application was based on identifying a tool that was not too limited or too complex for the database development.

A second technical challenge presented during the development of RASTRO was the space limitations of the application itself. Choosing a non-specialized application necessitated fractioning the data already consolidated so it could fit in to the application. Fortunately, this problem was easily solved because a newer version of the application was expanded and consolidated data fit it. Although solving this problem was not an issue for the development group, it raised awareness of the need for an application that prevents future limitations due to the amount of data gathered.

C. *Data Redundancy*

Data management requires backing up information in case the data is lost due to unpredictable crashes [28]. However, having a backup should be an alternative approach for data storage (where the copy is saved) and not a parallel procedure for data updating (where same information is uploaded more than one time), otherwise data management tasks will at least be doubled. The first versions of RASTRO database had several data redundancies due to its backup process but also due to its design. The aim of storing a replica of the original file is useful for preventing data loss; however, redundancies associated with the design create potential risks for data error. For instance, the fractioning caused by the growth of data gathered in RASTRO drove the database design to duplicate information linked to students, teachers, and schools. Each student entry had information related to his or her demographics, but also their teacher experience and school information; therefore, updating teacher experience implied updating information for each of the students in that teacher classroom. Although information should be highly accessible for the user, data redundancy should not be present within a single version of the database [21]. That is why newer versions of RASTRO minimized this data replication and instead developers created links between related data.

D. *Information Visualization*

The next problem was how to best present the data to the users. Since the research group involves several individuals, data is handled by different people and is retrieved for several different analyses. The importance of creating a user-friendly interface was identified as one of the core requirements for the database development. The first step for addressing this challenge was to clean redundant data while providing redundant visualization of that data. Many applications provide high levels of accessibility and data navigation when presenting information to the user [28]. Likewise, RASTRO was improved in order to communicate the information in more than one way while avoiding data redundancies present in initial versions of the database.

VIII. RASTRO Improved

After five years of data collection, data analysis, and database development, some changes have been made to the structure and automation procedures of the database. The analysis of lessons learned has led to major changes within the database and users have perceived benefits of automatized tasks and more stable structures.

A. *New Structure*

Understanding the general structure of school-based research is crucial for data characterization and categorization. For instance, a separation of data was performed for improving schema design [18, 21] based on levels of confidentiality, information related to student demographics, student assessments, teacher demographics, teacher assessments, and school information.

Demographic information for teachers and students included consent, gender, ethnicity, grade, and school. Besides this general information, students' data also included ascent forms (required for minors), primary teacher, and secondary teacher. These two teachers were the homeroom teacher and the teacher who implemented the research-based intervention for that classroom. Teachers' general information also included data about the treatment or control group. Although information related to schools was initially part of student and teacher data, during the stabilization stage it was entered separately to avoid redundancy and provide a consolidated dataset for schools. Finally, data gathered from student assessments and teacher assessments was stored in separated tables within the database. This separation was made to optimize space and enable the creation of assessment-specific automations for correcting and storing assessment responses.

B. *Uploading, Updating, Crosschecking*

The database development also included the development of programs to automate tasks. This was necessary due to the large amounts of data that needed to be uploaded or updated every year. At the start and end of each academic year, data were collected from as many as 15 schools, 168 teachers, and 3,388 students. Basic information such as student identification and assessment scores was needed quickly to provide teachers with feedback and researchers with results for analyses. In the first year of the project, those tasks were easily performed because all students were new, and just 227 of them were part of the project. Challenges in performing those tasks arose in the following years. During the second year of data collection, new students joined the project while some students remained, and identification of homonyms and returning students become essential for uploading information accurately. Every year thereafter, new students joined, some old participants changed schools but remained in the project, and still some others supplied homonyms or changed their names. This increased the probability of error in student identification and data decay [18]. The program that was developed for addressing this risk performed a crosscheck between approximately 3,200 unique participants and each group of students within each participating classroom. Tasks that took a researcher several minutes per student assessment are now performed by the program within just few seconds using rules for uniqueness and consecutive values [18].

Similarly, tasks such as scoring an assessment took a significant amount of time for researchers, even when templates were used for scoring each assessment. Scoring took a large amount of time because three different versions of one assessment were conducted with students, and translating those versions into one unified form was a complex process. Automatized tasks for scoring were developed based on uniqueness, consecutive, and null rules and regression outcomes from previous researches [18, 23-25], diminishing the time for this process from a couple of minutes per assessment to few seconds. Other automatized tasks included assignment of a student identification number to each assessment, consolidating assessment information, identifying inconsistences between information provided in class rosters, pre-assessment and post-assessments, and identifying spelling errors in participants' last names for participant data-recognition. This process of core-task-automation significantly shortened times between raw data collection and clean data consolidation.

IX. Further Work

Although several versions of RASTRO have been developed and many challenges have been addressed, there is much room for improvement.

The RASTRO database should be migrated to a stronger data-management application, one that has the ability to link related data, assure data integrity, and therefore allow for the creation of simpler queries for data retrieval. One of the principal advantages of this upgrade will be the reduction of time to enter and retrieve data and errors in the database. This migration will also assure that data will fit into the application. Although several applications meet these requirements, it is important that users with diverse backgrounds will be able to manipulate the data.

Other developments for a future version of RASTRO may include better user-interfaces. For instance, data entry can be performed through forms directly linked to the database information, providing automatic crosschecks before the data is stored. Another improvement for the user interface is the creation of automatic reports, created for retrieving the data in a user-friendly report. This is only possible if a database application is used. Finally, the creation of a formal procedure for data digitization, consolidation, and retrieval can help avoid common mistakes such as those overcome in this project.

X. Implications

The development of RASTRO has led to insights on data management for school-related research. The design process incorporated new structures for data gathering that where more compatible with the characteristics of K-12 settings. This also increased the flexibility of the database to manage some human error and particularities while automatizing the primary tasks needed for data entry, updating, and crosschecking. This insight may be useful to other school-related projects, not only in STEM education, but in other fields using similar research designs. Having a structured and automatized, yet flexible, database tool may contribute to other projects in shortening times for entering, cleaning, and retrieving data. Using a flexible and user-friendly interface will assure that the tool can be managed by people with a wide range of technical knowledge.

Acknowledgment

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Assessing the Impact of Service-Learning on First-Year Engineering Students' Understanding of Human-Centered Design

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***Abstract*—This paper represents an update of a three stage research project that culminates in investigating the impact of the service-learning pedagogy on students understanding of human-centered design. The first two stages of the project were disseminated in previously published papers where we discussed the discovery of distinct ways in which students experience human-centered design, along with another published paper discussing the development of an assessment task that would expose and capture students' understanding of human-centered design.**

Keywords*—*human-centered design, assessment, service-learning

I. Introduction

As the engineering education community has become increasingly concerned with engineering design education, research has been conducted to understand various issues associated with the complex phenomenon of the design process. Investigations into design have included; expert-novice differences in engineering design process [1], expert-novice differences in knowledge about the engineering design process [2], methods for assessing or measuring engineering design process and understanding (e.g. TIDEE) [3], and approaches for teaching engineering design [4]. In this project, we investigate these three issues: (1) different "levels" of understanding of design, (2) how to assess understanding of design, and (3) service-learning as an approach for helping students develop design skills, following Pellegrino's Content, Assessment, Pedagogy triangle [5].

II. Previous work

This work is a continuation of a three stage project that examines the learning of human-centered design. The project investigates three research questions:

1. What are the dimensions associated with having an understanding of human-centered design?
2. What is the impact of service learning on students learning and understanding of engineering design, and more specifically, on having an understanding human-centered design?
3. What are the attributes of service learning courses that help students develop an understanding of a human-centered design process?

The research focuses on human-centered design (HCD) as a version of an engineering design process which has a focus on, not only considering, but constantly involving stakeholders throughout the design process, and has been linked with innovation [6]. In earlier papers, we described a phenomenographic study in which we characterized seven different ways in which students experience and understand human-centered design to help us to articulate different stages in a learning trajectory [7,8] and are shown in Figure 1.

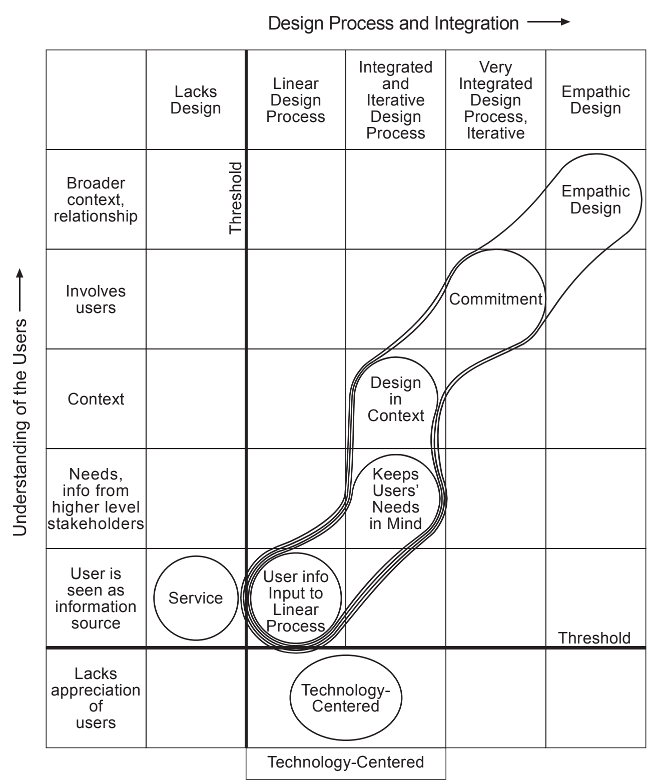

Fig. 1 Outcome Space for Students' Ways of Experiencing Human-Centered Design [7]

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The categories of experiencing HCD described were: technology centered, service, user as information input to linear process, keeping the users' needs in mind, understanding the need in context, commitment to involving stakeholders to understand perspectives, and empathic design [8]. Respectively, as the categories are stated, they represent a continuum of increased understanding of HCD [8]. With evidence of a HCD learning trajectory in hand we endeavored to create an assessment task that would also be capable of exposing students' understanding of HCD.

We next began to develop an assessment task that would elicit and capture students' understanding of human-centered design [9,10]. The purpose was to create an in-class assessment that could be used by any educator teaching design without using interviews as was done in the phenomenographic study [8]. This assessment tool provides a mechanism for researchers and educators to map a student's understanding of human-centered design to one of the seven stages identified in the phenomenographic study, without the use of extensive qualitative methods of analysis. Thus, the tool could be useful not only for potential research purposes, but more importantly could be used easily by design educators interested in providing students with quick feedback on their understanding of human-centered design. The creation and validation process of the assessment task followed a HCD process where stakeholders were involved, including many students and design educators. The assessment task underwent several iterations of pilot testing and revisions which included the task being reviewed by design educators and being reviewed by design education experts at an FIE special session in 2011. The final assessment task consists of a design task and reflection questions, which are to be completed individually and consecutively. The design task consist of a design scenario, blank paper for students use as they see fit, and a detailed table for students to indicate the various activities to be completed to address the concerns presented in the scenario (The assessment task development is discussed in detail in [10]). The final pilot included collecting data with students from two different institutions, one of which has an undergraduate degree program in human-centered design.

After completing the multi-stage validation process, we administered the assessment task to two groups of first-year engineering students at Purdue University. One group of approximately 110 freshman students were introduced to the engineering design process through more traditional pedagogical approaches such as an 8-week design project for an unspecified client, augmented with lectures, in-class activities and homework assignments aimed at developing specific design skills. The other group consisted of approximately 110 freshman students who were introduced to design through a service-learning experience. Each group of students was given approximately 60 minutes to complete the task and reflection questions. Students were introduced to HCD principles through some lectures but primarily worked with a real client. Design was mainly learned through the design of a deliverable for the client.

III. ANALYSIS

Analysis of the first-year engineering data is currently underway, with the guiding research question of: *Do students who learned design through a service-learning experience demonstrate a more comprehensive understanding of human-centered design than students who did not participate in the service-learning experience?*

Answering this question will help us to better understand the impact of service-learning experiences on students' learning of human-centered design skills and knowledge, and help inform decisions made by engineering institutions nation- and world-wide as other engineering education leaders consider adopting service-learning models. To date, we collected data from the first-year students at the end of their first-semester (after they either had the service-learning design experience or the more traditional experience).

To analyze, or code, the collected responses, we "place" each response into one of the seven categories described by the phenomenographic study [8]. The analysis approach we have taken has been to search the artifacts (the students written responses to the task) for evidence that would justify putting a student's response in a certain category. For example, we would look for stakeholder involvement in the design process or what type of information students were getting from stakeholders and how that information was integrated into the design. As we developed our analytic approach, each member of the research team scored a task individually, and then we each discussed the reasoning for each placement. This process not only helped us come to a consensus about what was being captured by the design task, but the discussions about the minute and distinct differences between the categories also helped to lay the ground work for an analytical rubric that is currently in development. In line with creating an in-class assessment, it would be necessary to have an analytical rubric to consistently and confidently rate each response. Once the analytical rubric has been developed we will calculate inter-rater reliability and score the 220 first-year students' responses.

IV. PRELIMINARY FINDINGS

To date, two coders have coded 70 design tasks, about 30% of total data set (35 students with service-learning design experience and 35 students with the more traditional design experience). Very preliminary results do show a variety of responses ranging from categories 1 thru 5, respectively; (1) technology centered, (2) service, (3) user as information input to linear process, (4) keeping the users' needs in mind, and (5) understanding the need in context. Preliminary results also show the service learning group has a higher concentration of responses that were coded to be in one of the higher categories, namely, (4) keeping the users' needs in mind. The preliminary results also show that the service learning students also tend to use the blank space provided in the design task more often than the non-service learning students.

V. Future Work

In the future we will need to administer the task to similar groups of students at the beginning of the semester to examine the possibility that the service-learning students may exhibit a more comprehensive understanding of human-centered design on the task because of differences in the populations. That is, there is a limitation in the study presented in this paper in that students self-selected into either the service-learning first-year engineering course or into the more traditional first-year engineering course. Hence, we need to determine if the students who chose to participate in a service-learning course as first-year students might start with a more comprehensive understanding, or perhaps appreciation, of human-centered design because they are more interested in designing for others than students taking the more traditional version of the class.

We will be collecting data from seniors, some with service-learning experience and others with limited or no service-learning experience. Comparing responses to the assessment task for these two groups will give us insight into what impact a continued service learning experience has on students understanding of human-centered design. It will also be interesting to note if some students not involved in the service-learning context are assessed to have a high level of human-centered design understanding and investigate that class structure and the methods of the design educator.

At the FIE conference, we will present our preliminary findings and analysis of the first-year engineering data. We will also report on the progress of the study of the data collected from the senior students.

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A Pilot Study: Documenting Engineering School Systems that Support High Student Retention

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The American Society for Engineering Education (ASEE) has engaged with the engineering education community to define and pilot the current best approaches for systematically collecting and analyzing student success data. Out of these efforts, ASEE has developed a survey that provides reliable, broad-based data for national retention and time-to-graduation benchmarks. ASEE plans to build on its retention and time-to-graduation survey and work collaboratively with engineering schools using a design-based implementation research approach [1]; and plans to document engineering school systems that support high student retention, with a pilot that focuses on schools that excel at retaining engineering students who are from the regular majority (i.e., schools that admit students through less selective admission requirements but are able to retain those students at high rates).

Keywords— (*student retention, engineering students, design-based implementation research approach****)***

I. Introduction

Since 2008 the American Society for Engineering Education (ASEE), with funding from the Sloan Foundation, has engaged with the engineering education community to define and pilot the current best approaches for systematically collecting and analyzing student success data. Out of these efforts, ASEE has developed a survey that provides reliable, broad-based data for national retention and time-to-graduation benchmarks. Schools that participate in the survey can measure their retention success against both a national benchmark and an aggregate retention of selected peers. ASEE plans to field the survey annually, increasing the number of schools that participate each year. During the summer of 2012, 123 engineering schools participated in the survey with 97 schools providing retention and time-to-graduation data.

ASEE plans to build on its retention and time-to-graduation survey and work collaboratively with engineering schools using a design-based implementation research approach [1]; and plans to document engineering school systems that support high student retention, with a pilot that focuses on schools that excel at retaining engineering students who are from the regular majority (i.e., schools that admit students through less selective admission requirements but are able to retain those students at high rates). From the 97 schools that submitted retention and time-to-graduation data in 2012, ASEE will create a subgroup of public schools with less-selective admission requirements. We will look at the distribution student retention and time to graduation for this subgroup of schools. We will select one of the schools to work with to pilot data collection from the subgroup that is consistently at the high end of the distribution for retaining and graduating students. The results from the pilot will feed into a full proposal, due September 2013, requested by the Sloan Foundation to document the systems of other engineering schools.

II. Pilot to Focus on Less-Selective Public Schools

ASEE will focus on less-selective public schools who educate the regular majority. We know from the work of Vincent Tinto that student persistence can be attributed to the interaction of student pre-college attributes, such as quality of high school education, parental socio-economic status, community where the student lived; with the college system after they begin attending college, in particular college academic and social systems [2]. More selective engineering schools can admit students that have a greater predisposition to persistence, thus contributing to a high student retention and graduation rate, and historically engineering schools have focused more on recruitment than retention [3]. Less selective public schools, because of their school mission, may not have the flexibility to recruit and select students for their engineering programs that have a high propensity to persist, but these schools can focus on structuring their programs to contribute to high student retention. Less selective schools, because of school mission, may not want to focus on recruitment as much as retention, and, if engineering is to become more diverse as a discipline, more emphasis should be put on student retention [4].

III. Documenting "Systems" that Support Engineering Student Retention

ASEE recently asked representatives from over 350 engineering schools to submit their student retention practices to ASEE. ASEE received over sixty submissions from more than forty schools. Two outcomes from this study include: 1)

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schools reported utilizing multiple retention best practices to retain students in engineering, and, 2) these best practices are implemented holistically, in a manner that could best be described as a system.

ASEE proposes documenting engineering school systems that support high student retention, first through a pilot with one school. ASEE will document the engineering school's system through reviewing school documents, and utilizing a series of inductive and deductive data collection processes drawing on on-line surveys, interviews, and structured focus groups to document the perceptions of those who are in the system – school of engineering administration, selected faculty and students.

We will use a process similar to one developed by William *Trochim* called concept mapping. Concept mapping is a structured process, focused on a topic or construct of interest, involving input from one or more participants, that produces an interpretable pictorial view (concept map) of their ideas and concepts and how these are interrelated. [5]

We will use concept mapping to create a pictorial view of the system that supports high student retention, as well as a written report on the system. As ASEE found through its documentation of retention best practices, and as cited in college retention research literature [i.e. 6,7,8,9], schools employ multiple strategies to retain students, and how these strategies are implemented and how these strategies work together as part of a system will be important to understand how schools can better retain engineering, in particular, students from the regular majority as well as students from groups that are under-represented in the field of engineering.

IV. CONNECTING THE DOTS – PRACTICE TO RETENTION RATES

Documenting school systems that support high student retention will help the engineering education community connect retention strategies and systems that support high student retention. Leaders in engineering schools whose systems have been documented will be encouraged to make presentations on their system within their school to interested peer schools. Peer schools that want to innovate their retention strategies by adapting what they have learned from their peers, can measure the success of their innovations in their school's retention rate by participating in the ASEE Student Retention and Time-to-Graduation Survey.

For engineering schools that are interested in increasing their student retention rates, they will have knowledge of successful systems that support student retention. Additional, ASEE will encourage schools to experiment at their own schools to implement what they've learned to increase their retention. Schools will be able to experiment and test the result of their experiments through ASEE's national retention and time to graduation survey.

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Out of Their World: Using Alien-Centered Design for Teaching Empathy in Undergraduate Design Courses

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***Abstract* - Designing for others is a paramount focus of teaching user-centered engineering design. This paper presents a novel engineering design brief presented to undergraduate engineering students to design for extra-terrestrials scheduled to visit their collegiate campus. Through this alien-centered design approach, students are pushed to develop empathy for a group of users quite different from themselves and to conceive and design within such an given context. A detailed plan of action is described for both cases with detailed deliverables aligned to course learning objectives. Examples of the interactions students make with their extra-terrestrial users are listed and examples of student work and final deliverables are highlighted. Reflections from the end of project are also included from students and instructors alike. The work presented here may serve as a building block to these types of successful engineering design projects in the classroom.**

Keywords – alien-centered design, user-centered design, empathy, context, engineering design projects

Introduction

Context and empathy are hallmarks of user-centered design practice [1]. Both engineering students and professional engineers early in their careers often have an initial mindset of designing for themselves rather than others. This can result in products that may not adequately meet the needs of their imagined users. This paper presents a novel engineering design brief presented to undergraduate engineering students to design for extra-terrestrials scheduled to visit their collegiate campus. By having students design for aliens rather than humans, students are challenged to develop empathy [2] and design for the needs of their users rather than for themselves. This paper compares two classroom implementations of this alien-centered design pedagogy: a freshman introductory design course and a junior electrical engineering design course.

This paper will present details about each of the stages of the design process in the two implementations, as well as the rationale for each of the teaching decisions, and how the activities map to principles of human-centered design. Additionally, we will provide more details about the different types of projects students worked on, and discuss how this technique could be adapted to other courses.

Case 1: Freshman Engineering Design Course

I. Context

At a large Midwestern research university, user-centered design has been a major focus of the first semester first-year engineering course taken by all engineering students. Students tackle an engineering design project in response to a given Request for Proposals (RFP), working in teams of 4. The focus of design projects change each semester. For Spring 2012, the course instructional team for one section challenged students to consider a new, inter-galactic student exchange program planned with students from the planet Xenos.

II. Course Design

In the second half of the semester (8 weeks), the 117 students in the section worked in teams to identify an aspect of the Midwestern University (MidwesternU) student experience that would need to be modified to accommodate the extra-terrestrial students. They posed questions to gather information that would help them learn about the "user group" and learn more about the context of the challenge. The instructional team wanted support the practice of asking questions so responses from the aliens were developed. Students were directed to identify all of the major stakeholders impacted by their project ideas and brainstorm multiple possible solutions. Teams were guided to use a systematic process for selecting a solution and created 2- and 3-dimensional models of their solutions (using SketchUp for the 2-dimensional models and everyday materials to create rough prototypes). Teams presented their final solutions through oral presentations and a written report.

Student teams also responded to feedback and new information throughout their project process. In particular, they needed to respond to updated information that the instructors received via "intergalactic correspondence with the Xenos (student) aliens." At times, the interpretation of information provided to students changed and even contradicted information that students had received earlier. As students were finalizing their project, they were given an opportunity to ask a last question "What one piece of information would help you the most as you finalize your project?"

III. Examples

Project initiation: Students were provided with the following prompt in the RFP:

MidwesternU will be piloting a new student exchange program this Fall: Students from Planet Xenos will be spending 9 months taking courses at the University as part of their intergalactic studies program. The MidwesternU would like your input—from the perspective of a student and perspective as an engineer—on things that the University can do to help the alien students adapt quickly. Proposals will be evaluated based on their ability to identify a critical need that is important for a successful alien student exchange experiences. The need may be associated with a broad range of topics: transportation to/from or around campus, a physical building space (internal and external), access to food, etc. Each team may define different needs. Your solution should not cost more than $10,000 to build or implement. We encourage you to imagine solutions that are considerably less expensive.

Project milestones and "design guides": Throughout the 8 weeks, students received design guides that scaffolded the design activities required for the project, putting the first-year engineering students on a path to successfully complete the project on a time. This scaffolding strategy has been found effective in moving students from being *beginning designers* to being *informed designers* [3]. The design guides serve as a tool to communicate with the students the instructional team's expectations for a particular stage of the project. In Spring 2012, there were 5 milestones, listed in Table 1.

TABLE 1
FRESHMAN DESIGN PROJECT MILESTONES

Milestone	Description
1.	Needfinding: Day-in-the-life of an alien story, photos of possible needs
2.	Problem Scoping: the team's focus, goals, constraints and criteria
3.	Concept generation
4.	Concept reduction and selection
5.	Concept detailing and prototype

Figure 1 shows an example of the Milestone 1 design guide. In previous semesters, students were provided a "checklist" outlining the elements they should have in each deliverable they produce at each milestone. However, a graphical representation of the expectation was found, in a less formal way, to be an effective technique to foster creativity and imagination in students' work. This was found to be especially necessary in the context of the alien-centered design because of the non-traditional way of working invoked. Students were encouraged to "play" with ideas and transform to innovations as opposed to rigidly following a predetermined checklist.

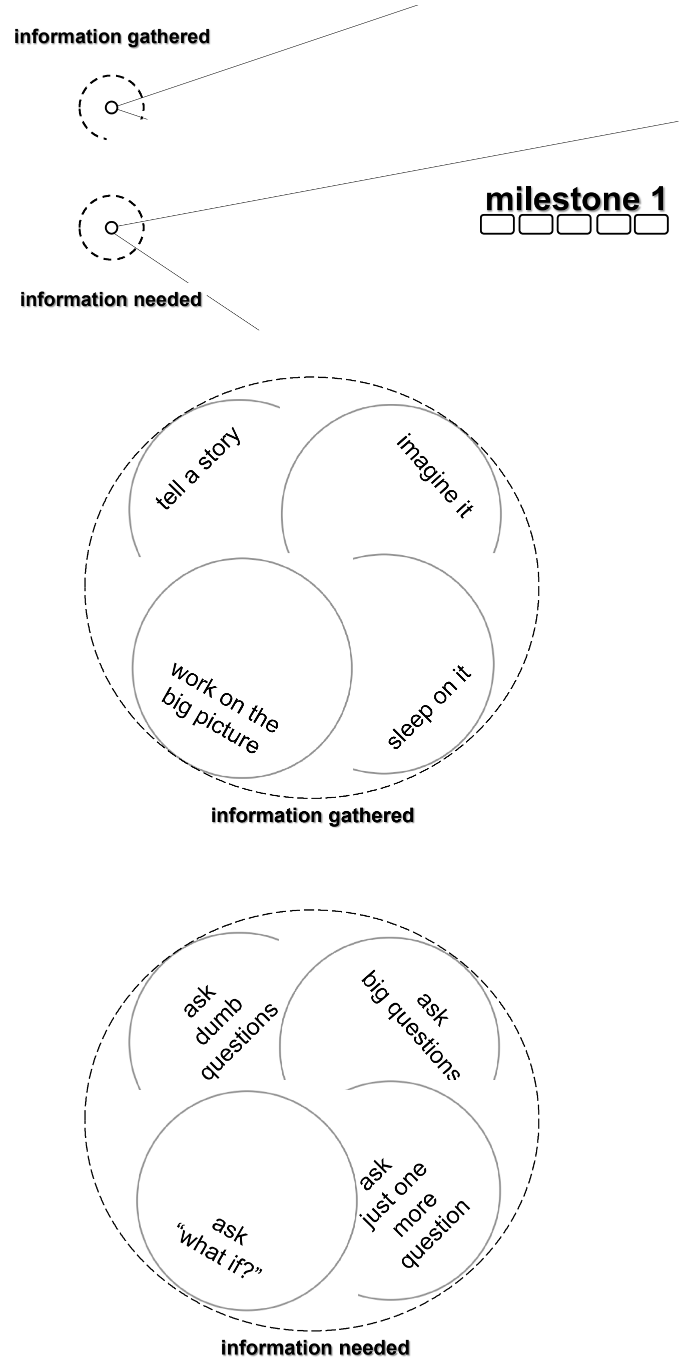


FIGURE 1
MILESTONE 1 DESIGN GUIDE.

Correspondence with the alien: With the completion of the first milestone, students gathered photos from around campus for situations identifying critical needs to be addressed. A story was written on each picture, describing the critical need in the context of "a day in the life of the alien," and elaborating on the design opportunities. Figure 2 lists two examples of pictures from around campus, and stories around the pictures describing critical needs that need to be addressed before the alien's visit.

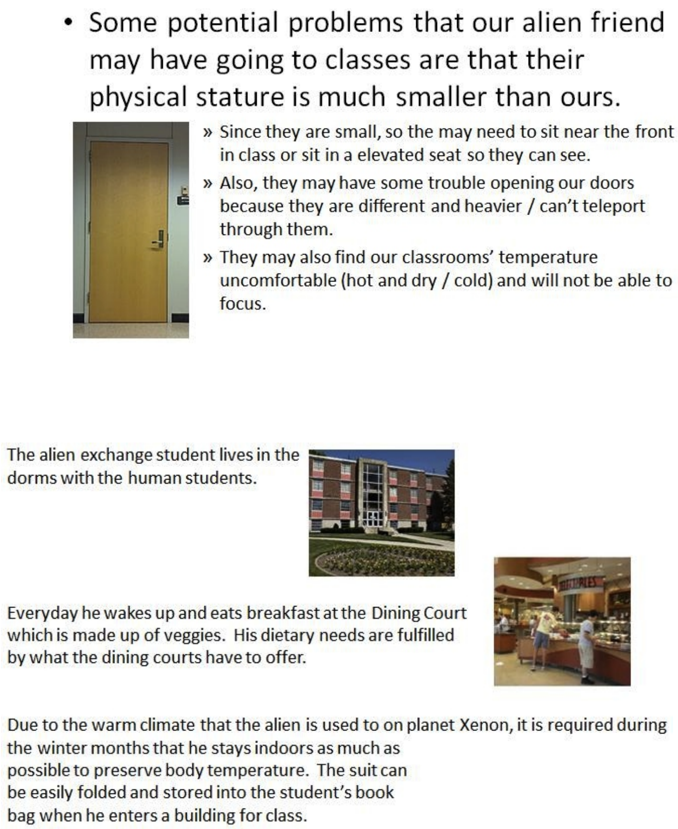


FIGURE 2
EXAMPLE STUDENT PHOTOS AND STORIES

TABLE 2
EXAMPLE OF SAMPLE COMMUNICATION WITH THE ALIEN

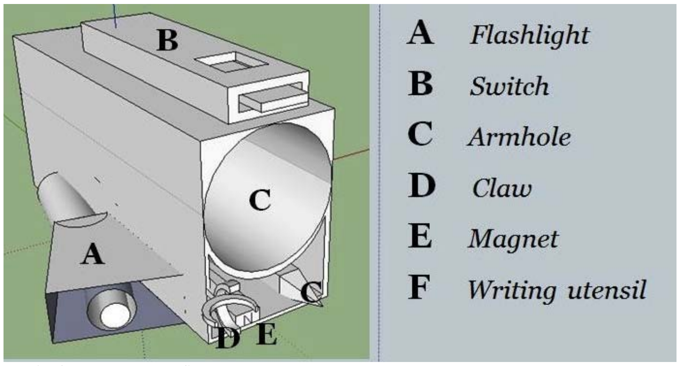
Questions and answers
Q: How do you look like?
A: Essentially, I can morph (change shape) to any of the basic volumetric shapes
Q: What do you do in your spare time?
A: After doing some research about your planet Earth, I figured that we have different concepts of time. My planet rotates twice as fast as your planet. We can, naturally, move three times as fast as you can. However, we are slow in accomplishing what we do, roughly half of you. So, I'm really not sure what you mean by spare time here.
Q: What kind of technology do you have?
A: It depends on where you are from Xenos; people in villages, for example, and given your previous question on time, use something similar to what you call sand clocks. In the advanced metropolitan areas, however, people can travel from one point in the universe to another through tunnels connected via black holes. These tunnels are sometimes being manufactured, and, some other times, they exist naturally, simply because of the physics of our universe. We figured out how to do all this. Does this make sense?
Q: How long and wide should the new keys of the piano be to fit alien's fingers?
A: How did you humans come up with the idea that we have fingers in the first place? I love music, though! I doubt I will be able to learn how to play your music that fast..
Q: Do we need to change the temperature control systems to fit your alien's body condition?
A: Nope! I'm fine!

The instructional team used this activity as an entry to direct students in the design activity. At the end of each story submitted, students were asked to provide questions they have for the alien. This technique simulates interacting with a direct user in a regular user-centered design. It is flexible, yet effective to enhance students' abilities to explore the design space by asking users about their needs (and remember that the users are very different from themselves). The Teaching Assistant compiled the questions and responded to them, playing the alien's role. This step was not as trivial as it may seem. It requires (1) providing design opportunities for projects that would last about 8 weeks; (2) providing incomplete information that are open to interpretation, simulating as much as possible a normal design situation; (3) showing the students that the design opportunities that they have shared are expandable, promising, and, most importantly, are listened to and communicated with the alien (i.e., the instructional team) so that they feel there is a response to their design work from the early stages of the design process. We felt that this was essential to the success of this design process; that is, the fact that there is a two-way communication between the designer (the student) and the alien user (the instructional team). An example of the importance of the step in directing students' projects is shown in one of the questions in Table 2. Some students were asking about temperature control. The instructional team knew that this may not be a fulfilling project for students in their freshman year, as it requires disciplinary knowledge beyond their grasp at this stage.

Students were also given the opportunity to ask one last question of the aliens as they were finalizing their design solutions: "What one piece of information would help you the most as you finalize your project?" This was done to simulate usability testing. The professor responded to each of these final requests.

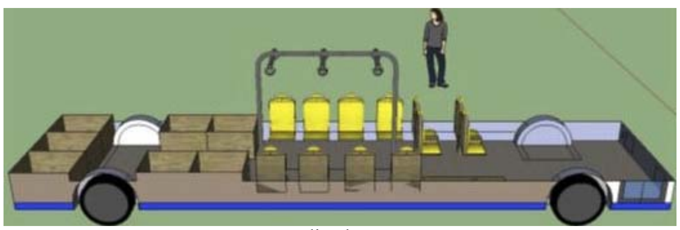
IV. Sample of Students' Work

Students were able to creatively respond to possible design opportunities. Projects ranged from assistive devices to fully functioning drinking fountains to orientation programs. Figure 3 shows both the range of scope and the modeling and rapid prototyping activities student teams undertook. Figure 3a shows an example of a platform that the alien can use as fingers (aliens did not have ones in the scenario provided). Figure 3b shows a non-functional prototype of a device that provides sustainable supply of energy from light (aliens needs a sustainable source of energy). Figure 3c shows a solution for the alien's use of the bus system (aliens could morph to basic volumetric shapes and needed to be supported while riding the bus). Figure 3d shows a design for an alien cycling machine (aliens could change shapes while exercising). Figure 3e shows a solution for the alien's need to understand time on Earth (aliens had a different perception of time; Table 2). Students' solutions were not constrained to physical products. In one of the solutions, and in order to help the aliens adjust to Earth culture, a brochure was suggested which includes information

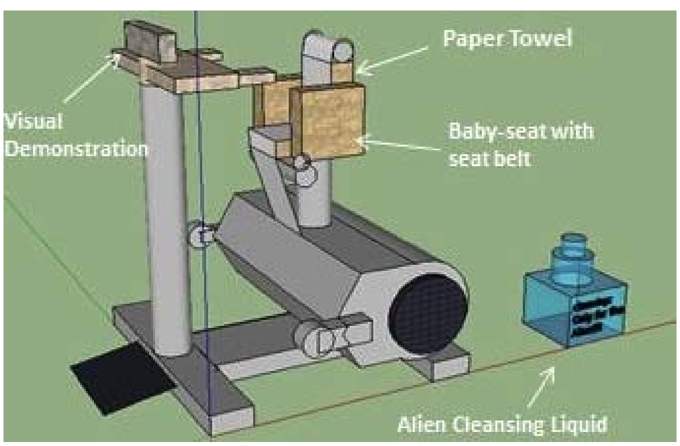


a. platform to use as fingers

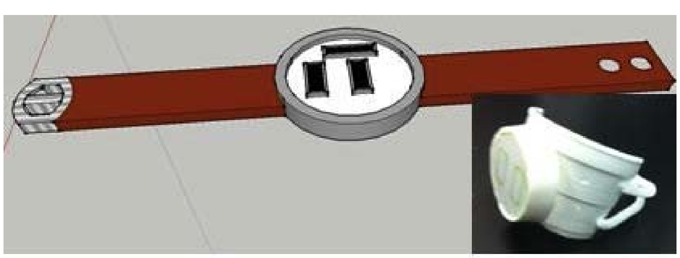
b. sustainable source of energy



c. alien bus system



d. alien cycling machine



e. alien time telling device

FIGURE 3
EXAMPLE STUDENT SOLUTIONS

about the person they will live with, as well as several tips about the local culture. The students in this project designed a sample brochure and demonstrated how an alien user would interact with it (interaction design).

V. End of the Semester Reflection

During the last class session of the semester, the professor conducted a debrief session where she introduced the ideas and terminology of user-centered design formally (through a lecture with PowerPoint presentation) and connected the major ideas of user-centered design with the projects the students had just completed (the students had given their final presentations in the previous class session and had submitted their final reports). For example, aliens the Teaching Assistant provided the students with the second set of “responses from the aliens,” where some of the information in the second set of responses conflicted with the information from the first set of responses. The professor connected this experience of receiving contradicting information (and the frustration that students experienced when they received conflicting information) to the experiences that engineers and designers typically experience while designing for customers, clients, or bosses that either change their mind about what they want, or have a difficult time describing their expectations or needs.

CASE 2: JUNIOR ELECTRICAL ENGINEERING DESIGN COURSE

I. Context

At a large Southwestern research university (SouthwesternU) in a project-based ABET-accredited general engineering program, students take full-term project classes every semester. Freshmen and sophomores take multidisciplinary project classes focusing on learning user-centered design from the top down, learning prototyping methods and developing empathy with real users in the community and developing world. Juniors take disciplinary project classes based on their chosen specialization (electrical, robotics, mechanical, or civil), and seniors take a year-long multidisciplinary sponsored capstone project. This section highlights the junior electrical and robotics specialization project course, offered in the Fall 2012 semester. This is the first specialization course that students take in the program, and in many cases provides their first exposure to embedded systems design beyond using Arduinos in their freshman year.

The context of the course was an exchange program with the Methanian aliens, who would be visiting SouthwesternU from their planet Arcturus IV as part of an intergalactic studies program [4]. Students were challenged to draw on their experience as both college students and student engineers to propose and prototype adaptive devices to help the Methanians during their time at SouthwesternU. Methanians have different physical characteristics, hear and speak at different frequency ranges than humans do, and have slower reflexes. Information on the characteristics of the Methanians was presented to students in the form of ancillary documentation.

II. Course Design

Over the course of 16 weeks, 20 students in groups of 4 used an engineering design process to *identify critical needs* (for interface, improvement, innovation, translation, etc.) of the

Methanians that could help them adapt to a semester on Earth, *pitch their invention ideas* to the class for feedback, and *go through a traditional embedded systems design process* to choose components, design circuits, create a printed circuit board, design and write software, and design and build product packaging. The final goal for each team was a fully-functioning prototype meeting the following requirements:

- Be an alien-centered design for the Methanians from Arcturus IV
- Use a Cypress Programmable System on a Chip (PSoC®) 5 Development Kit
- Be constructed on a custom printed circuit board
- Be programmed in C
- Receive input from at least one sensor
- Control at least one actuator based on input from the sensor(s)
- Be tested with a surrogate alien at least once
- Be documented with a poster describing how it solves the problem
- Stay within a budget of $60 per team member
- Meet additional requirements as defined and agreed upon by the team and the professor

The project requirements were designed to require a minimum level of technical rigor in all projects to meet course learning objectives while still allowing students to pursue their individual interests. Following discussion of requirements, teams completed the following major deliverables over the course of the semester:

Invention Pitch: teams presented 2 identified needs of Methanians based on the supplied medical charts and overview of Arturus IV, recommended inventions that addressed those needs within the constraints of the project, and received feedback from the class to help them choose one

1) *Problem Definition:* criteria and constraints
2) *Major Component Selection Rationale:* written report comparing and contrasting options for major electrical components
3) *Block Diagram, Electrical Hardware Design (schematic, bill of materials, power budget), Printed Circuit Board Layout, Software Design, Mechanical Design:* teams must create and maintain these design artifacts for their projects
4) *Gantt Chart:* requirement for project planning updated throughout the semester
5) *Design Review:* each design was reviewed in depth by faculty members and classmates
6) *Proof of Parts:* teams must submit proof that all parts they need have been sourced to avoid delays
7) *Progress Demonstrations:* teams must demonstrate to the class what they have working, share what they have learned so far, and describe next steps for their project
8) *Final Presentation and Demonstration:* team presentation in which the project results are reviewed in depth by faculty members and classmates
9) *Final Report:* team report documenting the project design, implementation, and evaluation
10) *Project Repository:* shared electronic repository containing latest versions of all deliverables
11) *Weekly Reflections:* students individually completed reflections on what went well in the last week, what could be improved, and what they will do in the upcoming week

III. Examples

Invention Pitch: based on provided medical records and survey information on Arcturus IV, teams identified a number of needs related to Methanians creation of and receptiveness to sound, sense of time and reaction time, dislike of light, and necessity of maintaining a reasonable temperature in order to nurture babies (see ***Error! Reference source not found.***

TABLE 3. EXAMPLE INVENTION PITCHES

Category	Inventions
Sound	• *Noise-canceling headphones* to minimize background noise that distract Methanians • *Speech compressor* to eliminate Methanian sounds that will hurt human ears • *Sound amplifier* to amplify weak Methanian voices
Time	• *Wristwatch alarm clock* to remind Methanians to attend class after sleeping for 34 hours at a time • *Robotic joint* to assist with slow Methanian reaction time
Light	• *Sunglasses* to filter the excessive ambient light present in the Southwest
Temperature	• *Cooling vest* to maintain Methanian pouch babies at a comfortable cool temperature

Problem Definition: each team clearly defined the problem and how their team's invention would solve it. For example, the Methanian Portal team decided to "design an apparatus which will provide easy access for the Methanian visitors, in and out of [SouthwesternU]'s buildings" to address the slow movement of Methanians that may cause them to get stuck in automatic doors. The Methanian Portal team's criteria and constraints are listed below in Table 4 and Table 5.

TABLE 4. METHANIAN PORTAL PROJECT CRITERIA

Criteria	Rationale
Have sensors to detect presence of a Methanian in front or back of the door	Need to allow the door to function automatically
Include safety features to prevent harm to the Methanians	Closing door has enough force to cause injuries, which are undesirable
Use a linear actuator to open & close the door	Since we were given an actuator, if we can make use of it, we save some of our budget
Build the door in an 'Iris' style	Will add a level of technical complexity that's more interesting to build than a standard door
Physical door must be scaled down in size, yet large enough to illustrate the concept	If we were to build a full-size iris door, we would likely have too much weight to move, and the cost would be prohibitive

TABLE 5. METHANIAN PORTAL PROJECT CONSTRAINTS

Constraints	Rationale
Designed for Methanians from Arcturus IV	The group in need of our design
Use a Cypress PSoC® 5 development kit	Microcontroller specified by instructor
Design and implement a daughterboard (PCB)	To interface the PSoC® with our additional components, sensors, actuators, etc.
Have at least one input device/sensor	Required by project definition
Control at least one output device/actuator based on data from the sensor(s)	Required by project definition

Electrical Hardware Design: One concern for adding significant context to a technical course is reducing the technical rigor. However, as shown in Table 6, all teams met or exceeded the technical requirements of the course.

TABLE 6. PROJECT TECHNICAL RIGOR

Team	Technical Characteristics
Methanian Alarm Clock	• *Sensors:* Matrix keypad • *Actuators:* LCD screen • *Other circuitry:* Backup battery • *Other features:* Real-time clock chip
Exoskeleton Methanian Arm	• *Sensors:* Limit switches, potentiometers • *Actuators:* Motor • *Other circuitry:* H-bridge motor controller • *Other features:* Screw drive for joint control
Methanian Noise Filter	• *Sensors:* Microphone • *Actuators:* Speaker • *Other circuitry:* Audio amplifier • *Other features:* Direct memory access-based analog to digital converter
Methanian Cooling Vest	• *Sensors:* Thermistors • *Actuators:* Water pump • *Other circuitry:* MOSFET pump control • *Other features:* Hand-sewn cooling vest
Methanian Portal	• *Sensors:* Ultrasonic rangers, buttons • *Actuators:* Linear actuator • *Other circuitry:* H-bridge motor controller • *Other features:* Iris-style mechanical door
Methanian Voice Compression Unit	• *Sensors:* Microphone • *Actuators:* Speaker • *Other circuitry:* Audio amplifier • *Other features:* Software/hardware FFT

Mechanical Design: All teams completed CAD drawings of their designs, in addition to creating fully-functioning prototypes of their mechanical and electrical systems. An example of the CAD drawing and picture of the Methanian Portal are shown in Figures 4 and 5.

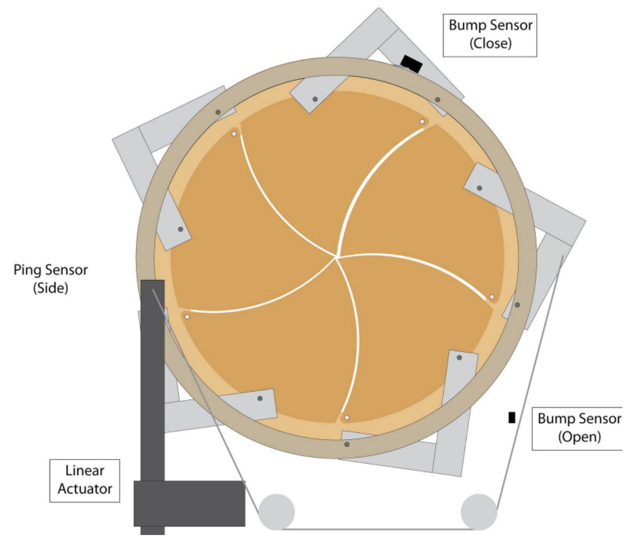


FIGURE 4
METHANIAN PORTAL MECHANICAL DESIGN

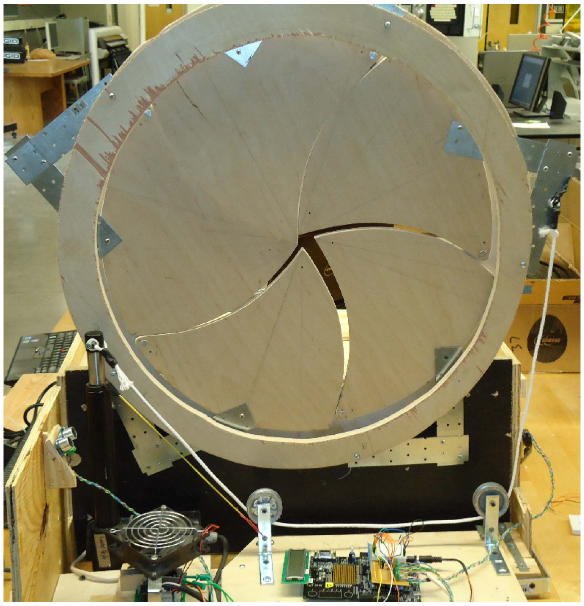


FIGURE 5
METHANIAN PORTAL PROTOTYPE

DISCUSSION AND CONCLUSIONS

Presenting an alien-centered engineering design challenge to imagine and make a solution for visitors to a college campus gives students both a familiar starting basis of understanding and a wonderfully out-of-this-world beginning point to reconsider what needs might be present for their extra-terrestrial friends. In consideration of specific learning objectives of the freshman introductory engineering course and junior electrical engineering course, both classes allow for creative and innovative student-directed projects while learning process-focused and technical-focused content.

I. Concentric Rings of Context

Some engineering design project courses serve to introduce or practice an engineering design project where students naively design a solution for themselves or someone very much like them; the context in which they work is implicit. By introducing a fantastical situation where the place and application is known but the user of such a system is not, make explicit that some of the stakeholders are beyond our familiar populace. The discovery of what needs can be addresses may then start with the familiar but then divergent brainstorming is sure to follow when introducing some of the unique constraints borne by Methanians at 7 feet tall and arms down to the floor. A use-inspired scenario is not enough – the student engineering design teams then must consider the place, things and people/extra-terrestrials to for whom to design.

II. Fostering Empathy

The necessary act of understanding an alien race in the context of human-centered design encourages students to truly examine situation from points of view different from their own. Admittedly in an extreme fashion, students are charged to problem solve with an uncertain user in mind. Since (as far as we know) aliens have not, in fact, visited us on Earth, the project can be considered a toy real world problem. With some direction, presentation of information about our extra-terrestrial friends, and a "conduit" through faculty to ask questions about their lives and needs, a mindful approach to respectful understanding and scaffolds to empathy exists. With scant given knowledge, it is seemingly impossible to dismiss the framing of the design challenge and it is necessary to adopt an alien-centered design process to discover needs and wants (ala user-centered or human-centered design processes popularized by IDEO and others in product development and experience design).

III. Intro to Engineering Design vs. Intro to Engineering

Such alien-centered engineering design challenges may serve to support slightly differing learning objectives. With the assumption that freshmen do not have previous exposure to an engineering design process, alien-centered design gives an introduction to engineering design, the processes and skills by which one problem solves as an engineer. The junior-level students designing for aliens have had previous introduction to an engineering design process and the project serves to be an introduction to engineering, specifically the discipline of electrical engineering. With the work presented here, it is most useful to note that this type of open-ended design project is flexible in scope and can benefit the students in either construction. The requirements and expectations of how far students are asked to take their ideas and level of refinement in the prototypes is of a number of parameters that might need to be adjusted depending on the epistemic audience.

IV. Balancing Breadth and Depth

The tasks students might focus on may very well differ depending on the level at which they are working. It is of the very nature of the specific course learning objectives as to how breadth and depth may be applied. For freshmen students, stepping through the steps of an engineering design process from scoping to initial concept, might only give enough time to select a concept and produce a rough conceptual prototype. For juniors in electrical engineering however, their imagined application and concept is the quick starting point and much of their time is spent developing detailed designs and seeing them through to a pre-production prototype proof of concept. Across these two course cohorts, the priorities within the learning goals for the instructors as well as the priorities of the actions of the students may be widely varying. The freshmen cohort are engaging in the breadth of a design process, aiming to go from the design prompt to solution. The juniors are quickly using a similar starting point to quickly dive into the technical depth expected of their solutions.

V. Allowing for Creativity, Motivation, Novelty & Fun!

For both sets of students engaged in alien-centered design, it was an opportunity to work on a divergent, open-ended problem. For many, the minimum of constraints allowed for their creativity to come forward. In addition, many student teams took their solution towards an area of concern that they found personally interesting and were motivated to consider what such a solution may be extended out into the near or long-term future.

With such a crazy starting point, alien-centered design projects can also allow for a greater (perceived) freedom in the student cohorts to aim for more novelty than project in which they might be designing for themselves. Alien-centered design projects also serve as audacious stories of engineering work for students relating this experience to fellow students, friends, family and prospective employers

VI. Appeal to Broader Applications

Extending the alien-centered design project approach, there are possibilities to connect to other, more traditional avenues for class engineering design projects. Designing for the developing world or universal design approaches have similar contexts of creating for users that may be less that accessible. The work presented here may serve as a building block to these types of successful engineering design projects in the classroom.

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Preparing Future Engineering Students through Math Competition in Inland Area

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Abstract*— MATHCOUNTS is a national program aimed at enhancing problem solving skills for middle schools students through a series of math competitions at the local, state and national levels. Currently in its 30th year, MATHCOUNTS is one of the country's largest and most successful education partnerships involving volunteers, educators, industry sponsors and students. As an extracurricular activity, MATHCOUNTS recognize and reward students for pursuing a deeper understanding of math concepts and their applications in science, technology, and engineering (STEM) fields. In this paper, I shall describes the effort made by the College of Engineering of California Baptist University in organizing the annual MATHCOUNTS Chapter competition for Inland Empire area and encouraging engineering careers among the local middle school students. After initial background introduction of the MATHCOUNTS program, the paper will focus on the growth of the MATHCOUNTS program in Inland Empire area during the last five years, the detail aspects of organizing this important competition, and the linkage between the competition and the career choices among the students involved in the competition. The long term goal of organizing this competition is to further promote and improve K-12 STEM education so that more students will choose engineering as their future careers and more students will be better prepared for the engineering careers they choose.

Keywords—MATHCOUNTS, STEM

I. MATHCOUNTS IN INLAND EMPIRE

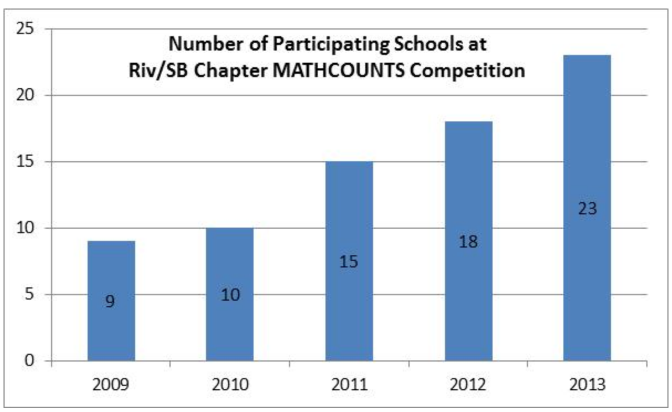
In its 30th year, MATHCOUNTS is an annual extracurricular program for 6th-8th graders. Each Fall when the school semester begins, the participating schools register with the national MATHCOUNTS office and assign a coach, usually a math teacher or sometimes a volunteer parent, to lead math club activity either after school or during the 7th period of the school schedule. The coach receives the annual MATHCOUNTS School Handbook and previous year competition materials to train students on topics and problem solving skills usually not covered in school math classes. The topics include arithmetic, algebra, geometry, number theory, and combinatorics. The level of difficulty of those math problems increases gradually as the students progress through a series of organized math competitions at four different levels: school, chapter, state, and national. The competition problems at all four levels are issued by the MATHCOUNTS National Office every year. The school round of competition is usually administered by the coach and is used, along with other performance measures at the discretion of the coach, to select the team members to represent the school for the next round of competition. At chapter level in February, each school is allowed to send maximum one team consists of four top students and 6 additional students competing as individual for a total of 10 students. In Inland Empire, the Riverside County and San Bernardino County form the local chapter. The winning teams and individuals at chapter competition move on to the state competition in March. The number of teams and individuals allowed to compete at state level is determined by the number of participating schools at chapter level. Then, the top four individual students at state competition move on to the national competition held in May. Each competing student at national level receives a graphic calculator in addition to a trophy. All members of the national winning team and individual receive a laptop, a expense-paid trip to Space Camp, and a meeting with the president in the White House. The participating students at different levels all receive valuable training in logic thinking and problem solving skills. Many of them continue math related activities and competition at high school and choose a career in STEM when selecting a college major. Most of them cited years later the positive impact of the program in their life.

Based on the number of participating schools and the competition performance, Inland Chapter is lacking behind in comparing with other neighboring chapters, such as Orange County and San Diego County. About five years ago, the chapter was even having a hard time to find a willing organization to host the chapter competition. The California Society of Professional Engineers Education Foundation (CSPEEF), who has been leading the California MATHCOUNTS program since the beginning, approached College of Engineering of California Baptist University (CBU) and found a warm welcoming home for the annual Inland chapter MATHCOUNTS competition. The College assigned a faculty member to be the coordinator and later become a board member of the CSPEEF.

II. ORGANIZING MATHCOUNTS CHAPTER COMPETITION AT CALIFORNIA BAPTIST UNIVERSITY

CBU's College of Engineering has been hosting the Inland MATHCOUNTS chapter competition for the last five years in each February at its beautiful campus in Riverside. The engineering students act as proctors and graders as part of their engineering service activity. Among students, teachers, parents, and siblings, this annual event attracts several hundred people to the campus on a Saturday between 8am to 3pm. Many of the youngsters set their feet on a college campus for the first time of their life, creating excellent marketing opportunity to promote university's programs. The Dean of College of Engineering offers $10,000 scholarships to winners of the competition if they choose to attend CBU's College of Engineering upon graduating from high school.

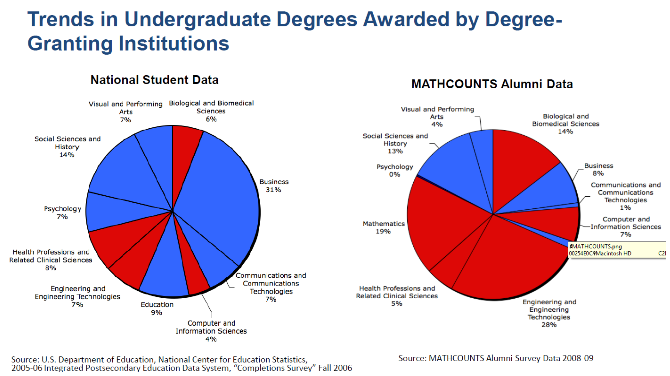
To attract more participation from local schools, the coordinator keeps close contact and communication with the coaches, encouraging and reminding them for timely registration. Due to the recent economic hardship and state educational budget cut, many schools participated before but decided not to continue due to $240 registration fee. To help the situation, the coordinator worked with a local community college and offered a mini-grant to cover the registration fee for eligible schools. Because of those efforts, the number of participating schools has increased steadily each year (showing below). For the 2012_2013 academic year, there were 23 schools registered the chapter competition, a record attendance. With over 50 school districts between two counties, this number still represents a small percentage of students involved in this activity. However, the number of attending schools is now at par with its neighboring counties, such as Orange and San Diego.



One of the highlight of chapter competition is that each competing student is treated a free lunch between written round competition and the countdown round competition at the CBU cafeteria, which is known in the community for its food quality. All costs of running the chapter competition is covered by CSPEEF through fundraising from local professional engineer societies. As we promote the program and increase the participation, it becomes a tougher task to fundraising about $2000 annual budget to cover student lunch and award toughies. At the present time, the coordinator is actively seeking funding sources to support the ever increasing participation from the local schools and welcoming support from local organizations.

III. Impact of MATHCOUNTS Program and Engineering Careers

CBU's College of Engineering has been hosting the Inland chapter MATHCOUNTS competition for the last five years. The first group of competing students is in their senior year in high school and is ready to begin their college life this fall. Therefore, we do not have the data to make a direct connection between CBU's chapter MATHCOUNTS competition and the career choices those competing students choose. At the national level, however, there are data to make a connection between the two. The following chart illustrates the career choices by students who had MATHCOUNTS experiences versus who did not [1].



It shows clearly that the overwhelming high number of students who had MATHCOUNTS experience choose to pursue career in STEM field. Another study conducted by Education Next, an education policy journal, found that by boosting students' math and science skills, the U.S. would add approximately two-thirds of a percentage point to the GDP each year [2].

From CBU's College of Engineering perspective, the long term goal of organizing this competition is to further promote and improve local K-12 STEM education so that more students will choose engineering as their future careers and for those who choose engineering as their career will be better prepared. Plan is under way to follow the students into high school and organize the annual AMC10/12 math competition.

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An initial comparison of the learning propensities of 10 through 12 students for data analytics education

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***Abstract*—The main focus of this ongoing effort is to compare the learning propensities of 10 through 12 students for data analytics education. Towards this end, a Microsoft Excel based university-level environmental engineering module was taught in a high school classroom with students in grades 10 through 12. The module focused on understanding the current trends and challenges in environmental pollution management and policy. Students were required to procure, analyze, and visualize data in order to propose an environmental policy that was aimed at reducing pollution. Initial data collected from the assessment of the student work alludes to the fact that despite being taught the same material by the same professor and teaching assistant, the success of the students, as measured by their final grades, varies substantially with their academic year. The underclassmen in high school did not display the academic maturity and comprehension that was displayed by the high school seniors. On the other hand, seniors demonstrated a strong propensity to learn and perform well.**

I. Introduction

Data analytics is a vital skill for STEM students. The main focus of this ongoing study is to codify the learning outcomes of 10^{th} through 12^{th} grade students for data analytics education. This effort will introduce in high schools, several 5-week data analytics modules taught at Drexel University's (DU) College of Engineering (CoE). In general, these modules cover topics that provide students an introduction to the technical challenges in several branches of engineering.

Specifically, we present initial results of a data analytics module that covers concepts from environmental engineering. Environmental engineering has been shown to help raise students' knowledge and change their attitudes in perspective of environmental issues. In [1], the authors present efforts wherein curriculum was developed for high school and university engineering students dealing with environmental issues involving fuel and vehicle technologies.

Furthermore, this work is support by the National Science Foundations's GK-12 program [2]. The GK-12 program features innovative collaboration between graduate students, university professors and high-school teachers. This practice has yielded positive results in the past as evidenced by the host of success stories mentioned in [2]. Additional evidence of a successful collaboration between university professors and high school teachers is found in [3]. In [3], the authors present efforts that were based on collaboration with a university professor to bring the idea of "wonder" into a 9th grade science classroom. Two classes were taught, but only one was taught with a sense of trying to evoke "wonder". The general results of the project were both qualitative and quantitative through journals and tests showing that through the phenomena of "wonder" there was evidence to show that it provides better retention and understanding of the material, thus resulting in a a more effective learning process.

Ultimately, the content and empirical results generated from this effort will be shared on a web portal to help inform 1) the engineering data analytics education community of the benefits and limitations of introducing data analytics concepts in high schools, and 2) the ongoing national dialogue on big data education, thereby helping all stakeholders better align their STEM educational efforts.

II. Method

A sophomore level engineering module was conducted in a high school classroom with students in grades 10 through 12. The group of students were chosen as a class that was involved in the National Science Foundation GK-12 program. This class was more specifically chosen because it was an engineering focused class with a diverse group of grade-level students. To the best of our knowledge no student had previous Excel experience and the assignments were part of the students' grade for the semester. The module was taught twice a week for a five-week period. This module focused on data analytics exercises as applied to environmental engineering.

The instructional and learning strategies utilized in this effort were inspired by the observations and recommendations derived from the National Academy Press Report on How People Learn (Bransford, Brown, and Cocking, Eds) [4]. The lectures were designed to introduce environmental engineering concepts. During lectures, the instructor introduced data analytic topics in a contextual manner using Powerpoint slides, demonstrated data procurement, analysis, and visualizations using Excel, and provided general insights about the topic being covered. This instructional strategy is in line with the recommendations of [4], wherein the instructor presents "some

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subject matter in depth, providing many examples in which the concept is at work."

During the lecture, the instructor presented several fundamental questions pertaining to the technical challenges of environmental engineering and invited the students to discuss possible answers. The students take over the discussion while being gently guided by the instructor to arrive at an answer. By doing so, the instructor used the findings of [4] wherein the authors note, "students come to the classroom with preconceptions about how the world works and it is necessary to engage this initial understanding". This instructional strategy allowed the instructor to draw out and work with pre-existing understandings that students bring with them [4].

The labs sessions were designed to enhance students understanding of the topics covered in the lectures. Students worked in groups of 2 on biweekly lab assignments that featured open-ended questions about the following topics:

1) Global Emissions of Carbon Dioxide
2) Historical New Jersey temperatures
3) Particulate matter data from an environmental monitoring system installed in Philadelphia
4) Emissions due to the transportation sector in the US
5) Emissions due to the energy sector in the US

The open-ended questions were designed such that when answered via appropriate data analytics, the answers provided the building blocks of the environmental policy mentioned earlier.

Websites that host datasets required to perform this analysis were provided to the students. However, students were responsible for driving their own learning with minimal or no input from the instructor. They were encouraged to search for data sources, select the appropriate amounts/types of data, apply the relevant data analysis techniques, and generate visualizations and insights to answer the questions. They were also encouraged to refer to online journal articles, chapters of seminal textbooks in the field, the slides that was presented by the instructor, as well as any other reputed online resources that they could find. Students were also encouraged to talk to each other to share ideas, information and knowledge.

A. Lecture and Laboratory session organization

There was a 65-minute lecture and a 65-minute lab period per week. Students used Microsoft Excel and data analytics concepts such as descriptive and predictive statistics to analyze, visualize, and summarize the key trends for the aforementioned topics. The 5-week module consisted of two biweekly assignments and a final environmental policy. Each assignment consisted of an excel workbook as well as a one page memo of their findings.

B. Personnel

The college professor and the teaching assistant who taught the sophomore level engineering class also taught the high-school class. The professor, Pramod Abichandani, of the class, Evaluation and Presentation of Experimental Data (EPED) at Drexel University (DU), collaborated with Mr. Matthew VanKouwenberg, a high school engineering teacher at the Science Leadership Academy (SLA) for this effort. The material covered at the SLA was the same as that taught at the sophomore level in DU's EPED class. Also the GK-12 fellow, Jamie Kennedy, ran the labs at both DU and the SLA. Students were required to work in pairs during labs.

III. Preliminary Results

A total of 8 groups (16 students) at the SLA were part of the effort thus far. These were divided into the following two cohorts:

1) Cohort A: This group consisted of students from grades 10 and 11 at the SLA. A total of 5 such groups were part of this effort.
2) Cohort B: The remaining 3 groups consisted of grade 12 students at the SLA.

The assessment tools consisted of a combination of analytic and summative rubrics. All assessment was done by the GK-12 fellow. The difference between the final scores of Cohort A and Cohort B was substantial. The Cohort B was at 71.6 percent average grade while the Cohort A was at 45.3 percent average grade. There was improvement upon the Cohort B group with the averages of the assignments increasing from 27.7 to 54.0 percent throughout the 5-week period.

IV. Discussion and Future Work

The results allude to the fact that despite being taught the same material by the same professor and teaching assistant, the success of the students, as measured by their final grades, varies substantially with their academic year for the group of students involved in this effort. The Cohort A students did not display the academic maturity and comprehension that was displayed by the Cohort B and sophomore college students. On the other hand, seniors demonstrated a strong propensity to learn and perform well.

One possible reason for such a substantial difference can be the difference in the emotional intelligence of students. In a related study [5], the authors examine the relationship between emotional intelligence and academic achievement in the transition from high school to university level. The results showed that academic success was strongly related to several dimensions of emotional intelligence. Furthermore, in [6], the authors examines the relationship between emotional intelligence and academic retention in the transition from high school to university level. The experiment was done over the course of two years tracking students that remained enrolled with university studies over their first couple years and students that withdrew. Results showed that students that remained enrolled with their studies had a broad range of emotional and social competencies.

In summary, the initial comparison alludes to the fact that despite being introduced to the same environmental data analysis concepts and material, the seniors (12th grade students) performed relatively well in comparison to the underclassmen (10th and 11th grade students) as witnessed by their final grades. At this stage of the effort, several reasons for this difference in performance are hypothesized. These include difference in emotional intelligence (as discussed earlier) and motivation for the class. Furthermore, the difference may be a function of the technical focus (environmental engineering and/or data analytics) of the effort. Future work will focus on understanding the possible causes of differences in student propensities. As more assessment data is collected during these modules, we anticipate gaining a better understanding of the learning propensities of 10 through 12 students.

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Embedding Design and Service-Learning into the K-12 Computer Science Classroom

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***Abstract*— In the pre-university setting, computer science course assignments are often project-based, but seldom do they include real-life problems in real time. Many assignments are strictly dictated by what textbooks suggest as valuable learning experiences, as long as they can be completed in just a few class periods. The number of students taking a computer science course continues to dwindle, as does the number of teachers certified to teach computer science.**

Building on two case studies of EPICS High in computer science classrooms, this paper will open discussion and explore novel ways of engaging computer science teachers and students through compelling community-based service-learning projects using engineering design concepts. As it is EPICS High's mission is to be a leader in developing, disseminating, and supporting service-learning models that engage high school students in engineering and computing-based design projects that meet the needs of their communities, EPICS High intends to build relationships with computer science teachers to learn the best way this model can be implemented in their courses and help these teachers pilot an EPICS project that connects with their community.

Keywords—Computer science, design, service-learning, K-12

I. Introduction

The decrease in the number of K-12 students engaging in computer science courses poses a problem, as there is a critical need in the U.S. for more computer scientists and engineers. President Obama has called for a new generation of STEM professionals that will maintain the country's leadership in the world economy. Added to this, there is a call in the computer science education community to have computing in 10,000 high schools taught by 10,000 well-qualified teachers by 2015. (Otherwise known as the NSF funded CS 10K Project [1].) New approaches are needed to achieve these goals. The literature predicts that service learning could attract more students into engineering and computing by introducing it through community-based projects. The results from service-learning confirm this. [2]

One exemplar of service-learning that includes computing is the EPICS Program, founded and headquartered at Purdue University. [3]. The EPICS Program is an innovative service-learning approach to teaching design where teams of students partner with local community organizations to identify, design, build, and deliver solutions to meet the community organization's needs. Data from EPICS shows that it is attracting traditionally underrepresented populations of students and increasing students desire to continue in engineering and computing. The potential to significantly impact K-12 pathways into engineering and computing motivated the creation of EPICS High in 2006. EPICS High is an adaptation of EPICS into the pre-university setting. It has been implemented in over 50 high schools in 11 states engaging over 2000 students per year. Student surveys have shown that the EPICS High projects are attracting students with no or little interest into STEM career pathways. An example is Jessica Roggenbuck who was an EPICS High project leader and featured in an article for the ASEE *Prism* Magazine

Jessica Roggenbuck is a student the University of Toledo. If you had told her as a high school freshman that she would be studying chemical engineering, you might have gotten a puzzled response. "Engineers? I thought they were train drivers," she admits with a laugh. But during her junior and senior years at rural Harbor Beach High School in Michigan, Roggenbuck developed a new appreciation for engineering while leading a team of 6 female and 1 male students in an after-school computer science based project [EPICS High]. The team of students designed a computer program that allowed charity food pantries track their inventories, "It helped me understand what an engineer does," says Roggenbuck. It also influenced her decision to pursue an engineering degree."[ref]

Jessica is not unique and her team is not unique. EPICS High is attracting women and underrepresented students at significantly higher rates than traditional program. Females represent 44% and underrepresented minorities are more than 50% of EPICS High students. The approach of EPICS is positive and there are examples of successful computing projects such as the one at Harbor Beach. There is, however, a lack of computer science teachers participating in this program who are integrating the concept into their curriculum or after school programs.

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Figure 1 EPICS High Computing Team from Harbor Beach, Michigan Partnered with local food bank

EPICS High has the potential to change the curve into and through computer science pathways on a national level. There is a compelling need for more computer science professionals but current approaches are showing only incremental changes. The EPICS approach of linking computer science learning with authentic and compelling human and environmental needs in the local communities of participants is consistent with diversity literature. The National Academy of Engineering's report "Changing the Conversation" discussed the need to change the perception of engineering and computing [4]. EPICS High projects align with these themes and result in tangible projects for the entire K-12 community to see what engineering/computing is and can be.

II. NON-TRADITIONAL CONCEPTS

Service-learning is not a new concept, nor is the computer science field void of any implementation of service-learning. However, most opportunities exist at the collegiate level instead of engaging high school students in these same valuable experiences [5, 6, 7]. One such attempt has undergraduate students mentor high school students as their service-learning, but only in a summer camp setting, engaging them in computer science activities and programs, not in service-learning activities [5]. Another research study initiated service-learning computer science courses for the lower level undergraduate courses, in hopes that participation would transition to retention. This concept worked well, and showed favorable results, but there was no mention of future work matriculating into the pre-college environment to see if similar results could be had with early exposure and engagement in service-learning [7].

The approach of EPICS High is to engage students and teachers in long-term partnerships where students develop solutions to local needs. There are many opportunities for computing projects. The Harbor Beach team mentioned earlier worked with the local food bank to increase its efficiency and effectiveness through the use of software tools. EPICS has taken the successful university approach to design using a human-centered approach, shown in Figure 2, and adapted it to the high school environment. Curriculum modules have been developed in the areas of design, community partnerships, teaming, project management, communication and ethics and culture. Teacher professional development equips teachers to lead student teams. EPICS staff and faculty work with the teachers to adapt the EPICS model into their schools. Some schools implement EPICS as an after school club or activity. Others integrate EPICS projects into science, math or technology courses. Still others have entire courses where EPICS is used to introduce students to engineering, STEM and design. Local professional are often used to mentor students and to supplement the expertise of the teachers in guiding students through the design process and into product delivery.

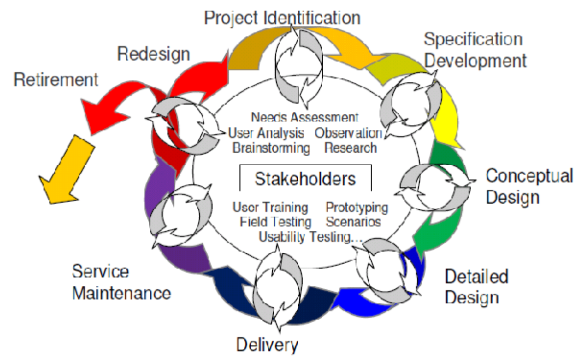

Figure 2 EPICS Human-Centered Design Process

There are many opportunities for computing projects within communities but there is a dearth of EPICS High projects in pre-college computer science courses. Typically, EPICS High has been merged into traditional science, technology, or engineering courses, with little focus on engaging computer science teachers.Even without a directed effort to promote the EPICS model in computer science, two EPICS High schools have begun to incorporate computer science into a community-based, service-learning program within their schools. This work in progress presents these two models as case studies and the presentation will explore the progress to date.

A. School 1: Park Tudor Upper School

Park Tudor is a college preparatory school located in Indianapolis, Indiana for students in grades 9-12. Park Tudor has an enrollment of 418 students with a 78% Caucasian population [8]. Students enroll in existing computer science courses but have the opportunity to work on EPICS projects with real users in the community. Projects include web design for a community non-profit group, cell phone application development for intra-school needs, or computer program development for course registration. The projects are offered as an option to the students within the courses.

B. School 2: George Westinghouse College Preparatory School

Westinghouse High School is part of the Chicago Public School system and draws students from over 300 schools in the Chicago, Illinois area. Westinghouse has an enrollment of 1,115, 89% of which are underrepresented minorities [9]. The school has created a separate EPICS course that is based on computer science with community applications. The class has partnered with Garfield Park Conservatory whose staff was having an organization problem with the plants. The goal of the project is to help them by organizing the plants according to their history and similarities with a new database. This, like all EPICS projects, involves interaction with the users and stakeholders and a plan for hand-off of the project to the community partner including user manuals and supporting documentation.

III. Lessons Learned

Even though there are just two schools in this case study, there are still many lessons that can be applied to a potential expansion of EPICS High into computer science courses. While there is a vast difference between the students in each of these two schools, each EPICS team has successfully delivered computer science projects that make an impact in their own community. This speaks well for a potential widespread implementation of a community-based service-learning component in computer science courses. Additionally, we can conclude that schools of varying sizes and demographics have equal opportunity for community impact.

IV. Future Work

Using the projects from our two case study schools as examples, the EPICS High program plans to recruit 5-10 new schools for the 2013-2014 school year to pilot the EPICS High Program in computer science courses. These schools will help establish best practices and create a model for service-learning computer science courses. These best practices will also be aligned to the CSTA K-12 Computer Science Standards so as to unburden the curriculum. Ideas for recruiting and retaining school participation, as well as dissemination, will be solicited from the audience for this presentation as well as future presentations at other engineering and computing education conferences.

Once best practices and standards alignments are achieved, additonal schools will be recruited to expand the reach of EPICS High and to engage more teachers and students in computer science design and service-learning.

V. Conclusion

This work in progress appeals to those interested in K-12 engineering and computer science education as well as those interested in novel applications of service-learning and design. As stated, there is little to no formalized computer science service-learning taking place in the pre-college environment. This is an enormous opportunity. The picture of the project team from Harbor Beach does not look like a typical computing project team. While that team was not in a formal computer science class the literature and the data from current EPICS High participants indicate that service-learning can be a significant tool in increasing interest and diversity within the computing fields. With the development of best practices aligned to the standards, this may well open the door to new career pathways for students to meet industry and societal demands. The presentation will include opportunities for discussion on how to implement such an approach on a national level. A successful pilot would present opportunities for research and contribute to the CS 10K project.

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An Innovative Approach to Secondary Mathematics for Engineering and Science

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***Abstract*—The purpose of this paper is to provide a framework for NICERC's Advanced Math for Engineering and Science (AMES) curriculum that will lead to a series of studies on various aspects of the curriculum. Included in the paper is a description of the content, an explanation for the integration of AMES with other curricula, and a description of the professional development for AMES. AMES is a high school curriculum aimed at integrating multiple disciplines in order to provide context for the mathematics concepts used daily by engineers and scientists.**

This paper begins by discussing the structure of AMES. The structure is based on an analytic geometry approach to concepts taught in high school and post-secondary institutions combined with a multidisciplinary approach providing the context. Additionally, the paper outlines a broad description of the content in AMES and how multiple disciplines such as history, physics, and American government are incorporated into various lessons. This paper then demonstrates how other curricula are interwoven into AMES. Lastly, the paper includes a description of the professional development component of AMES. This section discusses how the professional development engages teachers prior to implementing the course.

Keywords—mathematics; interdisciplinary

I. Introduction

Secondary mathematics is usually presented as a subject that stands alone and is not related to other subjects taught in high school such as history or English. However, students enrolled in interdisciplinary classes experience advancement in metacognitive skills and critical thinking [1]. This suggests that classes should contain interdisciplinary components. Furthermore, there has been a recent push for teaching engineering in K-12 schools to foster higher achievement and greater interest in science, technology, engineering, and mathematics (STEM) courses and fields [2,3]. Along with this, as the Common Core standards are being implemented throughout the United States, curricula must be created that support these new standards. The Cyber Innovation Center, a 501c3 not-for-profit, is currently developing Advanced Math for Engineering and Science (AMES), a curriculum that integrates various STEM and liberal arts disciplines and meets mathematics and English language arts standards set forth by Common Core.

II. Curriculum Structure

The Advanced Math for Engineering and Science curriculum is being created using an analytic geometry base. The content, however, stretches past analytic geometry in order to integrate seamlessly with other engineering and science topics as well as topics in liberal arts disciplines.

Analytic geometry was chosen as the base due to the widespread use of representing geometric models in an algebraic form in order to solve engineering and science related problems. Evidence of this can be found in entry level engineering classes. For example, in the Statics and Mechanics of Materials text book by Riley, Sturges, and Morris, the first 70 pages are devoted to topics such as vectors, free body diagrams, and finding rectangular components in more than one dimension [4]. Another example of this can be found in "Engineering Dynamics" by Kasdin and Paley. Four out of the five major parts of this text are titled, "Particle Dynamics in the Plane," "Planar Motion of a Multiparticle System," "Relative Motion and Rigid-Body Dynamics in Two Dimensions," and "Dynamics in Three Dimensions" [5]. All of these are titles that suggest the student should be highly competent of coordinate systems and comfortable with switching between a coordinate system and the algebraic representation of the figures in that coordinate system.

The incorporation of other disciplines in AMES provides a new aspect to mathematics in the high school classroom. An example of this integration is that students will be required to learn the history of the mathematics they are studying throughout the course. They will be required to keep a timeline that includes major historical events, such as the opening of certain trade routes and notable national and international conflicts. The purpose of this is for students to provide a context for the discovery of new mathematics ideas and when these ideas were first studied. Another example of this multidisciplinary approach is a lesson devoted to applying mathematics to governing laws through axiomatic methods. The purpose of this is for students to apply higher level mathematics concepts to tangible ideas and practical scenarios.

III. Curriculum Content

Studies have shown that post-secondary freshmen and sophomore students lack essential mathematics skills required

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in engineering and science courses [6]. For example, in a study done by Aung, Underdown, and Qian, freshmen and sophomore engineering students received low scores when quizzed on the equation of a line, finding the dot product of two vectors, and working with matrices [7]. Because of this, the designers decided to include three essential threads: Coordinate Systems; Vectors, Matrices, and Axiomatic Methods; and Conic Sections. Each thread is composed of multiple units (e.g., Cartesian coordinates or polar coordinates), and each unit is composed of various lessons relating to the topic of the unit. Lessons include items consisting of the lesson notes, research assignments, the historical construction of mathematics, hands-on projects, and supplementary exercises intended to be used at the teachers' discretion.

More specifically, the mathematics content includes but is not limited to the following:

- Cartesian/Rectangular Coordinates
- Polar Coordinates
- The Imaginary Plane
- Three Dimensional Space
- Vectors
- Matrices
- Axiomatic Methods
- Conic Sections

Although several sections cover topics students may have already discussed in the past, the curriculum takes a different approach, or point of view, to the learning process. For example, in the unit on polar coordinates, students are required to derive the sine and cosine values of the special angles given a pair of sine and cosine values of one angle instead of being given a completed unit circle with each sine and cosine value previously computed. This will allow the students to practice pattern recognition, a fundamental concept in mathematics.

In some lessons the students are required to research various mathematicians and the history/creation of mathematics topics and present their findings. The purpose of this is to have students discover how the mathematics of the past developed over time into the mathematics used today. By doing this, students are also taught to communicate the mathematics they are learning in a variety of ways such as papers, presentations, and informally through group work.

Lastly, the students are required to complete hands-on projects that allow them to see where the mathematics occurs outside of the classroom. This project-driven approach in AMES curriculum allows the students to focus more on the mathematics being taught instead of the project being completed [8]. For example, the students will create a tension mechanism and study the forces in the system while studying vectors and vector components. While it is fun for the students to construct the mechanism, they will spend more time drawing free body diagrams, calculating tension, and finding vector components when various weights are applied to the system.

IV. Integration of Other Curricula

NICERC has previously developed its Physics curriculum and Cyber Science curriculum. While developing the AMES curriculum, NICERC is also developing a middle school course, STEM Explore, Discover, Apply (STEM EDA). Since mathematics is not a topic that exists alone, the developers of these curricula are integrating each previously developed course with AMES. This integration will provide connections for the students who are simultaneously taking or have previously taken these courses and provide potential research opportunities. Although these courses can be used to build upon each other, AMES could function as a stand-alone course as well. Also, in order to meet the changing standards, Common Core State Standards (CCSS) will be used throughout the course.

The Physics curriculum takes a project-driven approach to teach electricity and magnetism, work and mechanics, waves and sound, light and optics, and thermal fluids. The AMES curriculum will integrate with the Physics curriculum by focusing on the mathematics fundamentals used in Physics. This will allow students to deepen their understanding of the underlying principles that describe the physics phenomena being studied. The desired outcome is that students will enter college feeling comfortable about the mathematics used in the physics topics listed above.

The Cyber Science curriculum teaches cyber concepts and fundamentals to high school sophomores and juniors. In order to do this, the students use a robotics platform and conduct ethical and historical discussions about cyber. The AMES curriculum expands upon the skills Cyber Science students developed holding ethical and historical discussions and focuses them on mathematics. This allows students previously enrolled in Cyber Science to continue to develop their technical communication skills. Where applicable, the same robotics platform will be used to teach the application of mathematics topics included in AMES.

The STEM EDA course focuses on using the engineering design process as a guide for engaging middle school students in STEM. AMES will take the engineering design process and apply it to mathematics with the intent of showing how the engineering design process can be used in various disciplines, showcasing the interconnectivity of these disciplines, and reinforcing the engineering concepts they have previously learned.

As it is pertinent to new curricula, AMES will meet several of the standards set forth by the Common Core State Standards. Keeping in mind that many of the topics covered in AMES are more advanced than the topics covered in the CCSS, several of the lessons will exceed CCSS for mathematics. Also, since several topics students have previously learned are covered in more depth, AMES contains a cross course overlap of CCSS. Furthermore, there will be several lessons that will satisfy many of the CCSS for English Language Arts for 11th and 12th grade since the students will be constructing content specific documents throughout the AMES curriculum [9].

V. PROFESSIONAL DEVELOPMENT

Often, teachers are given little to no training with unfamiliar curricula they are required to teach. Similarly, teachers typically do not have the opportunity to provide feedback on the curricula. AMES will provide teachers with professional development training that allows them to become familiar with and provide input on the curriculum. The professional development is immersive in the sense that the teachers can learn about the content from a student's point of view. Also, after the professional development workshops and throughout the year, the teachers will be asked to provide feedback on the curriculum in order to make improvements. Furthermore, the professional development provides an overflow of information to allow the teachers to learn the structure and content of the curriculum deeply. Finally, during the professional development workshop, teachers will be given all the physical and cognitive tools needed to teach the course.

VI. CONCLUSION

Since the Advanced Math for Engineering and Science curriculum is still in development, the various aspects mentioned in this work are subject to change between now and the piloting of the course. The first professional development workshop will occur during the summer of 2013. The course will then be piloted at the schools that have teachers participating in the summer workshop.

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What is the Role of MOOCs in Engineering Education?

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***Abstract*—This paper is a description of the FIE workshop on the role of MOOCs in undergraduate engineering education.**

Keywords—MOOCs, undergraduate engineering education

PANEL DESCRIPTION

MOOCs (Massive Open Online Courses) are a recent phenomenon that, some believe, will transform higher education. With their low cost and potential to reach a large number of students, MOOCs have the potential to broaden access to education at all levels. The capabilities of the technology and its widespread distribution make interactive online learning possible at any time, in any place, at any pace. MOOCs have infiltrated higher education at such a rapid pace that there has been little time for large groups of educators to have meaningful discussions about how MOOCs can be leveraged to support student learning. This special session is designed to meet this need.

There are two main goals of this interactive session. The first is to bring together a panel of diverse experts and engineering educators to provide an opportunity for them to exchange ideas about the potential of MOOCs to transform engineering education. A second goal is to initiate the build of a community of engineering educators interested in MOOCs, and identify a set of research questions regarding MOOCs and student learning. In light of these goals, the intended audience for this session is engineering faculty interested in learning about and using MOOCs.

This interactive session will have two main parts: panelist presentation and discussion; and alternating small-group and large-group discussions. The panelist will present and discuss during the first 40 minutes of the session, and the remaining 50 minutes will be spent in alternating small-group and large-group discussions (i.e., approximately 10 minutes in small group discussions answering a question, then 5 minutes to discuss as large group; then repeat until the 50 minutes is complete). Three experts from different perspectives will be on the panel: a Learning Scientist that studies STEM learning in online contexts, and two NSF Grantees/Engineering Educators using MOOCs in their course and/or other pedagogical approaches that involve online learning.

Essentially, the panelists will be asked to respond to two main questions: 1) What potential do MOOCs have for improving student learning in engineering? 2) What research do we need to do on MOOCs to make further gains in student learning? After the panel of experts shares their responses, the participants will be given an opportunity to respond to similar questions as part of small-group discussions with their colleagues. The insights from each group will be documented, synthesized, and summarized in a report that will be written after the conference. This pilot workshop is the first of a series of workshops that will take place at engineering conferences to build a community of engineering educators interested in MOOCs.

The expected outcomes or future work as a result of this session include a report to the National Science Foundation that summarizes highlights from the presentation and group discussion, along with a charge for the next series of panels at other engineering education conferences. This will be a public report that will be made available to the session participants and the general public within a month after the session. Another outcome of this session is the creation of a listserv that will be used to capture the initial interest of engineering faculty interested in MOOCs, and to distribute information (including a copy of the report provided to NSF).

This session is the beginning of an effort to develop a community of practice that will interact after the conference. It brings together experts both within and outside of engineering to share ideas that engineering educators should be thinking about as we identify ways to leverage MOOCs in engineering education.

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Defining and Assessing Engineering Ethics

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***Abstract*— The motivation of the special session was to allow engineering educators and researchers to experience two different instruments intended to assess ethical reasoning--one which measures general moral reasoning, and one that is situated in the engineering context—so they can identify the knowledge, skills, and attitudes that are specific to engineering. This will inform how we teach and assess engineering ethics, and equip educators with tools for using these instruments as part of the student learning. The special session format will allow for discussion and debate on the relevance of the approach and appropriateness for our own classrooms.**

Keywords— engineering ethics; moral reasoning; assessment

I. Goals and Outcomes of the Special Session

The primary goal of this special session is facilitate a conversation around different approaches to defining and assessing engineering ethics. An expected outcome of this session will be an increased understanding of what specific knowledge, skills, and attitudes (KSAs) are needed to be able to make ethical decisions within an engineering context, if any, and what assessment tools are available to measure these. This will help educators and researchers develop and assess effective engineering ethics curricula. The discussions will lead to future research collaborations.

II. Special Session Description

A. Session Content

The need for understanding and enhancing engineering students' ethical development has been the subject of numerous publications and has been embedded in ABET criteria. Engineers in today's global society are interacting with ever more of the world's peoples and cultures. These interactions are introducing greater social and ethical complexity to the profession than has been incorporated previously and are raising the importance of practicing engineers becoming capable ethical decision makers. As engineering educators, we are responsible for helping to develop these ethical decision-making skills in our students so they might transfer them into practice in the profession. However, to determine whether or not students are developing these skills as would be practiced in engineering, we must be able to assess assessing student's development in ethical decision making within an engineering context.

This interactive session will explore strategies to assess ethical moral reasoning in this complex engineering context by participating in both a general instrument of moral reasoning [1-4] as well as in an engineering ethical reasoning instrument [5-6]. The session is designed for participants to experience the assessments and prompt discussion around the assessment tools and relevant questions for our community. What are the important issues that engineers need to consider? What aspects of ethics do we need to be teaching? Do we need our own engineering ethics materials or are more general ethical materials and tools fine?

The session will include a review of the developmental framework which has provided the basis for assessing moral reasoning, a discussion about what knowledge, attitudes, and skills are needed by our graduates, and a brainstorming session for the participants to collectively consider possible future approaches for engineering ethics assessment in education and research contexts. This session will also provide a forum for the active exchange of ideas around the questions mentioned above. The session will help to develop a network of engineering educators concerned with both teaching and research related to engineering ethics.

B. Session Agenda

Time	Cum. Time	Activity
2 min	2	Introduction of the facilitators and the goals of the session
5 min	7	Introduction of participants
18 min	25	Small group: Each small group, organized by tables, will first individually complete a *general* ethics instrument question; then complete the question together as a group; they will additionally reflect on the knowledge, skills, and attitudes (KSAs) which are assessed in the instrument.
10 min	35	Discussion: Small groups will share their experiences taking the instrument individually and as a group, as well as the KSAs assessed by the instrument
18 min	53	Small group: Each small group, organized by tables, will first individually complete an *engineering* ethics instrument question; then complete the question together as a group; they will additionally reflect on the knowledge, skills, and attitudes which are assessed in the instrument.
10 min	63	Discussion: Small groups will share their experiences taking the instrument individually and as a group, as well as the KSAs assessed by the instrument
5 min	68	Presentation of the developmental framework underlying both instruments
10 min	78	Small group: How do we teach ethics in an engineering context versus ethics in general? Is it different? If so, how? Groups will create lists of teaching

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		activities and methodologies for teaching within this context, as well as describe what is unique, if anything, about engineering ethics.
10 min	88	Discussion: Small groups will share their ideas for teaching engineering ethics.
2 min	90	Wrap-up—thank participants for attending the session.

C. Anticipated Audience

The session is designed to reach educators and researchers who are concerned with teaching and measuring ethics in an engineering context.

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Ill-structured problem solving in a workplace simulation environment: challenges of the learning experience and skills developed

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***Abstract*—Engineering workplace problems are complex and ill-structured. Students should be faced with this kind of problems during their studies in order to be better prepared for the workplace. However, there is still little evidence on the strategies to support students' learning during workplace problem solving. The general objective of our on-going research is to identify teaching strategies that would best support students in solving ill-structured problems while preparing them to step into the work environment after graduating from the conventional engineering curricula. To this end we designed the professional practice course for final year Information and Communication Technology (ICT) engineering students. Educational principles applied include problem and project based learning, workplace simulation and experiential learning. In this paper we describe the research design that centers on determining the challenges that students perceive during different phases of ill-structured problem solving process, with relationship to their learning styles and skills development.**

Keywords—ill-structured problems; teaching strategies; workplace simulation; engineering practice

I. INTRODUCTION

Engineering practice means solving workplace problems that are complex and ill-structured, and students should be faced with this kind of problem solving during their studies in order to be adequately prepared for the industry [1].

The need for the engineering curricula to comprise training in problem solving and soft skills in order to achieve competencies for engineering practice has been emphasized by professional engineering bodies dedicated to the education and accreditation worldwide (such as ABET, FEANI, IEAust). In Serbia, where the conventional engineering curricula are taught at most universities, this need has been recognized by the academy, industry and students themselves [2].

It has been shown that learning experiences that best support the development of expert professional practice include those where students engage in authentic engineering projects [3]. Providing feedback on the learning processes is crucial for students to understand what they can do well, and what they need to improve. Preparation for future engineering work should also include fostering competencies for problem solving, independent and collaborative learning by using complex ill-structured real world problems in a problem based learning setting [4]. Literature on problem-based and project-based learning is comprehensive (e.g. [5][6]), with abundant examples of implementation practices (e.g. [7]).

However, the research on how to design courses in order to support student engagement and learning during ill-structured problem solving in engineering is still limited [8] [9]. One of the few studies conducted with this objective is a longitudinal study conducted with 130 first-year engineering students [10]. This study identified the most salient out of the set of 6 pre-defined challenges that were experienced by students during design problem solving. These challenges appear as overlapping waves during a design task. Another study investigated students' difficulties in solving ill-structured problems on a smaller scale of 10 students in first-year computer programming course and found that students present difficulties in the interpretation of the problem, formulating questions to enlighten the problem, analyzing the problem constraints and registering effectively the new problem information [11].

Understanding well the issues and challenges during ill-structured problem solving and the pedagogical strategies to deal with them is crucial to producing effective instructional designs for teaching and learning in the context of preparing students for the workplace. In order to confirm issues identified in previous studies, and to further explore them in the context of workplace problem solving we designed and implemented

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the Project planning and organization in engineering practice course at the School of Electrical Engineering of the University of Belgrade. The general objective of our research is to identify best teaching strategies to prepare students to enter the work environment immediately after graduating from the conventional engineering curricula.

For our research we chose the action research approach as an active investigative method which enables its participants to take part in a dynamic educational process, with the aim of strategic improvement of practice [12]. In the iterative process we focus on collecting evidence about the extent to which the practice is consistent with the pedagogical aims, identify inconsistencies between the aims and the practice and reframe both the research and practice for the next research cycle. Action research thus integrates research and practice into one process by generating and testing new forms of action and reflexively guiding the pedagogical enquiry.

In the first phase of our research we identified major challenges that students encounter during the problem solving process and opportunities students perceive as a result of this learning experience [13]. The challenges found included: a) where do I start? Defining the ill-structured problem; b) learning to ask questions in requirements gathering; c) connecting theory and practice; d) self-guided study and information gathering; e) facing the reality: site survey; f) dealing with ambiguity; g) dealing with constraints and trade-offs; h) learning to communicate clearly; i) dealing with failure. The findings of the first phase were based on the qualitative data collected during three ten-week courses with participation of 46 final year telecommunications engineering students. As a result of the first phase of our research some questions were raised that we intend to explore in the next phases of the research.

In this article we present the research design for the second phase of our action research that centers on examining main challenges that mark different phases of ill-structured problem solving process, and the corresponding skills development as perceived by students. We also examine any relationship they may have to the students' learning styles.

II. DESCRIPTION OF THE LEARNING ENVIRONMENT

The Project planning and organization in engineering practice course is designed in such a way to resemble the real-world situations that are particularly found in small and medium enterprises (SME) where an engineer is often required to combine the roles of a system designer and project manager in different phases of the product or service development. Course objectives include experiencing and fostering processes of project planning, organization and basic systems engineering design, while developing problem solving, teamwork, communication, presentation and idea generation skills.

Educational principles applied include problem-based and project-based learning, with an emphasis on constructivist approach to learning [14] and experiential learning inspired by Kolb [15]. The simplified reality of the workplace and its essential functions are represented through a role-play simulation.

Kolb's experiential learning theory emphasizes the central role that experience plays in the learning process, claiming that knowledge is created through the transformation of experience [15]. According to this theory, learners need four abilities for effective learning: a) concrete experience, b) reflective observation, c) abstract conceptualization, and d) active experimentation. On this basis Kolb identified four prevalent types of learning styles that can be determined using Kolb Learning Styles Inventory (LSI) and that can determine the ways students respond to different teaching strategies.

Role play simulation is an effective technique that facilitates teaching and learning of professional skills supporting the process of preparing engineering students for entering the industry [16].

In our student-centered approach the instructor (the first author) is a facilitator of learning, she works with students on the creation and development of knowledge and skills, guides and stimulates discussion and monitors group processes. The emphasis is not on teaching content, but on guiding students in their experience of "how to work". The students own the problem; they find solutions by themselves with minimal help but with an always present and supportive instructor. In the role play the instructor takes the roles of client, boss, sub-contractors or any other third party that needs to be covered. Real suppliers are contacted throughout the course but in the absence of their feedback the instructor takes their role too.

The course is organized in three- and four-hour classes and lasts a total of 80 hours. Students are divided in teams of 3-5 to work on a project with the task of presenting a wireless system proposal in response to a tender, including preliminary design of the system, detailed project plan and final budget for design, supply, installation and commissioning of the system.

III. RESEARCH DESIGN

Based on the first phase of our research, following research objectives were identified for the second phase of our the study: (1) to explore what are the challenges that students perceive as the most important during different phases of the ill-structured problem solving process; (2) to examine students' perceptions on the skills that they develop in different phases of the learning experience; (3) to determine if their skills development and challenges perception are related to their learning styles (4) to re-define teaching strategies based on the results (1-3).

The participants of the second phase will be15 to 20 final year students in the summer semester 2012/2013.

The research is a mixed-method research. It combines qualitative and quantitative research as defined by Creswell and described in [17] where qualitative and quantitative data are collected concurrently or sequentially, are given a priority, and involve the integration of the data at one or more stages in the process of research.

We shall use some of the instruments from the first phase of the study: protocols for structured participant observation, open-ended questionnaires, scaled-type surveys for overall skills development and Kolb LSI for learning styles. Additional instruments that are created for this phase include challenges and skills lists that were developed based on the results of the first phase of the research and tested in the pilot study [13]. Students will be asked to fill in their perception of the major challenges and levels of skills development in the challenges and skills lists that they will fill in every two classes (corresponding to 7-8 hours of project work). In the challenges list students will select and prioritize (from 1 to 5) five greatest challenges that they faced in the previous period. Skills list is a scaled list where they will select the level (from 1 to 10) of their skills development in the same period.

Collected data will be analyzed applying qualitative and quantitative data analysis. Qualitative analysis will include analysis of the open-ended questionnaires and participant observation protocols filled in during field work. Quantitative analysis will include analysis of the scaled type surveys, Kolb LSI and challenges and skills lists.

IV. EXPECTED RESULTS

With this study we hope to contribute to the research on how to support students during ill-structured problem solving process, that has been called for in the literature and on previous FIE Conferences [8][9]. Our goal is to determine major challenges students perceive during ill-structured workplace problem solving and corresponding skills that students develop. We hope to obtain results that could inform future research regarding the relationship between students' learning styles and challenges students encounter or skills they develop in the problem solving process, with the general objective of defining teaching strategies that would best support students while preparing them for engineering practice.

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Information and Communication Technologies literacy from engineering students at the University of Buenos Aires.

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***Abstract*— A survey concerning literacy in Information and Communication Technology (ICT) was held at the School of Engineers of the University of Buenos Aires. The overall aim was to state if ICT literacy could be considered as an existing background among our student population. In addition we wanted to identify possible environments where students and faculty can interact and learning is possible. Building such environments is highly dependent on previous experience of students to ICT and its breadth of use. In this work we detail the survey results, draw some conclusions and outline some considerations on how to deal with ICT in the classroom.**

Keywords—ICT Literacy, freshmen, computer in the classroom, background skills

I. Introduction

In his work "Teaching Digital Natives: Partnering for Real Learning" [1] Prensky states that "... *students who don't concentrate in school will sit for hours ... totally focused in movies or video games*". He concludes that students' tolerances and needs have changed learning to focus only on what interests them. The author characterizes these young people as *deeply and permanently technologically enhanced* and labels their generation as Digital Natives, and endorses today´s teachers as Digital Immigrants.

Prensky's concepts of Digital Natives and Digital Immigrants and the classification according to the age has and is been challenged by solid research data [2,3]. However it remains clear that the use of Information and Communication Technologies (ICT's) will influence the way these students learn. A simple example is that, being our students commuters, chat-rooms eases a lot team meetings when some teamwork must be done.

Supporters of this digital native/immigrant distinction tend to assign broad characteristics (e.g. a specific learning style, amount and type of technology used and/or a set of learning preferences) to an entire generation and suggest all young people are expert with technology. The date of the beginning of this generation seems to vary from 1980 to the late 90's according to the availability of ICT's in the population under study.

However, while the proportion of young people who use the Internet and other new technologies is higher than the older population there are significant differences in how and why young people use these new technologies and how effectively they use them [4] Also, the complexity and diversity of use of new technologies by young people tends to be ignored or minimized in many arguments in support of the digital native thesis.

In the University of Buenos Aires, the School of Engineers Faculty attitude towards ICT varies. Some argue that, as with proficiency in English, ICT literacy is a skill we shall ask them to manage but do not have to teach. English as a foreign language is offered free of charge in six levels for all students, along with a set of other languages. The Engineering curriculum asks for a level in English and the Language departments is responsible for the testing, but no course is mandatory. These faculty members expect that non -specific ICT's should be dealt with in the same way.

On the other hand, some Faculty members believe that special time must be allotted in Lab to teach the use of general ICT that can support the academic life. These ICT include social networking. However they understand that teaching tools is not the aim of their courses and that can be a controversial task. Advanced students might get bored and lose interest while other may get stuck in syntactical (surface) detail not grasping the purpose of the tool.

There is a third group that believes that the familiarity with ICT's is related to the field discipline (majoring) our students choose. These faculty members propose to deal different with students whose majoring is related to ICT (Computer, Software and Electronics Engineers).

Our institution decided to offer grants in using ICT's in the classroom, and we applied and obtained one aiming to foster ICT in the engineering courses. It is related to general ICT tools such as social networking, simulations, group-work and personal technology; not to specific field discipline software such as calculus where the tools are long incorporated in the courses.

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In order to begin the project we decided to learn how familiar our students are with the ICT technology in their academic and social life.

II. The Survey

A. Research Questions

We posed three research questions to be answered with a survey:

1) Can we expect students to learn core ICT skills independent of the curriculum, as is the case with English language?

2) Is there a preference in core ICT tools ready to be integrated in the course to enhance student´s experience?

3) Is there any difference in ICT literacy according to the majoring our students choose?

Answering these questions will provide us an overview on the approach our students have to the ICTs. This overview will allow us to prepare a plan for integrating ITCs in the courses, beyond the standard use of course related tools

B. Data collection Methodology

The data was collected using an on-line questionnaire during the first term of 2012. It was hosted on a free server dedicated to surveys. Students completed the survey during a 30 minutes period in their Lab course time. After completing the surveys the normal activity was resumed and 20 minutes before the end we held a group interview addressing the survey. Our aim was to learn how the student understood the different survey questions in order to aid us in the data interpretation.

The survey was anonymous and the only the age and course was mandatory information. The students were able to skip questions at will.

The survey comprised four sections

1) Personal details: gender, age, course, Internet access at the place of residence; working hours, Internet access at the place of work, types of devices owned and used regularly.

2) Technology formally used on the courses: including tools that are part of the institutional online campus (moodle) and other tools and systems either personal (e.g. laptop, media player, etc) or are openly available online (e.g. Wikipedia, social networking sites, etc.).

3) Technology used for learning but that is not formally required

4) Technology used for recreational purposes.

Course's faculty worked with us in the survey and interpreting the results. We knew in advance the technology required in their course asked in section 2. However the answers from the corresponding section differed with the reality. This discrepancy was addressed in group interviews and provides a cue on the perception students have of the class or the way they answer to survey questions.

III. Survey Results, Personal Data

A. Demographic data

The survey was responded by 337 students of the School of Engineers of the University of Buenos Aires. Ages range from 18 to 48 (303 students chose to answer) from 18 to 48 with an average of 22.1 and a SD of 4; 39 students were over 30. There were 225 male and 82 female students with similar average age.

We divided the students in two groups according to their field of study: those who pursued engineering field disciplines non related to ICT (Information and Communications Technology) and those who did (Electronics and Informatics Engineers). There were 74 non-ICT students (53 male and 21 female) and 263 ICT students (202 male and 61 female).

All non-ICT students were sophomore students. The ICT students were a mix of freshmen, sophomore, Junior and Senior.

TABLE I. Demographic Data

	Non-ICT		ICT		All Answers	
Total	74		263		337	
avg(age)	20.4		22.9		22.1	
Male	53	71.6%	202	76.8%	255	75.7%
avg(age)	20.6		22.6		22.2	
Female	21	28.4%	61	23.2%	82	24.2%
avg(age)	20		24.7		23.17	

Internet access at home or place of residence was up to 88.1% with little variation and Internet at work was present in the 95% of the cases. Only 13% declared to have filtered Web access, mostly from educational institutions. For the population under study, Broadband access from 4+ Mb/sec is a commodity.

B. English Knowledge

The question was posed in two terms: "Can you read and understand an English study text?" And "If you answered Yes to the preceding question, do you feel comfortable studying from an English text or do you prefer studying from a text in your native language?".

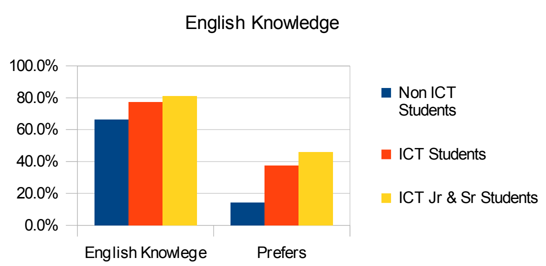

Fig. 2. English as Preferred Language

Of the non-ICT students, a 66% asserted proficient English knowledge but only 14% stated it as the preferred text language. Figures change to 77% for ICT Students and 37% as the language of choice. In the Junior and Senior sub-category 81% declares proficiency and 49% chose the English written texts. Obviously they have already had experience with translation misunderstandings.

C. Devices Owned

As a last Item in the Personal Details section we explored the devices owned and regularly used by the students.

The most popular devices were CellPhones, Computers, Audio & Video equipment (including mp3/4) and Digital Cameras. Smartphones come next with a logical increase of ownership with age (and working status). We detected very few game consoles and tablets and practically no e-readers or portable game consoles. Only 50 of the 337 students (14%) did not declare to have some kind of Personal Computer.

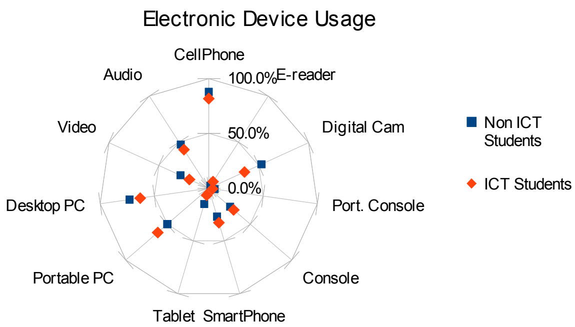

Fig. 2. Student Electronic Device ownership and usage

A networking analysis figure like Figure 2 shows no particular clustering or difference neither between non-ICT and ICT students.

The result raises several questions. We assume they under-reported the gaming devices, which we could not confirm without the interviews. We also suppose there is some serious overlap with the functionalities of the devices, e.g. audio or video players, digital camera and CellPhones. As we were interested in ICT we instructed specifically to take the devices as functions and tally every function they own. In the group interview we discovered that most of the students did not follow these instructions.

IV. Technology Formally Used on the Courses

The students are assisting to courses whose faulty form part of the research group. That means we already knew the answer to this part of the survey. We included it in order to evaluate is students were able to record the kind of tool they were using.

The following tables summarize the answers (ordered by declared use)

TABLE II. MANDATORY TECHNOLOGY USED IN COURSES NON ICT STUDENTS

Item	*n*	*%*
e-Campus	60	81.08%
Course Web Page	54	72.97%
e-mail	54	72.97%
Groups	47	63.51%
Online Reading	41	55.41%
Document Sharing	38	51.35%
Simulations	34	45.95%
Slides	30	40.54%
Animations	30	40.54%
Google	27	36.49%
Video	26	35.14%

TABLE III. MANDATORY TECHNOLOGY USED IN COURSES ICT STUDENTS

Item	*n*	*%*
Course Web Page	177	67.30%
e-mail	171	65.02%
Groups	159	60.46%
e-Campus	156	59.32%
Online Reading	140	53.23%
Slides	124	47.15%
Document Sharing	122	46.39%
Code Share	112	42.59%
Wikipedia	79	30.04%
Simulations	70	26.62%
Video	64	24.33%

There are some problems with these figures. All the courses have a Web Page and every piece of news about the course is published in it. However the fraction of students that answers using the Web Page is less than expected. E-campus use is non- mandatory but all the non-ICT courses used in the survey were using it, again this fact is under-reported. Less than half of the students assert the course uses slides as part of the material for students, and all the courses did. E-mail and groups are overlapped, several students cannot tell apart a mail-group address from a Google or Yahoo group.

Used as a control question, student´s answers allowed us to evaluate the accuracy of the other sections. We have to be cautious with the answers because students do not understand the words we are using or the services we are referring to.

V. Technology Used for Learning, Social Life and Recreation

A. Note taking and Learning.

Students need to take notes. Note taking and reviewing are labeled in the literature as encoding and external storage respectively. Encoding is described as generating a personalized written record of the lecture or the class activity. Storage is keeping this written record during the gap between presentation and evaluation and to use the record for review or study guide [5].

The potential productivity of reviewing notes is limited by the encoding function of the note taker. Students are notoriously incomplete note-takers, generally recording less than 50% of the critical ideas [6] [7]. These facts are addressed by providing students with instructor's notes in the form of course slides. In all the courses we provide the slides in advance of the corresponding lecture. We had some previous experience in researching the way notes were used [8].

We asked students how they used the technology as an aid in taking notes, in class and out of class when preparing to sit for tests.

Results are summarized in Fig 3 and 4

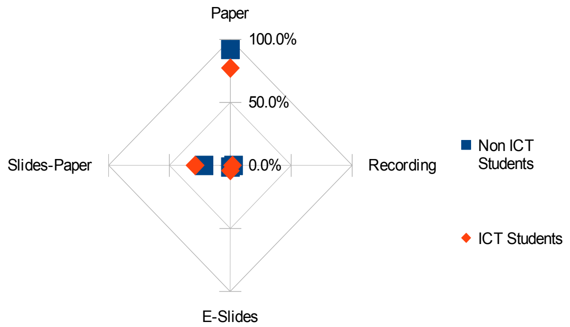

Fig. 3. In class Note Taking

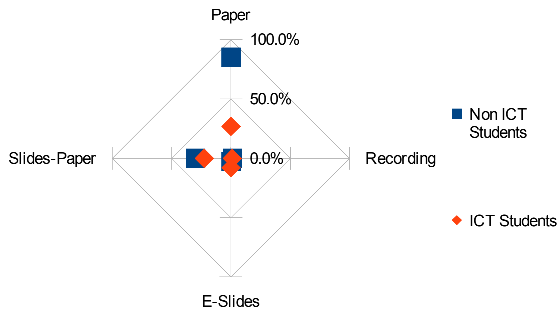

Fig. 4. Note Taking when studying

Slides are clearly under-used, ICT Students use an editor (not necessarily a note taking software) but very few used the e-slide as basis for electronics annotations. They are introduced to this kind of tools in class and teachers use e-annotations in lectures. Also they do not report recording a class. The overall schema seems very traditional and poorly affected by the technology.

When we ask for the most popular ICT aids used in both groups, the same Items appear. The difference in the positions is accounted for a greater heterogeneity of the ICT Students population, in age and courses. Students rely on e-mail as the preferred communication method. SMS are less used as teamwork seems to be done using the ad-hoc software available in the e-campus or general sharing technology such as Google or Yahoo groups, Dropbox or Software Configuration Management (SCM) Tools.

TABLE IV. TECHNOLOGY USED WHEN STUDYING NON ICT STUDENTS

Item	n	%
Course Web Page	55	74.3%
e-Campus	55	74.3%
e-mail	55	74.3%
Online Reading	49	66.2%
Wikipedia	45	60.8%
Google	45	60.8%
Groups	41	55.4%
SMS	41	55.4%
Slides	38	51.4%
Doc Share	38	51.4%

TABLE V. TECHNOLOGY USED WHEN STUDYING ICT STUDENTS

Item	n	%
Course Web Page	166	63.1%
Online Reading	162	61.6%
Wikipedia	153	58.2%
e-mail	144	54.8%
Groups	142	54.0%
Doc Share	138	52.5%
e-Campus	132	50.2%
Code Share	127	48.3%
Slides	116	44.1%
Google	112	42.6%

Simulations and Videos regarded as very helpful by faculty are low in student's use. Students also do not seem to search for similar material at other Universities. It is remarkable because the authors spent a lot of Lab-time showing material from sister institutions, playing with simulations and videos to underline key concepts and using the online backup facilities to recover past classes information.

B. Social life and recreation.

Again students seem here to under-report some activities such as gaming and over-report others such as book reading. They do not specify what they understand as “file sharing” and in the group interview they further refined the activity as “sending interesting stuff”.

A few of the students integrate several activities under a social networking tool such as Facebook. Students regard Facebook as a publishing tool, but when they want something to reach somebody they resort to e-mail or messaging. From interviews with high-school teachers, this trend will change as younger people integrates their messaging in the social networking software.

We did not ask about the legality of downloads or the precedence of the movies or the proper attribution of credits.

TABLE VI. ICT USED IN SOCIAL LIFE AND RECREATION

Item	n	%
E-mail	257	76.26%
Music	247	73.29%
Social Networking	231	68.55%
File Sharing	229	67.95%

Item	n	%
Photo	223	66.17%
Movies	223	66.17%
Books	211	62.61%
Wiki	201	59.64%
Video	195	57.86%
Torrents	160	47.48%
Online Gaming	158	46.88%
Forums	146	43.32%

We found no difference or clustering regarding majors an academic maturity

VI. DISCUSSION

A. General remarks

Some Items such as gaming appear to be under-reported and some such as books are clearly over-reported. We attribute this to a response bias [9] where students responds wishing to please an engineers image of themselves.

English language is perceived as a mandatory skill among students. In the case of ICT students where data form higher courses is gathered, it can be seen that mastery in English increases as they progress in their careers. It is usual for teachers to make students read material in English and the awareness of the importance of the language increases with this practice.

This is not the case with the ICTs. Analyzing the reported data on mandatory technology and comparing it with the technology we know is used in the courses, we found that a lot of technology went unnoticed. In the group interview we could state that students did not identify the used technology with the survey Items.

Sometimes a tool is introduced in class either in an explicit way such as explicit asking Software Configuration Management tools in sophomore year of ICT students or in an indirect way, such as using it in a lecture. Survey data shows that the tool is not integrated into the student baggage of skills. They do not appear using it afterwards unless they are asked to.

B. The Research Questions

For the first research question, *can we expect students to learn core ICT skills independent of the curriculum as is the case with English language?,* our answer is that we cannot rely on external sources to teach technology to our students. We must allot class time to show and explain the use and advantages of the technology, balancing it with the course context. We cannot expect an independent awareness such as we do with English reading proficiency.

Regarding the second question, *is there a preference in core ICT tools ready to be integrated in the course to enhance students experience?,* we did not found any preferred ICT tools which students masters ready to integrate in the teaching and learning process. Students showed experience in browsing, messaging, mailing and file sharing. However this experience has to be enhanced with grouping, virtual meeting and forum participation. Also supporting technologies such as on-line backup and on-line annotations must be shown and used in lectures to help students to incorporate their use.

For the third question: *is there any difference in ICT literacy according to the majoring our students choose?* We found no difference neither among different major's cohorts nor among different stages of their academic career.

The main difficulty with ITC tools seems not to be related to the mastery in the technology but to the approach to the learning experience. Students favor passive technology such as online reading to more active such as the use of simulations to explore possible outcomes. When using ICT as a recreational or social resource students also rely on passive technology and as a way of connecting among themselves. There is little evidence of the use of technology in collective creative way. This is in line with the research data that rejects the notion of Digital Natives [3].

C. ICT Literacy

Literacy has no single or universal definition and its meaning has changed over time from an elementary 'decoding' of written information to a range of more complex and diverse skills and understandings [10].

Literacy tends to be viewed either as an individual attribute or a social practice and is considered a set of practices which have the potential either to empower (by enabling critical analysis) or disempower (by merely reinforcing existing unequal relationships within the community) individuals [11].

In international policy papers referring to ICT three terms are used -skills, competence and literacy-. *Skills* and *competence* are particularly common in the industry, adult education and professional training sectors and are based on step-by-step systematic model of instruction. They emphasizes the achievement of clearly pre-specified and measurable skill levels rather than a broad conceptual understanding of ICT features and its potential in various domains. In contrast, the term *literacy* has become increasingly more accepted because it is perceived as broad and open enough to include a full range of cognitive and non-cognitive human attributes

ICT literacy can be defined as a *transferable set of capacities related to ICT use* [12]. Being 'transferable' points out that ICT literacy is a generic tool that could be applied for a variety of purposes and in a diverse array of situations. ICT literacy includes not only knowledge and instrumental abilities, but also personal and interpersonal attributes, as well as capabilities to apply them in specific contexts.

We collected data about the amount of use of ICT, a more specific survey for ICT literacy has to be done by evaluating problem solving using ICT's. Although students do use the ICT's on a regular basis, our analysis does not support the view that they can be regarded as computer literates.

A UNESCO document [13] referring to a model curriculum of ITCs in secondary schools describes four stages in the way students and teachers learn about and gain confidence in the use of ICT. These four stages are *discovering learning how to use, understanding how and when to use* and *specializing in the use of ICT tools*. From the survey we can conclude that most students are somewhere between discovering and learning how to use the tools.

VII. FUTURE WORK

The partial literacy of students and the disparities of their skills, if not attended to, might seriously compromise some students' ability to succeed. Faculty cannot assume prior knowledge IT skills. The inconsistency in student skills makes it difficult to design effective technology-enhanced instruction.

A first step is to investigate each course needs of ICT and compare the needs with student´s skills periodically. With the surveyed data an action plan to better integrate technology into courses and help students access academic information from their many and diverse devices and platforms must be created.

The plan's goal is to give students different options for interacting with the academic material and with instructors. Blended/hybrid learning environments must be developed to meet students' preferred styles of learning.

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“Unmuddying” Course Content Using Muddiest Point Reflections

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***Abstract*—Class instruction is a living and ever evolving process aimed at providing students with a quality education. Instructors are responsible for analyzing their courses to ensure that delivery of information is effective. Changes made are usually based on student assessments; however, our reactions to assessments are flawed without student insight. One method to obtain student feedback is through muddiest point reflections. This activity asks students to reflect on what was just taught allowing students the opportunity to share what was “muddy”. This mixed-methods study provides vignettes from faculty members on their use of muddiest point reflections and an assessment of what value students associate with such an intervention. Faculty members who have used this approach say it drives change within their classes. The analysis of student value beliefs revealed muddiest point reflections as an intervention that positively impacts interest, attainment, and utility value without negative cost. The appeal of muddiest points was also evident with 77% of students hoping to see muddiest point reflections in another class and 93% agreeing to recommend their course experience to a friend. These findings suggest that students agree more than disagree that muddiest point reflections are a valuable addition to their educational experience.**

Keywords – muddiest point reflection, curricular change, formative feedback, associated value

I. INTRODUCTION

One of the primary roles of faculty is the responsibility to teach students. Additional responsibilities can sometimes diminish the priority level placed on teaching, which in turn prevents many faculty members from putting in the necessary time to evolve their teaching practices. Preparing courses, especially those taught year after year, can eventually lead faculty to fall into the trap of simply using notes or slides from past years to save time. This approach may save time, but fails to meet the changing needs of our students who have high expectations from their instructors.

One very simple method to improve teaching is to employ *muddiest point reflections*. Muddiest point reflections involve simply asking students to anonymously reflect on what was “muddy”, i.e. confusing, during class and to rank their level of confusion. Reflection can occur by providing students with a document to record difficulties throughout the class or by dedicating five minutes at the end of class. This intervention provides an opportunity for students to reflect in a way that is beneficial for both them and instructors; students reflect on what they understood from the class, while instructors obtain valuable insights into what was confusing for students. This direct feedback allows instructors to instantly reflect on how well they taught the course content and how they may change their delivery or pedagogical approach next time. Additionally, taking five minutes of time at the beginning of the next class meeting provides instructors with an opportunity to cover the material again in an effort to address student concerns and misconceptions. This short, noninvasive effort not only addresses students falling behind, but also shows students a commitment to their education especially when the instructor puts direct student quotes on the screen. In effect, the “muddiest point” technique establishes a critical student/instructor dialogue.

The following study reports the use of muddiest point reflections in three material science and manufacturing courses. These reflections have revealed many confusing topics such as secondary bonding, Miller indices, and eutectic phase diagrams to name a few. Emerging muddiest point topics have led to various changes in the course content and delivery for these instructors as well as increased interest from other faculty members. Specific efforts undertaken by these three instructors include creating YouTube Muddiest Point video tutorials, building a FAQ resources website, implementing preview problems based on the next class’s content, and embedding active student-centered pedagogical approaches. These efforts have shown dividends in a short

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period of time as demonstrated by the over 33,000 hits in less than seven months for the twelve video tutorials posted and the 93% of students who indicated the videos supporting their learning.

The goal of this paper is to share instructor experiences with muddiest points focusing on how these reflections have impacted their courses. Additionally, this paper will investigate the following research question:

What value do students place on muddiest point reflections?

II. Background

A. What are Muddiest Point Reflections?

"Muddiest points" are unclear concepts generated by students. In 1988, Frederick Mosteller first implemented muddiest points through the solicitation of responses to the following three questions: 1) What was the most important point in lecture?, 2) What was the muddiest?, and 3) What would you like to hear more about? After analyzing the student comments, Mosteller addressed issues using both class time and handouts. Anecdotally, Mosteller stated that although this activity required class time, the students enjoyed the exercise and he was able to modify 15% of his class behavior [1, 2]. Also in 1988, Angelo and Cross highlighted "muddiest points" as a subsection of one of thirty classroom assessment technique classifications [3]. It has been suggested that the collection of most interesting points is a beneficial addition to balance perceived negativity by focusing only on muddiest points [4]. In summary, the seminal publications of Mosteller, Angelo, and Cross launched the widespread, but under-analyzed, use of "muddiest points" today.

B. Motivation for using Muddiest Points

The use of muddiest points is evident by the over 8,200 hits revealed when searching Google Scholar. The success of "muddiest points" is due in part to its ease-of-use and large impact. Muddiest point requires very little time and minimal change to the syllabus. It allows students to reflect, retain, synthesize and build knowledge. Muddiest points not only benefits students but faculty as well. It allows faculty to more effectively question students, assess their difficulties, identify next steps, and help modify lectures for future semesters [5].

C. How to Collect Muddiest Points

Muddiest points may be implemented through a few simple steps, outlined by several groups [5-7]. First, instructors should hand out muddiest point sheets/cards at the beginning of class and remind students to begin filling them out, anonymously, 15 minutes before the end of class. Instructors should then collect and record responses (in an Excel spreadsheet, for example). The responses must then be analyzed so the instructor can identify the most relevant issues requiring a strategized response. We are proponents for use of direct quotes when responding to student misconceptions as "student voice" strengthens student-instructor interactions[8].

D. Cyber Implementation of Muddiest Points

The original method of collecting muddiest points used blank index cards [5]. Today, there are many media that can be utilized to collect muddiest points. For this study, researchers used custom forms requesting both muddiest and interesting points which facilitated the use of student quotes when responding. Alternatively, others used in-class clickers and online multiple-choice forms with generalized topics as choices to quickly and quantitatively assess the muddiest points [9, 10]. Similarly, there are many options for responding to muddiest points including the creation of screencasts and podcasts [10-12].

E. Impact of Muddiest Points

Although the use of "muddiest points" is widespread, limited work has been done to determine the student value of this exercise. King determined that the "muddiest points" technique was favored by the majority of the students as demonstrated by their response rate. More specifically, 75% of students that answered other subject-based clicker questions also answered the clicker question on the muddiest point. King's study also uncovered that, although the majority of topics were conceptual, the majority of students had trouble with quantification [9]. Pinder-Grover, et al. showed that final grade correlated with frequency of use of muddiest point screencasts [10]. Here, we hope to further characterize the impact of "muddiest points" on engineering students by examining the efficacy of determining its value and cost to students.

Our efforts are supported by expectancy-value theory and the significant body of work indicating that the value of learning a specific domain predict the amount of effort they will put into learning and the quality of that learning [13-17]. Expectancy-value theory states that associated value is determined by the level of interest, capability of attainment, utility toward goals, and cost associated with a given activity. Research has clearly demonstrated that college student' effort and achievement are influenced by the connections they make between the content of their courses and their personal futures [18, 19]. Belief about the utility of learning activities for achieving future goals is called *Perceptions of Instrumentality.* If students believe that mastering the content of their coursework is important for their future, then they will be more willing to put forth effort. Students who are interested in the short-term value of what they are learning are more likely to use learning strategies that facilitate quick learning, rather than deep understanding. Students will also expend less effort trying to master the tasks at hand [20].

III. Methods

The following mixed methods study is broken up into two distinct components. First, we include three vignettes by instructors discussing the impact and perception of muddiest points from the their perspective. Second, we surveyed students in the three instructors' courses to assess their perceptions of associated value toward muddiest point reflections.

A. Instructor Sample

The instructors include three faculty members teaching materials science and/or manufacturing courses in three different engineering degree programs. Each faculty has utilized muddiest point reflections for a minimum of two semesters as a way to impact change within their class.

B. Student Sample

Our student sample included 109 students enrolled in the three material science and manufacturing courses described in the faculty vignettes. Students ranged from sophomores to seniors across various engineering majors.

C. Instrument Design

An instrument was created for this study to investigate student beliefs towards the value of muddiest point reflections. The developed instrument used three sources to establish items: 1) literature regarding value and motivation [17, 21-28], 2) a value survey previously used to assess grading system beliefs and impact of peer mentoring [29, 30], and 3) an uncharacterized attitudinal survey developed by one of the instructors for his course. The instrument consisted of four broad questions with additional items associated with the first two questions (see Appendix I).

Each item was placed on a 4-point agree-disagree Likert scale (completely agree – agree more than disagree – disagree more than agree – completely disagree). Items included in questions 1 and 2 were derived using the previously described expectancy-value theory. The remaining two questions were included to determine whether students would like to see increased use of muddiest point reflections and if they would recommend the course they are currently taking to a friend.

D. Data Collection and Analysis

The survey was administered by the instructors in their classes; two instructors administered the survey using paper and pencil while the third administered the survey online via Qualtrics©. Student identities were completely anonymous. Each respondent was required to answer all of the questions to complete the survey. The results were tested for validity and reliability using factor analysis and internal consistency (Cronbach's α). Mean score differences were then used to assess the value students believed muddiest point reflections had for their respective courses and future goals.

IV. Results

A. Instructor Vignettes

Through autoethnographies— "studying one's own culture and oneself as part of that culture" [29]—we provide vignettes of three instructor experiences using muddiest points in materials science and/or manufacturing courses.

Vignette 1 – The first vignette looks at a course titled "Structure and Properties of Materials". This course covers the basic concepts of material structure and its relation to properties contextualized by real-world engineering applications. It is a required course for Mechanical, Industrial, and Materials Engineering majors usually taken freshmen/sophomore year.

"Initially, when I started to use 'muddiest points', the goal was to elicit confusing concepts from students in order to respond to them; however, over six semesters, the 'muddiest point' strategy has evolved into much more than responding to student issues. It opened a channel of communication and mutual trust between the students and me, which turned an instructor's monologue into a student-instructor dialogue. As such, the interaction enhanced the student learning experience as well as the teacher's instructional experience. Much more than 'muddiest points' are elicited from comments including alternate conceptions, vocabulary issues, rushed teaching, bad handwriting, questions of curiosity, and comments on related student experiences. Students can reflect on their learning over a class as well as discover the issues their fellow students are struggling with. With student 'muddiest point' input, improved teaching strategies can help diminish previously difficult conceptions. Overall, 'muddiest points' enhances both student and teacher metacognition about learning and instruction, respectively."

Vignette 2 – The second vignette looks at a course titled "Engineering Materials and Manufacturing". This course is a required fundamental sophomore course taken by students enrolled in a Bachelor's of Science in Engineering program. The course covers the characterization, structure, and properties of materials, manufacturing processes, engineering metrology, quality assurance, and cost modeling.

"My foray into using muddiest point reflections began when a colleague suggested the tool as a method to engage students. After two semesters of using muddiest point reflections, I've come to the realization that the tool provides mutual gains for both my students and me. Muddy points revealed in my first semester have led me to make changes not only during the current semester, but beyond to the following year. The knowledge gained from my students has encouraged me to try new approaches including video tutorials, jigsaw activities, and in-class activities. As a professor, I like to believe that I can generally tell when something isn't clear. Muddiest points is the tool that helps confirm or deny my intuitions"

Vignette 3 – The third vignette looks at a course titled "Modern Engineering Materials". This course covers the role of materials in engineering, properties of materials, nonferrous and ferrous systems and applications, heat treatment and strengthening mechanisms, various polymeric, ceramic, composite materials biomaterials and their applications, failure theories, characterization, corrosion and environmental issues, and project work involving selection and design with various material systems.

"Working with a close colleague, I was encouraged to try addressing the current needs of students by using their own strengths and weaknesses. The 'muddiest points' technique is a form of Just-in-Time Teaching (JITT) that I find is much less intimidating than traditional JITT. The entire lecture is not modified to suit the previous students' comments but the

students do feel they are a part of the process when their own words are used to clear up muddy points. Students are made a part of the learning team; they are the players and the faculty member is the coach unlike in a traditional classroom when the faculty is a performer on stage and the students are mere audience members."

B. Value Survey Validity and Reliability

The survey was first tested for validity and reliability. Factor analysis revealed three factors with weights ranging from 0.710 to 0.890 (Table I).

TABLE I. FACTOR ANALYSIS

Item	Factor 1	Factor 2	Factor 3
1a	0.749		
1b			0.869
1c	0.783		
1d	0.721		
1e			0.832
1f			0.890
1g	0.779		
2a		0.710	
2b		0.785	
2c		0.858	
2d		0.847	
2e		0.861	

Expectancy-value theory was used as a means to obtain construct validity. The construct of value described in the theory was tied to each of the three factors: Factor 1 – Intrinsic & Attainment Value; Factor 2 – Utility Value; and Factor 3 – Cost. Factor 1 included both intrinsic and attainment value as suggested by previous research using similar surveys [17, 18].

C. Associated Value of Muddiest Points

The data from the validated instrument was then used to assess student beliefs pertaining to the value of muddiest point reflections. To simplify the presentation of the results, *agree* and *agree more than disagree* responses as well as *disagree* and *disagree more than agree* responses were separately pooled together and presented as percentages (see Tables II – IV).

1) Interest/Attainment Value: Interest or intrinsic value is an individual's anticipated enjoyment of engaging in a particular activity. Related to interest value is attainment value or an individual's perception of how the activity contributes to the conception of who he or she is fundamentally. Results suggested that the majority of students found muddiest point reflection to positively impact their experience in the class.

TABLE II. INTEREST/ATTAINMENT VALUE RESULTS

Interest/Attainment Value	Agree	Disagree
motivated me to do well in the course	62%	38%
was an effective way to increase my engagement in the course	81%	18%
helped me better understand my own personal learning	71%	29%
increased my level of responsibility	64%	36%

2) Utility Value: Utility value is an individual's perception of the advantages that result from engaging in the task for future goals or rewards. Results suggest that students overwhelming found the material learned in their course to be of value to them in their current and future endeavors as learners and professionals.

TABLE III. UTILITY VALUE RESULTS

Utility Value	Agree	Disagree
will be of value to me after graduation	83%	17%
was useful in my pursuit of my career and/or graduate school goals	79%	20%
helped me see the relevance of engineering to the real world	89%	11%
helped me learn the importance of materials science to engineering	94%	6%
helped me learn the importance of manufacturing to engineering	90%	10%

3) Cost: Cost represents an individual's perception of the sacrifices required, including effort, time, and psychological impact, for successful impact of an activity. Results suggest that students did not find muddiest point reflections to be a frustrating activity that took too much time and effort.

TABLE IV. COST RESULTS

Cost	Agree	Disagree
required too much effort	17%	83%
made me frustrated and anxious	11%	89%
required too much time	14%	86%

4) Appeal: The final two questions pertained to the students' desire to see muddiest point reflection used in other courses as well as whether they would recommend a course with this muddiest point reflections to a friend. The majority of students (77%) agreed that they would like to see this tool used in their other courses, while overwhelmingly (93%) recommending the course to a friend. This final result is likely impacted by more than just the muddiest point reflections including the course content and the instructors themselves.

V. DISCUSSION

The use of muddiest point reflections is a simple intervention capable of major impact on the delivery of course content. The benefit to such formative feedback is the associated gain for both instructors and students. The instructor vignettes frame muddiest point reflections as a catalyst for change in pedagogical practice. The vignettes report muddiest points providing a "channel of communication and mutual trust" with the students. That channel provides a way for students and instructors to have a dialogue between one another, in turn restructuring the course from teacher as "performer" to teacher as "coach". This role change allows students to voice their opinions as a means to impact course content delivery. Instructors can then use student opinions to "confirm or deny intuitions" about what is being assumed to need changing.

From a student perspective, the survey revealed overwhelmingly positive value associated by students toward the muddiest point reflections. Students saw this opportunity as a way to positively impact interest, attainment, and utility value without too much negatively associated cost. Such results suggest that students found muddiest point reflections to improve the course in a way that made the course more enjoyable and valuable. This increase in value resulted in high appeal for the course by students and a likelihood of recommending the course to a friend. While this final result is likely impacted by the course content and the instructors themselves, the instructors can still appreciate that students view using such activities as a means to obtain positive student reviews.

VI. Concluding Remarks

Our initial research demonstrated that reflections have affected pedagogical changes in the classroom. Students found interest, attainment, and utility value in muddiest point reflections, while not costing them too much time and effort.

Our future work will focus on better quantifying improved student enrollment, achievement, and attitude due to implementation of muddiest points. Further, our continued goal with this research-to-practice effort is to bring greater awareness of muddiest point reflections to STEM faculty in an effort to continuously improve higher education.

Acknowledgments

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APPENDIX I: STUDENT VALUE OF MUDDIEST POINT REFLECTIONS SURVEY

Directions: Please read each of the following statements and indicate your level of agreement based on your class experience. Do NOT choose multiple letters for one question (Ex. B/C).

A: completely agree   B: agree more than disagree   C: disagree more than agree   D: completely disagree

1. The "muddiest points" daily reflections used in this course…

   a. motivated me to do well in the course. _____

   b. required too much effort. _____

   c. was an effective way to increase my engagement in the course. _____

   d. helped me better understand my own personal learning. _____

   e. made me frustrated and anxious. _____

   f. required too much time. _____

   g. increased my level of responsibility for my own learning. _____

2. The material learned in this course…

   a. will be of value to me after graduation. _____

   b. was useful in my pursuit of my career and/or graduate school goals. _____

   c. helped me see the relevance of engineering to the real world. _____

   d. helped me learn the importance of materials science to engineering. _____

   e. helped me learn the importance of manufacturing to engineering. _____

3. I would like to see muddiest point reflections used in other courses. _____

4. I would recommend this course to a friend. _____

Learning from Industry by Using an Inquiry Based Learning Approach

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***Abstract*—Inquiry based and constructivist activities can motivate students to take charge of their own learning, understand multiple perspectives and develop high level reasoning skills.**

This paper describes a case study of six year teaching practice in one of our Master courses. The course requires the students to acquire critically analysis, evaluation and research skills. The course also requires the students to acquire the techniques and technologies related to many aspects of an enterprise website. There are only 32 hours for class meetings so the students have to work by themselves in most of the time. The best way to achieve the course requirements is to use the constructivist activities, let the students individually or collaboratively to work with the relevant partners and build the required knowledge and skills gradually. An assignment was developed which requires the students to investigate different aspects of an enterprise website. To complete this assignment, the students need to use an inquiry based learning approach.

The practice is evaluated by using a set of survey data, a set of data observed from the marking reports and the industry feedbacks. The practice is effective, while the practice is improving; the students' abilities of planning, investigating, analyzing, communicating and reflecting are improving as well. The students' contributions are valuable to the industry. The paper also includes a discussion which links the teaching practice with the relevant theories.

Keywords—teaching and learning; inquiry based learning, industry inquiry; website.

I. INTRODUCTION

Inquiry based and constructivist activities can motivate students to take charge of their own learning, understand multiple perspectives and develop high level reasoning skills [1]. Bruner's educational theory argues that learning is an active process and knowledge transmission depends on the individuals' participations and reconstructions [2]. We need to work both independently and in collaboration to create engaging learning communities [3]. Much education literature emphasizes the shift away from teacher-centered education to student-centered learning. Interactions, communications or collaboration with more capable peers during problem solving will enhance the learners understanding [3, 4]. When students manipulate artifacts themselves and think freely about problems, they become more actively involved and generally more systematic and scientific in their discovery of laws.

This paper describes a case study of six year teaching practice in one of our Master courses. In a subset of the requirements, the course requires the students be able to

- identify the most common system architecture;
- critically evaluate and determine technologies/tools for developing and maintaining enterprise websites;
- research design issues related to content, appearance, media and architecture;
- analyze the usability & accessibility for an enterprise website;
- investigate server-side administrative issues;
- evaluate client-side considerations;
- analyze security problems;
- explore management issues relating to security, encryption, verification, site auditing, certification, privacy and copyright.

In summary, the course requires the students to acquire critically analysis, evaluation and research skills. The course also requires the students to acquire the techniques and technologies related to many aspects of an enterprise website. There are only 32 hours for class meetings so the students have to work by themselves in most of the time. The best way to achieve the course requirements is to use the constructivist activities, let the students individually or collaboratively to work with the relevant partners and build the required knowledge and skills gradually. In the inquiry based learning, students are typically presented with a task to do and have to discover for themselves, with teacher facilitation as appropriate, what knowledge gaps they may have and the skills they may need to develop [5]. Inquiry skills improve student ability to acquire knowledge [6] and these skills are particularly important for Master students, so an inquiry based approach should be adopted.

Based on the above understanding, an assignment was developed which requires the students to investigate different aspects of an enterprise website. To complete this assignment, the students need to use an inquiry based learning approach. In

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inquiry based learning, students can also gather information by conducting interviews with local experts, family and community members [1]. The inquiry happens in two ways: using various web based online testing tools and communicating with the administration team of an enterprise website. Students are responsible for arranging their own communication, although suggestions and help may be gained from the lecturers. The students then will report their findings and critique their findings. Creating and demonstrating new knowledge require students gather data but go beyond simply reporting their findings [1]. Students are encouraged to reflect and think independently and critically. This study covers the teaching practice in the time period from the second semester of 2007 to the second semester of 2012. Each semester, we have one class in this course. The student numbers are various from 10 to 27 among the semesters.

The data were collected by observation, informal survey and informal conversations. The data were analyzed to find students' learning in planning, investigating, analyzing, communicating and reflecting. Only one of the classes was surveyed and the questions were around the students' attitudes, practices, the tools used and their industry partners' reaction.

This paper discusses the possible improvements and links the practice with the relevant theories. It also discusses the strategies to overcome the challenges experienced.

In the following sections, the teaching practice is described first, that is followed by the presentation of the data and analysis, then the teaching practice and the relevant theories are discussed, a summary is in the last section.

II. THE TEACHING PRACTICE

A. The Assignment

It is an individual assignment and the students are required to work on an existing enterprise website of their own choice with the condition that each student must work on a different website from the rest of the class. The students are required to research aspects of design, architecture, development, administration, management of the website, and then critique. The assignment mainly consists of five components: Technical Report, Architecture Report, Industry Policy Report, Critique and General Presentation. In the first component, the students are asked to investigate technique information such as usability, accessibility, popularity; in the second component they are asked to investigate architecture information such as visual design and content organization. Self-testing and online testing tools are the important instruments for the first two components. In the third component, the students are asked to investigate the management policies of the website such as system maintenance policy, security policy as well as privacy and copyright policy, industry inquiry is the main instrument for this component. In the fourth component, the students are asked to critique on the information gathered from the first three components. The most productive and worthwhile inquiry-based activities require students to gather data but go beyond simply reporting their findings [1].

The tools used include HTML validation tool, CSS validation tool, accessibility testing tool, popularity testing tool (e.g. NetCraft, Alexa), SEO analysis tool (e.g. The Reaction Engine) and technology look up tool (e.g. BuiltWith)

The assignment experienced two main structure changes in the time period covered in this study. Initially, the critique was only required on the information presented in the technique report. It was suggested that the assignment was too easy at Master level. In response to that, since the first semester of 2010, the critique has been required on all the three components: technique, architecture and industry policy. Lately, it was raised that the assignment work load is too heavy, as the students have to submit three reports for this assignment. To address this issue, the three were merged into one report and the critique was integrated with each of the first three components in the second semester of 2012. In the second semester of 2011, the following guideline for the whole process was introduced:

- Gather Information
  - Source Code and Page Extensions
  - Online Tools
  - Client Side Tools
  - Self-testing and Browsing
  - Industry Inquiry
- Report Information
  - Organise
  - Present
  - Analyse
  - Interpret
- Critique by Applying Relevant Guidelines/Principles
  - Brief/Refer Information Gathered
  - Link to Relevant Guidelines/Principles
    - Books
    - Research Literature
    - Common Practices
    - Online Technique Reports

The case studies of deconstructing website from Smashing Magazine were also introduced and discussed in the second semester of 2011.

B. The Industry Inquieries

The students are responsible to arrange the communications with their industry partners. Initially, the students send a request to express their interests to study their website as part of the assignment and ask for their support. If the response is positive, the collaboration starts. The students then send a set of questions. The industry partners may not be able to answer all the questions and they may refer the students to their colleagues or their business partners for further inquiry. The students then start to write their reports; they are usually welcome to go back to their industry partners if needed.

C. The Classroom Activities

A number of group classroom activities were designed to equip the students with the required knowledge and skills for the assignment, including news portal evaluation, server monitoring evaluation, web hosting evaluation and search engine optimization activity. The students work in group first and then report their findings to the whole class, there may be inter-group discussions at this stage.

D. The Challenges

From the practice of 2012, some of the challenges stood out, which are mainly related to the practical constraints of the learning context, such as it's hard to find an industry partner who is willing to support the assignment, the website management was reluctant to reveal some of the technique and management information due to confidentiality and etc. We encouraged the students to negotiate with their industry partners and get as much information as possible. We also encouraged the students try more options including those oversea websites.

III. The Data Analysis

A. The Survey Data

The students from 2010 Semester 1 were surveyed, among 20 students, 16 answered the questions. The survey started with a few general background information questions regarding their experiences related to website, it then focused on the industry inquiry. All the questions related to the industry inquiry and their answers are listed in Table I. All the questions are multiple choice questions except Qj. The participants may select multiple answers for Qg and Qi.

- Qa How easy to gather the data required for your industry report from the administration team?
- Qb How important your industry report to the website administration team?
- Qc Does the administration team appreciate your industry report?
- Qd Does the website administration team appreciate your critique on their management policies?
- Qe Will you provide your industry report including the critique part to the administration team?
- Qf How many staff have you communicated with from the administration team to gather the data?
- Qg In which way did you communicate with the administration team?
- Qh How much have you learned about website management policy from this process?
- Qi How would you like to learn website management policy?
- Qj If you have any other comments on this topic, please write here.

TABLE I. Collaboration Learning

Questions	Answers			
Qa	Easy	OK	Hard	Other
	2	10	3	1
Qb	Very important	Important	Don't know	Not important
	7	7	2	0
Qc	Yes	No	Don't know	
	10	1	5	
Qd	Yes	No	Don't know	
	9	1	6	
Qe	Yes	No	Don't know	
	12	1	3	
Qf	1	2	3	>3
	5	7	2	2
Qg	Email	Phone	In person	Other
	13	6	7	0
Qh	Nothing	Little	Average	Plenty
	0	1	2	13
Qi	Industry	Literature	Lectures	Other
	12	11	10	1
Qj	In general, they needed more guidance.			

The responses to question Qb, Qf, Qg, Qh and Qi are also depicted by a pie graph and bar graphs. Fig. 1 shows the responses to Qf and Fig. 2 shows the responses to Qg. According to Fig. 1, 69% respondents communicated with more than one staff from their industry partner. According to Fig. 2, 81% respondents used email for the communication; 38% used phone and 44% communicated in person. A student might use multiple ways for the communication. No other methods were specified in this survey, however, according to the informal feedbacks from the students, online chat is also an important method used by the students to communicate with their industry partners. Although the assignment is an individual assignment, collaboration is happening as well. Electronic tools, particularly email, play an import role in this collaboration.

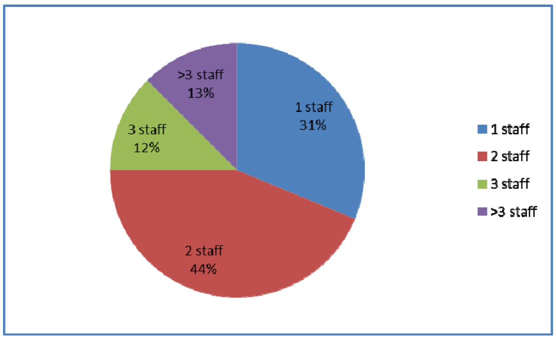

Fig. 1. The number of staff communicated by the students.

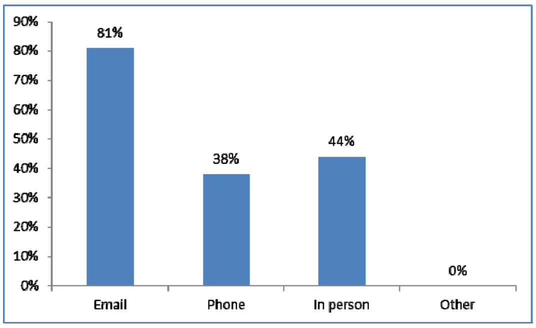

Fig. 2. The methods used to communicate with the industry partners.

The responses to Qb can be found in Fig. 3, which show that 88% respondents believed their reports important or very important to their industry partners. The responses to Qe in Table I show that more than 75% respondents would provide their reports to their industry partners. These suggest that the students are not only learning from the industry, their contributions are valuable to the industry as well.

Fig. 4 shows the responses to Qh which solicits students' opinions on their learning from the industry inquiry process. The answer is positive, 81% respondents believed that they have learned plenty from this process. All the respondents believed that they had learned something from this process. Fig. 5 shows the responses to Qi, which asks the students to select different learning approaches for website management policy. According to Fig. 5, the respondents valued the three given approaches closely, where the industry inquiry was the most favorable (75%) and the lectures was the least favorable (63%). These suggest that the students believed that inquiry based approach is more suitable for them to learn website management policy although the other supplementary approaches are still needed. One student specified that they also can learn it from previous experience.

In addition to the answers to the multiple choice questions, some students made extra comments, such as "Very good paper, has relevance to industry. Even with my experience, I learnt quite a lot of things regarding importance of policy", "Very enlightening, great impact on website owners and helpful", "This assignment promotes learning", to express their satisfactory. One student made comment of "subject literature should be discussed more in the class" which is interpreted as the students need more guidelines.

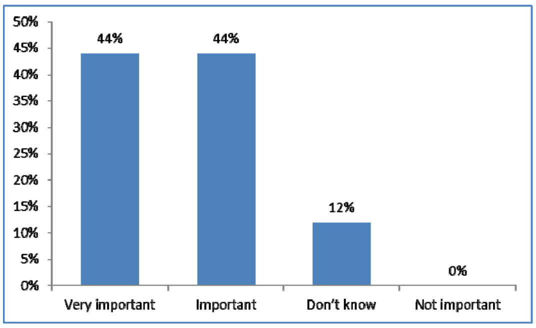

Fig. 3. The students' views on the importance of their reports to their industry partners.

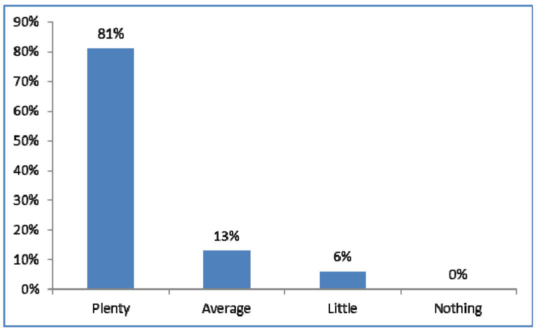

Fig. 4. How much the students have learned.

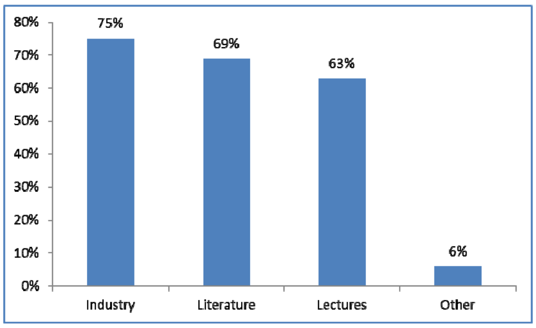

Fig. 5. The learning approaches selected by the students.

B. The Marking Report Data

After changes and improvements, the assignment was getting mature since 2010. The structure of the assignment was stable from 2010 Semester 1 to 2012 Semester 1. The marking reports in this time period was analyzed to evaluate the student learning from this inquiry based process. Only the marks for management policy report and critique report were analyzed as they are the most relevant part for planning, investigating, analyzing, communicating and reflecting. The students need to plan a set of questions before the industry inquiry and then investigate the website management policies by communicating with their industry partners. The students also need to analyze and reflect on the information gathered in their critique reports. Table II shows the data observed from the marking reports.

From Table II we can see that the marks of the critique reports were relatively low in 2010s1, which were improved in 2010s2 and were further improved later. The standard deviation were larger initially and getting smaller. On the other hand, the marks of the management policy reports had been consistently good in these five semesters. In 2011s2, the marks were further improved.

There is a need to review the improvements introduced in this time period. In 2010s2, the instructions for the critique report had been improved. It was

You should give reasons for your opinions and back them up with specific examples.

TABLE II. DATA FROM MARKING REPORTS

Semester	Policy Mean (30)	Critique Mean (30)	Policy STDEV	Critique STDEV
2010s1	22.58 (75.25%)	18.55 (61.83%)	2.60	3.41
2010s2	22.56 (75.21%)	21.25 (70.83%)	2.76	3.55
2011s1	22.06 (73.54%)	20.31 (67.71%)	2.80	2.96
2011s2	24.04 (80.12%)	22.26 (74.20%)	2.42	3.05
2012s1	23.47 (78.25%)	22.47 (74.91%)	2.22	2.06

In the survey conducted in 2010s1, a student expressed that they need more guidelines on these reports. In response to that, more research articles were introduced and discussed in the classes in 2010s2 and the instructions for the critique report became:

You should give reasons for your opinions and back them up with specific examples. You should summarize the facts you are critiquing and then apply the principles given in the lectures or literature with proper referencing.

Table II suggests that the above changes had a positive impact on the marks of critique report and had no impact on the management policy reports. In 2011 Semester 2, a guideline for this assignment was introduced. Table II suggests that the guideline had a positive impact on the marks for both of critique reports and management policy reports. The standard deviations for the marks of management policy reports were quite consistent and they were further improved since 2011s2. However, the standard deviations for the marks of critique reports were larger at the beginning and they became smaller since 2011s1. These suggest that while the teaching practice is improving, the students' abilities of planning, investigating, analyzing, communicating and reflecting are improving as well.

C. The Industry Reaction

The industry reaction was gathered by student feedbacks and the emails voluntarily sent by the industry partners.

Initially when the students express their interests to study a particular website, the administration teams may not response at all due to their busy work or confidentiality. Then the students have to try next option. According to the responses to Qa in Table I, more than 75% respondents didn't think it's hard to find an industry partner. As a matter of fact, some of the website administration teams are very happy to support the students, "It's my pleasure to help you out regarding on your research. Also it was glad that you have selected my project for you assignment".

After the students start to ask questions, some of the industry partners start to hesitate due to certain sensitive questions. We encourage the students to negotiate with their industry partners and get as much information as possible. If it's still difficult, we encourage the students try more options including those websites hosted overseas. Online communication tools can help for remote collaboration [7]. According to Fig. 2, most of the students have used phone and email in their communications, more tools used in [7], such as online chat, online forum and peer-to-peer messaging can be used by the students to communicate with their oversea industry partners effectively.

If the inquiry goes well, finally, most of the students will present their reports to their industry partners. According to the responses to Qd in Table I, more than 56% respondents believed that their industry partners appreciated their reports and their critiques. This is confirmed by the emails from three industry partners, "Your report looks great, awesome work. Your paper is quite timely as we are going through a redevelopment project of the website because of a lot of issues you have outlined", "Thank you for your report document – it is an interesting read!", "I am quite impressed by the work had been done. The reports contain high amount of useful information and analysis that are needed in our system. We could update some information about what knowledge of current student learning. At same time, we could have opportunity to refresh our knowledge of IT field".

IV. DISCUSSION

According to [5], the characteristics of inquiry based learning include:

1. The task is based on an open problem – open in the sense that there are numerous approaches to solution;
2. Initially, the student(s) are presented with the problem, and must discover for themselves the nature of the problem, and in particular to identify what knowledge and skills they will need to investigate and develop in order to solve the problem;
3. Where students are required to demonstrate self-analysis and critical thinking in order to choose between a number of possible solutions and approaches;
4. Where the teacher or lecturer acts as a facilitator in the process – but avoids simply providing solutions or being prescriptive in approaches.

Interpreting the above in the context of our teaching practice should help to validate the practice:

1. The students are asked to investigate the technique and management aspects of an enterprise website, which is an open problem;
2. Initially, the student(s) are presented with the assignment, the students need to identify their industry partner, the students need to decide what tools they need to use and what questions they need to ask;
3. Where students are required to demonstrate self-analysis and critical thinking in their reports;
4. The lecturer acts as a facilitator in the lectures and class activities, and provides outside classroom support.

Based on above, the teaching practice does have the characteristics of inquiry based learning.

“A WebQuest is an inquiry-oriented activity in which some or all of the information that learners interact with comes from resources on the Internet” [1, 6]. WebQuests are designed to use learners’ time well, to focus on using information rather than looking for it, and to support learners’ thinking at the levels of analysis, synthesis and evaluation [1]. Although our teaching practice was not designed in a WebQuest format, these purposes are consistent with our initial considerations. It should be helpful to check the teaching practice with the WebQuests to formalize this process and to identify the merits and demerits of the teaching practice for future improvements.

The outline of a WebQuest given by [1] includes:

- Introduction
  - To prepare and hook the students
- Task
  - What the student is going to do
  - A description of the culminating performance or product
- Process
  - How the learners will accomplish the task
  - Clear steps to accomplish the tasks
  - Tools and resources they will need to gather and organize information
- Evaluation
  - Criteria needed to meet performance and content standards
- Conclusion
  - To bring closure
  - To encourage reflection
- Teacher’s page
  - Information to help other teachers implement the WebQuest:
  - Targeted learners
  - Standards
  - Suggestions for teaching the unit
  - Sample student work (sometimes)

The WebQuest used in [6] contains the following stages:

1. Introduction—sets the stage; provide background information about the scenario.
2. Pooling knowledge—an opportunity for students to discuss the issue, drawing on, and combining, prior knowledge, and to stimulate critical reflection.
3. The team—allocation of specific roles for group members.
4. The task—explanation of the expected outcome from the group.
5. Where to look—students working in role, individually or in pairs, research links to appropriate web resources.
6. Getting together—time to share and synthesize findings within groups, and put together a presentation.
7. Share and Review—group presentations and questions.

Both of the WebQuests from [1] and [6] include *Introduction* and *Task* parts. [1] contains *Process* part and [6] contains *Where to look* part. [1] contains *Evaluation* and *Conclusion*; [6] contains *Getting together* and *Share and Review*. [1] contains *Teacher’s page*; [6] contains *Pooling knowledge*. While these two versions share many common components, [1] emphases the process and allows more flexibility, for example, the inquiries are not limited to the Internet; the students can also get information from their community experts; [6] focuses on group activity. WebQuests are usually collaborative ventures, requiring students to work in groups, often with particular assigned roles [6]. Our assignment is an individual assignment which is supported by the class activities and accompanied by the collaboration with the industry partners. A mixed version should reflect this teaching practice better. The following is a WebQuest with the context of our teaching practice:

1. Introduction—define the assignment requirements discuss them with the students in the classes.
2. Pooling knowledge—relevant class activities to equip the students with required knowledge and skills.
3. The tasks—explain what are expected from the students’ reports.
4. Industry Partner—the students to find a website they will study and the administration team they will work with.
5. Process—a guideline for the whole process is given; a set of tools are provided for the students to decide which tool to use and what information to collect. The students will analyze and organize the information gathered. The students will critique on the information presented by applying the principles found from various sources (lectures, literature and etc.)
6. Evaluation—a marking guide is provided in the assignment and is discussed in the classes.

The above list validated our teaching practice from WebQuest perspective. However, a *Review and Reflection* step seems missed. Adding this step by asking the students to do a presentation on their report should improve the teaching practice.

Research showed that university–industry links often rely on informal and formal social links [8]. Matching between universities and firms rarely occurs as the result of a search involving complete information on the whole range of options available to a firm [8]. This explains the challenge some students are having: it’s hard to find an industry partner. A possible solution is to encourage the students to use their social network. Another possible solution is for the lecturer to maintain a potential industry partner pool. Initially, the pool should contain those industry partners collaborated with the past students, the pool should be regularly updated by removing those who are not interested to participate anymore and adding new industry partners who are interested.

On an individual level, the question is how the academic researchers and industry staff can be aligned to produce mutually beneficial results [8]. This explains why many students have got their industry partners without difficulty. The students' contribution is valuable to the industry partners. As a matter of fact, providing their final report is the condition of their industry partners for most of the students.

The similar practice should be applicable to other subjects which are closely related to industry at Master level. The teaching practice should be adaptable to the third year undergraduate courses as well by making necessary modifications to the required tasks and evaluation criteria to accommodate the analyzing, critique and collaboration abilities of undergraduate students.

V. SUMMARY

The findings of this study showed that this inquiry based learning approach is effective; the students valued it more important than classroom lectures and their own literature research.

In this inquiry based learning process, the learning is mutual between the students and their industry partners. The students not only learn from the industry, their contributions are valuable to the industry as well. The industry partners welcome the students' reports and think they are valuable to their business.

A number of ways were used in the communications and email was the most popular one. More online tools could be used to facilitate remote communications.

While the teaching practice is improving, the students' abilities of planning, investigating, analyzing, communicating and reflecting are improving as well.

The teaching practice is validated with WebQuest. Adding a *Review and Reflection* step should improve the practice.

To deal with the difficulty in finding an industry partner, we encourage the students try more options including those oversea websites. The students should also be encouraged to use their social network. Another possible solution is for the lecturer to maintain a potential industry partner pool.

The similar practice should be applicable to other subjects which are closely related to industry at Master level. By making necessary modifications, it should be adaptable to the third year undergraduate courses as well.

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Scaffolding Students in a Complex Learning Environment

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***Abstract*—The design of distributed systems is a rather complex and difficult task. Distributed systems are complex systems that can be characterized as wicked problems because they involve an intricate combination of changing relationships between their various components. Research shows that it takes a lot of deliberate practice to move from the mindset of a novice to the mindset of an expert. To start cultivating experts design mindset we designed a cognitive support system consisting of a suite of mechanisms characterized by mentorship and social interactions around a real-world project. In a problem-based learning environment with cased-based reasoning, students have to follow a systematic approach using a common system of activities of "ritualized" activity structures. The systematic approach is based on the Rational Unified Process, CATs (Classroom Assessment Techniques) with rubrics, and scaffolding: questions prompts, peer-review, expert modeling, and self-reflection. This paper describes the challenges faced by novices and instructors in wicked problems design tasks in the context of developing a prototype and its framework and middleware for a complex distributed application while learning distributed systems concepts. It also outlines our interactive learning environment to scaffold the design and developing process improving student's problem-solving skills and time on-task to reduce frustration.**

Keywords—component; complex systems; distributed systems; Problem-based Learning; scaffoldings; wicked problems.

I. Introduction

Today's software engineer is expected to develop, maintain and comprehend highly complex distributed systems (HCDSs) of unprecedented size and complexity. HCDSs must be capable of delivering timely information to increasingly large numbers of users into an environment in which software and hardware are changing at an increasing rate. HCDSs are characterized by a large number of mission-critical, heterogeneous interdependent subsystems executing concurrently with diverse and often conflicting quality of services (QoS) requirements. To ensure that users experience the best QoS according to their needs and specific contexts of use, HCDSs need to be context-aware, adaptable, and dependable. HCDSs must support heterogeneity of the underlying communication infrastructure, mobility inducing changes to the availability of resources and continuously evolving requirements. [1] [2]

HCDS or systems of systems, as defined by Fisher[3], depends on distributed control, cooperation, influence, cascade effects, orchestration, and other emergent behaviors as primary compositional to achieve its purpose. Emergent behavior is the inevitable consequence of the independent management, operation, and evolution that characterize this type of systems and is unavoidable in the presence of autonomous constituents. Recognition of the importance of emergent effects in determining the global characteristics of systems imposes a change in perspective on the scope of a system. New software engineering methods and approaches are needed that manage emergent behavior and exploits emergent effects and offer the possibility of cost-effective and predicable solutions. [3]

HCDSs exhibit the characteristics of wicked [4] or ill-defined problems [5]. The design and integration of complex software components can be construed as an evolution from previous models of software design, and therefore becomes a wicked problem also.

Ill-defined problems refer to the fact that the design problem is incomplete and has no one single solution, while wicked problems are progressively defined during the design process. Wicked problems are essentially unique and each can be considered to be "a symptom of another problem" [5]. Wicked problems require an ongoing iterative analysis between problem and solution to begin to understand either, and to find the best possible compromise between design constraints when an optimal solution is impossible [6].

The decision-making strategies commonly taught in Software Engineering curricula and employed by novice software designers are not effective when applied to large, wicked real-world problems. Research shows that novice designers tend to think linearly and concentrate only on the problem at hand. Novices also tend to use trial and error strategies and lack confidence in their design decisions. [7].

Teaching distributed systems principles, paradigms, software engineering techniques, and engaging students in problem solving do not ensure the development of expertise. Research shows that it takes a lot of deliberate practice to move from the mindset of a novice to the mindset of an expert [8].

In this paper, we will describe our mentoring approach and scaffoldings to improve our novices' design skills in an interactive learning environment. We will show and analyze

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our data comparing how the addition of scaffoldings helped us to reduce the time it takes to develop expertise in our students and use in-class time and time on-task more efficiently to reduce students frustration.

II. Scaffolding

A. *The original notion of scaffolding*

Wood, Bruner and Ross [9] defined scaffolding as an instructor or expert "… controlling those elements of the task that are essentially beyond the learner's capacity, thus permitting him/her to concentrate upon and complete only those elements that are within his/her range of competence "(intersubjectivity). The expert is the domain expert as well as a facilitator who is knowledgeable of the skills, strategies and processes required for effective learning. The key features are intersubjectivity, ongoing diagnosis, tailored assistance and fading [9].

A shared understanding of the goal of the activity provides motivation. Both expert and learner collaboratively redefine the task (combined ownership) that the learner needs to accomplish.

Appropriate support becomes a scaffold only when it is based on ongoing diagnosis of the learner´s current level of understanding. The teacher provides assistance in a timely and effective manner to the learner's present focus, thereby helping the learner with his/her current difficulties. The expert should have knowledge of the learner's capabilities that changes as the instruction progresses, as well as allowing learners to play a role in negotiating interactions. However, if the learner lacks the necessary skills, the information is outlined around the expert way of accomplishing the task. Scaffolding should be removed gradually and then removed completely when mastery of the task is demonstrated. [10]

The notion of scaffolding with individualized support explains the multifaceted nature of learning appropriate to deeply learning new concepts and skills and their applicability, in parallel with learning cognitive, social, and communication skills. However, by broadening the notion of scaffolding to the entire class of students, the one-to-one interaction between teacher and student is not possible [10].

B. *Broadening the notion of scaffolding to the entire class*

Recent design research on interactive learning environments has adapted the notion of scaffolding into classroom communities with students working in small groups. Hogan [11] defined an instructional scaffold as "a tool for acculturating students into the thinking patterns of experts". Puntambekar and Kolodner [9] defined distributed scaffoldings for science students, as a learning support addressing the need to provide multiple types, sources, methods, and amounts of supports to increase a student´s ability to perform a skill. An interactive learning environment based on a socio-constructivist model, such as inquiry and project-based approaches situate learning in complex tasks. To help students with such tasks, classroom activities are designed so that peers can scaffold each other. Support and scaffolding is provided through different resources and tools. Tools provide support for solving problems, for the processes in completing an activity, for understanding the domain, to help them to develop scientific arguments by scaffolding the process of constructing an argument and to reflect on the process [12].

The classroom embodies a community-of-learners approach [9]. Several discussion tools can be used to support the occurrence of discourse among students in the classroom and to provide prompts that enable them to think about the processes and reflect on their learning, and encourage dialogue among groups of students [10, 13]. Classroom events such as design discussions [14] enable students to share, review and critique design ideas. The more knowledgeable peers contribute by raising important issues providing clarifications and less knowledgeable members play an important role by bringing up questions and asking for clarifications.

The focus of ongoing diagnosis needs to shift to the group as a unit. Online discussion tools can help a teacher examine group's progress over time and analyze whether students' dialogue shows an increasing depth of knowledge. [10] Ongoing diagnosis and fading scaffolding are closely coupled. The aim in designing support is to ascertain that students learn the necessary domains and skills and are able to generalize them to other contexts. Teacher's role is to maintain a delicate balance between guidance and discovery and intervene removing or changing scaffolding tools after students/groups make progress. [10]

III. The Distributed Systems Learning Environment

A. *Complex Systems Challenges.*

To teach distributed systems design we have to answer some questions: How can the "wicked" problems posed by complex systems be addressed? The first step in coping with a wicked problem is to recognize its nature and their properties.

Rittel and Webber [4] describe the nature of wicked problems as a set of ill-defined problems that are too complex to be solved by rational systematic processes. Wicked problems have no definitive formulation and no optimal solution because problem definition and solution co-evolve. The solving process is inherently nonlinear. The solutions are never true or false but instead are qualitatively judged as better or worse. The realistic goal is a "satisficing", i.e. combining satisfy with suffice or "good enough" solution.

Novice designers have a tendency to treat all problems as tame because of their previous experiences, these problems are easier to solve, reinforced by the lack of understanding about wicked problems dynamics and the approach they require. A tame problem [4] is one for which the traditional linear process is sufficient to produce a workable solution in an acceptable time frame. Many traditional exercises in Concurrency and Introductory Software Engineering courses fall into the category of tame problems.

Students do not think beyond the written description of the problem. They shift rapidly from problem analysis to solution generation and failed to elaborate solution alternatives. There are some deep principles that underlie many complex systems, [15, 16], such as function, behavior, structure, and emergence. The other question is: How can we help students to view a complex system as emergent or causal depending on the point of view one is taking?

B. Cognitive Challenges

Some research studies [15, 17] have found that one of the major issues affecting students' ability to learn about complex systems and other challenging topics is their cognitive, metacognitive, and self-regulatory processes. It is to a great extent dependent on the deployment of such processes to plan, sustain, and reflect on the complex mechanisms underlying learning about complex systems. Researchers argue for the importance of experience with complex systems. Also, they argue that discovery alone is not sufficient. Students need scaffolding to guide their exploration and experience. Open-ended learning environments offers the potential to foster student's learning, but due to the complex nature of learning about these environments, it is necessary to support student's learning by providing embedded scaffolds designed to support certain learning and inquiry processes.

PBL is an open learning environment in which students learn through facilitated problem solving. PBL is designed to help students to construct an extensive and flexible knowledge base which integrates information across multiple domains in long term memory; to develop effective problem-solving skills; to develop self-directed, lifelong learning skills; to become effective collaborators; and to become intrinsically motivated to learn [18].

In addition, students' interaction with others is not only guided by the learning task, it is also shaped by their emotions, perceptions, and attitudes [17]. Some social-emotional processes are beneficial for learning others are not [19]. Therefore, the relationships between motivation, peer interactions, and wicked problem solving are worth further attention to answer the questions: How much time might it take to develop expertise in our students? How could we improve the process? The successful guidance of PBL is largely dependent on the availability and skills of instructors who can scaffold students' problem-solving activities [18].

C. Our PBL course.

When we designed our first PBL course, we acknowledged that we would find the challenges outlined above and some hurdles. The domains of distributed systems themselves span and integrate a vast range of subject matter. Students have never directly experienced complex systems concepts before. Our PBL focused on a design project following the software engineering best practices. We match the form and complexity of the problem to a real distributed problem to contribute to the realism of the experience. The engineering best practices suggest to develop a middleware that, through the provision of proper features, supports distributed applications by masking the distribution and heterogeneity of the execution and networking environment. Different software engineering techniques, such as software architectures, middleware, component-based development, service-oriented systems, etc. were introduced to deal with this type of systems. [1]

Having a small number of students each semester, we were able to use diagnostic assessment tools exhaustively in order to have a close observation of our students' learning process. In order to reach our course goal to develop independent learners with professional (expert) design skills, we arranged additional out-of-class meetings to help students to develop common positions on relevant issues when they did not meet the in-class meeting goals. We were there for office hours, kept scheduled appointments, and made time for students/teams when they needed additional help. We arrived at class early and stayed after class.

After each semester we answered the questions we pose as ongoing diagnosis, reviewed literature and transformed our cognitive support system (scaffoldings) for improving the process and using the in-class time more efficiently. Our support system in 2008 included CATs with report feedback, meetings, peer-review with a facilitator and feedback, and in-class experiments. In 2009, we added the self-reflection writing activity and rubrics. In 2010, we added question prompts, in 2011, the expert modeling scaffolding and in 2012, a PBL approach with Case-based Reasoning (CBR) focused on a design project. [20, 21,22]

Our PBL approach with CBR focused on an in-class design project, from the initial statement of a real world distributed problem to a working prototype for the whole class. We gave twenty students (our novices) the problem statement and material to work with. Students had to follow a systematic approach using a common system of activities, called a tool of "ritualized" activity structures, as suggested by Kolodner et al. [14] for solving the problem.

Kolodner et al. [14] defined "ritualizing" as articulating and normalizing a sequence of activities and setting expectations about how and when to carry out them. It is a way to incorporate aspects of design expertise as a potential strategy for helping novices solve ill-structured problems in more expert-like ways. The tool would be designed to engage novices in deeper analysis and understanding of the macro-system in which the problem and possible interventions were embedded [23].

We complemented PBL's self-directed learning with lectures. Students had to search and analyze algorithms, but complex design techniques and key concepts about distribution's complexity, concurrency, and synchronization were difficult to master by students by themselves. These concepts were introduced after the need to learn them has been established in the context of observed phenomena or unexpected system behaviors during design and implementation on a "just-in-time basis" [19].

Our PBL approach has four stages. Each stage represents a different aspect of the design and requires different student's abilities and skills. Students are repeating the cycle while revising and improving each time. The stages are based on the traditional Software Development Process RUP (Rational Unified Process Software Development Process [24]). For documentation, students had to use UML diagrams as recommended by RUP and, state transition diagrams and protocol design recommendations. The stages are:

1st stage: *Start point*. It is a pre-session preparation as in a Case-Based Learning approach [25]. The aim is to establish a community of learners and engage students in reasoning based on previous experience.

2nd stage: *Application prototype and framework API development*. This stage comprises the first iteration of the software development process of the in-class project. The first prototype of the application has to be developed using concurrent models and patterns using CBR. The prototype has to show the expected behavior of the system, the concurrency, synchronizations between processes and performance issues in a centralized environment. Framework APIs have to be developed. The APIs has to support the needs of communications, coordination and synchronization of the application processes or objects. The prototype has to be implemented using the framework APIs. The outcome has to be a working prototype in a centralized environment.

3rd stage: *Middleware design and implementation*. This stage comprises the second iteration of the software development process. The application processes will be distributed and a middleware to support the frameworks API will be developed. Students have to develop the communication, coordination and synchronization protocols. The outcome has to be a working distributed prototype.

4th stage: *Student team's project*. For a giving middleware specification, students have to find a suited application, to propose a distributed solution, and to develop the solution (as in stages 2 and 3). We have included this stage in order to foster the skills they have learned. It assesses students' skill at synthesizing what they have already learned about the field as they plan their own project [26]. Scaffoldings are removed in this stage, but students are permitted to ask for guidance in out-of-class appointments.

IV. Our Tool of "Ritualized" Activity Structures

Our tool is an outline of the activities of design process steps using the RUP Software Development Process and guidelines with embedded scaffoldings [20, 21,22].

Students like to have formal processes or procedures to use for problem solving, but the UML formal procedures they learned to use in former subjects do not work well with ill-formed problems. Experts use UML diagrams only after they make the final design decisions for the RUP phase. A flexible and adaptable "design thinking" process for guiding design decision-making would provide an alternative to these formal procedures. This process could explicitly incorporate scaffoldings for looking at the big picture of the system, the use of rules, principles, and/or practices for examining the design and generating solution alternatives, selecting and evaluating candidate alternatives, and reflecting on what has been accomplished in an iterative approach.

We are supporting this design thinking process using the CATs (Classroom Assessment Techniques) related to Assessing Skills in Problem Solving [26] for the "ritualized" activity structures in the form of reflective writing and sketching activities. Students working in teams, have to follow the guidelines and activities of the corresponding RUP phase. The Assessing Skills in Problem Solving CATs are: Problem Recognition Tasks, What's the principle?, and Documented Problem Solution.

CATs are mandatory homework. CAT's requirements are UML diagrams, state transition diagrams, informal diagrams or sketches, annotations (textual and graphical), corrections, alternatives, etc. to communicate ideas and decision arguments to support student's design thinking process. Students have to write their arguments and the collected evidence for their positions in argumentative essays. The CATs activities are based on Quellmalz's [27] key strategies of critical thinking.

Cross [11] calls sketching an "intelligence amplifier" and enumerates how sketching helps design thinking. It enables designers to handle different levels of abstraction simultaneously, enables identification and recall of relevant knowledge, assists in problem structuring through solution attempts, and promotes recognition of emergent features and properties. Informal diagrams and sketches offer a great way to examine the relationships among objects in the different problem domains, as well as their interactions. Sketches hide students from making premature design decisions because the UML notation pushes them to think of abstractions and focus on understanding the problem space.

Explicit strategies for developing arguments has been introduced using the basic tools for writing argumentative essays at the beginning of the course and out-of-class time has been scheduled to help them with these reflective writing activities [28].

Software design is a collaborative activity and developers work in face-to-face settings. CATs act as the coordination mechanism to support the design dialogue during the discussions and peer-review sessions. CATs and rubrics also act as formative assessment tools for ongoing diagnosis, to give feedback, and for "just in time" mentoring for reflection during the meetings, in the sense of thinking about something again [20, 21,22].

Rubrics assessment purposes are to improve the reliability of scoring written assignments and active participation during meetings. Rubrics convey goals and performance expectations of students in an unambiguous way, convey "point values" and relate them to performance goals, and engage students in critical evaluation of their own performance [29]. Rubrics are also a guide of how to do the work.

A. Assessing skills in Problem Solving CATs

The Problem Recognition Tasks CAT assesses students' skill at determining what kind of problem they are faced with, so they can choose the appropriate solution [26]. Students have to describe the problem using the requirements analysis and analysis diagrams of the software development process to solve the problem following the guidelines and activities of the CAT. Particular problem types, characteristics, variables, boundaries, etc. must be recognized and identified.

The What's the Principle? CAT assesses students' ability to associate specific problems with the general principles used to solve them, i.e. how they use models and abstraction in our subject [25]. Students have to decide what principles to apply in order to solve the problem and their alternatives using models and patterns of the design phase.

The Documented Problem Solutions CAT [26] assesses how well students solve problems and how well they understand and can describe their problem-solving methods and strategies. Students have to decide how they implement the solution using the designed framework APIs, algorithms, interprocess communication tools and distributed algorithms.

B. Scaffoldings.

We introduced additional scaffoldings to improve novices' problem-solving skills [22].

1) Question prompts.

In addition to the problem-solving outline, the students are receiving prompts consisting of elaboration and metacognitive questions for each activity [30]. Research reported in [30] had found question prompting to be an effective instructional strategy for directing students to the most important aspects of a problem, as well as encouraging self-explanation, elaboration, planning, monitoring and self-reflection, and evaluation.

2) Peer review.

The peer review mechanism was designed to enable students to see multiple perspectives from peers' reports and help them notice things they might not have thought about previously. By reviewing their peers' thinking, students are supposedly compelled not only to attend more closely to their peers' ideas, rationales, plans and solutions, but also to their own for self-reflection [30].

3) Expert modeling.

Expert modeling are provided by presenting students with expert's reasoning during discussion meetings. This support mechanism is expecting to offer students an opportunity to observe the expert's reasoning, which they would compare with their own reasoning. It has been assumed that the comparison would result in disequilibrium [30].

When students are immersed in a design activity, they are often unable (or unwilling) to acquire knowledge that cannot be immediately put to use. If they do not see the need for help, it is unlikely they will ask questions. Experts notice features and meaningful patterns of problem solving that are often not noticed by novices; they organize knowledge in ways that reflect a deeper understanding of their subject matter and they have varying levels of flexibility in their approach to new situations [30].

In 2011, we included the expert-modeling scaffold to be able to help novices to focus on hidden relational properties of the problem during the in-class meetings. We are introducing them in practices of reasoning about systematic exploration of possibilities (finding gaps, or finding unexplored relationships between problems and potential approaches) and scenario-based reasoning to explore assumptions and consequences. This scaffolding has reduced student´s frustration during the first two stages of our PBL approach.

4) Self-reflection

A meeting ended with a self-reflection writing activity with a few reflective questions. Self-reflection is an important mechanism to supplement the expert modeling mechanism and allowed students to observe an expert's reasoning facilitating students' reflection on the gaps between student's and the expert´s reasoning [30].

5) Agenda and goals

A collaborative design session is more likely to succeed when designers agree on ground rules for conducting the session. By setting time limits and achievement goals, designers can force themselves to focus on the fundamental problems.

V. STAGES AND SCAFFOLDING

A. Start Point or pre-session preparation.

Our students have no expertise in case-based reasoning. CBR refers to reasoning based on previous experience [31].

We adapted an approach used with medical students [25]. Students in informal teams have to solve assigned small real-world cases applying background knowledge of concurrency concepts, models, patterns, and software engineering techniques as homework. Each case is an open-ended problem with a few alternative solutions to solve with the provided CAT's guidelines and activities.

The goal is helping students to "re-index" old experiences and to abstract out generalizations from experiences and reviewing background knowledge with a different approach [25]. Students will need CBR to design and build the first prototype of the class project.

As have been reported in [31], failure at applying an old case in a new situation triggers explanation that might result in reinterpreting (reindexing) old situations and/or discovering new kinds of interpretations (indexes). Crucial to interpreting failure is useful feedback from the world, to evaluate a solution, allowing indexing that discriminates usability of old cases and allowing good judgments later about reuse.

Case discussion in class using the CATs of the interviewed team, (peer-review scaffolding) begins with a discussion of the case requirements and the proposed solutions using provided guiding questions (questions prompts scaffolding) with the other teams. Instructor and students may call time-outs at key times to discuss the ongoing discussion content to help the interviewed team to solve the problem. During time-outs other students provides feedback and assistance to this team. Instructors (expert modeling scaffolding) provides guidance and ask questions when the students seemed off track or unsure about the content to facilitate discussion.

The session ends with a self-reflection writing activity summarizing the case characteristics (domain, variables, constraints, etc.) and selected solution. The next activity for the team is implementing the solution.

Reports (CATs, self-reflection writings, annotations, etc.) and programs have to be shared using some web tool, such as DropBox; to have a resource library for the next stages of PBL as is mandatory for a community of learners.

B. Application prototype and framework API development..

This is the most challenging stage for novice designers. Students are not aware that a nontrivial portion of a software team's work for the initial stage involves improving their understanding of the problem domain from a succinct problem statement (design brief) and a vague set of requirements to produce a design that addresses users' needs. More than half the cost of the development of complex software systems is attributable to decisions made in this initial phase.

Students and novice designer find it difficult to cope with problem scoping and information gathering. These are aspects of design activity that involve identifying criteria, constraints, and requirements; framing the problem goals or essential issues; gathering information; and, stating assumptions about information gathered. CATs, instructor's guidance and scaffolding can facilitate the problem solving process and enables students to bridge the gap between their current abilities and the intended goals of expertise.

In the past semester, we scheduled several meeting for peer-review with question prompts, expert modeling, and self-reflection writing to discuss the "The Problem Recognition Tasks" CAT. Expert modeling were used to help them to learn how to use CBR effectively with expert reasoning as outlined in the CATs.

Experts are able to activate mental models that connect relevant previous experiences with domain specific knowledge and skills. They activate a mental framework for representing the problem and seek solutions. Experts integrate given information with prior knowledge and experiences to make inferences that go beyond the state information [32]. Design activities would more or less creative according to conceptual domains evoked sources. Experts can refer to intra-domain or inter-domain sources in order to engage in analogy making for solving the design problem. [33]

Lectures for "just in time" concepts were given to complete student's knowledge or "expertise" about patterns and frameworks, and analogies.

Another aspect of design behavior thought to be important and difficult to master by students is the generation and consideration of alternative solutions. Students tend to focus on one design and tried to make it work. The "What's the Principle?" CAT helps them analyze the interrelations and connections of the complex system, and generated alternatives. In our experiences, at this time, students had accepted peer-reviews, expert modeling and writing as tools for support and confirm facts and ideas. Students are becoming aware of the need of help or information.

Once students have conceived alternative solutions to the design problem, they are applying their technical knowledge to the proposed solutions and using the results to decide which solution to carry out. They are validating system goals, constrains, and connections, and interrelations. They are documenting the solution using the "Documented Problem Solutions" CAT. Then, we are dividing up the class into programming teams to build the prototype and framework APIs.

C. *Middleware design and implementation*

Experiments and programming exercises in the lab are introduced to check and exhibit distributed systems complex behavior against student's expectations and to show students how a population of asynchronously executing processes without central top-down control can exhibit unexpected or "emergent" behavior at the system level. Paradigms and protocol design approaches are introduced with examples.

Students are following the same set of CATs, with peer-review and question prompts. Expert modeling occurs when students are seeking for the opinion of an expert or cannot reach consensus about the solution.

TABLE I. STUDENTS ACHIEVEMENT AND OUT-OF-CLASS TIME REQUIREMENTS

	2008 Students = 8					**2009** Students = 6					**2010** Students = 6					**2011** Students = 20					**2012** Students = 20				
STAGE 1 Cases	*Average*	*SD*	*Weeks*	*Office*	*Extra*	*Average*	*SD*	*Weeks*	*Office*	*Extra*	*Average*	*SD*	*Weeks*	*Office*	*Extra*	*Average*	*SD*	*Weeks*	*Office*	*Extra*	*Average*	*SD*	*Weeks*	*Office*	*Extra*
Design	Background review					Background review					Background review					Background review					9.91	0.10	1	2	0
Implementation																					9.86	0.19	1	2	0
Total Scores			2					2					2					2			9.89	0.09	2	4	0
STAGE 2 Prototype																									
Design	8.92	0.67	6	6	4	9.62	0.32	5	6	3	9.87	0.10	4	3	2	9.37	0.65	4	2	1	9.76	0.31	3	2	0
Implementation	9.64	0.48	3	4	2	9.86	0.21	3	4	1	9.86	0.21	3	3	0	9.62	0.35	3	3	0	9.79	0.18	3	2	0
Total Scores	9.17	0.60	9	48	6	9.70	0.26	8	42	4	9.87	0.12	7	21	2	9.46	0.50	7	17	1	9.77	0.23	6	12	0
STAGE 3 Middleware																									
Design	9.91	0.18	3	6	1	9.88	0.19	3	4	1	9.88	0.19	3	2	0	9.88	0.11	3	2	0	9.89	0.10	3	2	0
Implementation	9.89	0.19	3	4	1	9.85	0.21	3	4	1	9.85	0.19	3	4	1	9.83	0.17	3	4	0	9.83	0.16	3	2	0
Total Scores	9.90	0.17	6	30	2	9.87	0.19	6	24	2	9.87	0.19	6	18	1	9.87	0.11	6	18	0	9.87	0.08	6	12	0
Scaffoldings	*exp.*					*+self reflection writing*					*+question prompts*					*+expert modeling*					*+ start point (CBL+CBR)*				

Office= Out-of-Class Office hours/week for mentoring *Extra= Extra Meetings (Additional Out-of-Class Meetings)*

VI. RESULTS AND DISCUSSION

We use a standards-based grading system where each student, as shown in Table I must meet a determinate level of achievement. Each step is evaluated in points from 1 to 10 using a grading rubric. These are formative assessment earned points for ongoing diagnostics and feedback. In the five terms, the points' statistics are similar, meaning that student's achievement level remained reasonably high. The difference appears in the mentoring office hours and additional (extra) meetings we held with the students/teams to reach this achievement level. In 2008, we use 78 in-person office hours in 15 weeks for mentoring of only 8 frustrated students claiming for hints and clues to understand where and why they failed.

As described by Carver et al. [34] "one of the frustrating things about learning software engineering for students is that there is no definitive right answer to many questions, against which their own answers can be compared. Mistake time estimates cause a great deal of frustration and even anger on the part of students, who might feel less intelligent for not being able to get the task done in an arbitrarily short period. If subjects become frustrated, the data provided may be of lower quality because subjects may either quit before completing the task. If students learn a new process and it requires more effort than the estimate they are given, they may become disillusioned with the benefits of software process and see only that process is time-consuming and provides little benefit".

Problems should promote conjecture, argumentation, and peer criticism, by lending themselves to multiple interpretations or solutions, sometimes depending on which of a variety of conflicting perspectives students take on. Students need to work out the problems together and have an authentic need to ask each other to justify their points of view [31]. Open-ended learning environments with embedded scaffolds designed to support the learning and inquiry processes meet the goal to develop student's expertise reducing frustration.

Supporting our learning environment with scaffoldings and introducing students in CBR reduced the used office hours to 24 hours in 12 weeks for 20 students. Office hours were used for team conflict mediation, for helping students to reach agreement about the use of some tool or diagram.

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Using a Competency-Based Instructional Approach in Thermodynamics

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***Abstract*— Many engineering classes are highly sequential, causing students that fail to grasp initial topics to struggle as courses progress. Despite instructor exhortations to master fundamental subjects, students often continue to struggle instead of investing the time to review. Because students do not proactively re-learn initial content, a competency-based approach was implemented in a highly sequential thermodynamics course. In the approach, students scoring below 80% on the first exam were required to pass an online review quiz in order to take subsequent exams. Only 3 out of 135 students were unable to take the second exam, but all were able to pass by the time of the third exam. Significant increases (p<0.01) were achieved in both the average course grade and average grade on the third (final) exam as compared to the previous offering of the course, with the average grade on the final exam rising from 66.5% to 74.0% and the overall course grade rising from 76.2% to 83.2%. The competency-based structure forced students to review fundamental material that is necessary both later within a course and in subsequent courses, and seems to particularly benefit the poorer performing students. This may have impacts on student retention and persistence.**

Keywords—competency; student success; persistence

I. Introduction

For many topics within science and engineering, later content builds heavily on initial content. Prerequisite courses abound, with various mathematics classes being necessary for many engineering courses, physics being necessary for statics, statics being necessary for mechanics, thermodynamics being necessary for heat transfer, and so on. Additionally, courses themselves are often sequential, with later content building heavily on content introduced at the beginning of the course.

Students that fail to grasp initial topics necessarily struggle with later topics. In the context of the progression of multiple courses, falling behind can negatively impact student progression and persistence, as failure to master prerequisite courses increases the difficulty of subsequent courses [1-3]. Additionally, students that fail to master initial content within a single course will continue to struggle as more complexity is added to the analysis. In statics, a student struggling to draw correct force body diagrams will have a difficult time calculating moments and reaction forces [4]. In calculus, a student that struggles with basic derivatives will have a difficult time using the chain rule to take more complex derivatives. This struggle with basic steps has multiple ramifications. Homework assignments take longer when what should be 'easy' steps continue to be a challenge, which may increase the incidence of incomplete homework assignments or copying. Moreover, students often fail to see the path to the solution when they lack the mastery of the steps necessary to get there.

While an instructor can emphasize the importance of the initial content to students, students frequently do not heed the advice given them. Additionally, an instructor can discuss the importance of the initial content to students that struggle on early exams, but few students will actually resolve the misconceptions and lack of understanding that caused their poor performance. Because various factors compete for students' time, they expend their effort on the tasks they deem most valuable. Since any efforts made by the student to review the initial content are typically not graded, getting students to see the value of reviewing previous material is difficult. Thus, students often do not recover from struggles with initial course content and their struggles perpetuate.

Engineering thermodynamics is one subject for which content is particularly sequential, with every topic building directly on previous topics. Students that fall behind consistently do nothing to re-learn initial content, and as a result they often continue to fail for the rest of the semester. Realizing that students would not proactively put in the effort to re-learn initial content, a competency-based approach was implemented in the Spring 2012 offering of Thermodynamics I at our institution. This paper describes the effect of the approach on student performance.

II. Methods

A. Thermodynamics I Course Content and Sequence

At our institution, the Thermodynamics I course begins with an overview of how energy is transferred and transformed in engineering systems. Because energy is often transferred into and out of fluids, the course then discusses the typical

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phases of matter (solid, liquid, vapor, ideal gas), and how phase is affected by energy transfers. In particular, students learn to use tables and equations to relate the energy of a substance to other properties like temperature and pressure. After students learn how to relate substance properties to each other, they then learn to perform energy balances, applying the first law of thermodynamics. Energy balances are used to relate energy changes within a substance to energy transfers to and from the substance. Without being able to relate substance properties to each other, students will be unable to perform energy balances.

The course then discusses the second law of thermodynamics, which has various formulations but basically states that things tend towards disorder. One implication of the second law is that the property entropy, which is a measure of disorder, can be balanced and used to determine the energy of a substance or energy transfers, which can then be used in conjunction with energy balances to determine energy transfers and substance properties. Without being able to utilize energy balances, the information from the entropy balance is not useful.

Throughout the course, each step is foundationally important to the later content. Students must master early content in order to be able to succeed later in the course.

B. *Course Structure*

The competency-based approach described in this paper was implemented in the spring 2012 offering of Thermodynamics I. The course was a typical lecture-based course, with frequent in-class discussions and exercises, in addition to homework assignments every 1-2 weeks. The course had two sections, with enrollments of 60 and 75. Homework assignments constituted 16% of the course grade, and three exams constituted 28% each. The first exam covered only the use and evaluation of properties, the second exam covered energy balances, and the third exam covered energy balances together with entropy balances, reflecting the three major foundational topics of the course. Because each concept built so heavily on previous content, a progressive grading scheme was used for the exams. The overall exam grade was set to be no lower than the grade on the third (final) exam, and the first exam was dropped if students improved on the second exam. This grading scheme was justified because a student necessarily would have had to master and utilize the content from the first two exams in order to be able to complete the third. A benefit of this scheme is that students that received low grades on early exams could still have hope for improving their course grade rather than being anchored by poor initial performance.

C. *Competency-Based Approach*

Because students often did not review initial content and instead continued to fail, the system implemented in spring 2012 actively forced students to re-learn initial content that they failed to master and demonstrate their competence before moving on. Since the use of properties was required for everything else in the class, students were required to demonstrate competence in evaluating substance properties. Students that achieved above 80% on the first exam were exempted from any further review. Those that scored below 80% on the first exam had to either take an oral exam with the instructor during office hours or retake randomized online makeup quizzes until they achieved above 80%, and they were not allowed to take any subsequent exams until they had done so. The grading policy for this course was a key element enabling this system, since a student could take a zero on the second midterm and still have their exam grade determined by the final exam.

Only one online quiz was made available each week. Students were allowed a single attempt at each quiz in order to encourage them to actually review the material rather than repetitively take the quizzes while blindly hoping for a better outcome. The online quizzes were implemented using the randomized question bank feature of Blackboard Learn®, an online interface. In this feature, a pool of questions can be generated from which the online quiz draws randomly. Thus, a single bank of questions could be made while still ensuring that students had different quizzes each week, and different quizzes from each other.

While the content for the second midterm (energy balances) was also a foundational skill for the class, the competency-based approach was only implemented for property evaluation so that we could do an initial trial on a fundamentally important topic that was easy to implement in an online quiz format.

D. *Data Analysis*

Student performance data were evaluated and compared to the previous offering of the course with the same instructor, which occurred during spring 2011. The instructor was experienced in teaching the course, and the student course evaluations were highly positive and comparable both semesters. A t-test was used to compare data between the two semesters. Only the third (final) exam and course grade were used in the comparison because a slight reorganization in the course sequence caused the first two exams to cover different ranges of topics between the two semesters. The final exams were not identical but contained similar problem types. While the scores for the final exam in Fig. 1 exhibit two peaks, the bimodality coefficient is 0.40, below the value of 0.55 that is indicative of bimodality. Thus, the data is not considered bimodal, and the t-test is valid.

III. Results & Discussion

In terms of demonstrated competence with property evaluation, only 3 students failed to achieve above 80% on the online quizzes before the second midterm, but all three were able to achieve it by the time of the third exam. In contrast, approximately 15-20% of students were still unable to evaluate properties on the third exam during the previous offering of the course.

A significant improvement ($p<0.01$) in performance was seen in the average course grade and average grade on the third (final) exam upon implementation of the competency-based structure as compared to the previous offering. Table 1 shows the average exam and course grades for the two semesters. The average grade on the final exam rose from 66.5% to

TABLE I. AVERAGE EXAM AND COURSE GRADES

	Exam3	Course Grade
Spring 2011	66.5%	76.2%
Spring 2012	74.0%	83.2%

74.0%, while the overall course grade rose from 76.2% to 83.2%.

The normalized grade distributions for the third exam and course grade are shown in Fig. 1. During spring 2011, the grades on the final exam exhibit two peaks, with one of the peaks occurring in the 'F' range and the other in the 'B' range, as Fig. 1 shows. This prevalence of students failing the final exam is indicative of the number of students that were still struggling to grasp fundamental skills required throughout the course. During spring 2012, this occurrence disappeared, but the peak remained in the 'B' range. This implies that the competency-based approach was particularly effective in helping students that were struggling to grasp basic concepts, and an improved performance resulted especially among the worse students. The overall course grades for both semesters were close to a normal distribution, however a significant shift towards higher scores was seen during spring 2012 when the competency-based approach was implemented.

An additional benefit of the competency-based approach is that students seemed to gain a greater appreciation for the importance of building proficiency with basic skills. One student in the end-of-semester course evaluation commented "*I felt that the makeup exams were very useful in helping me understand how to use the property tables. I think the idea of having to get above an 80% on the test is an effective way of making students learn the material and not just try to get by*." Another student commenting on the retakes said *"This forces people to confront their struggles with initial material which is critical to success in the rest of the course."* No students complained about the extra workload of re-taking online exams, as they seemed to grasp the importance of the skills they were practicing.

In the current offering of the course (spring 2013), the minimum score to exempt students from retakes was raised to 85%. Additionally, the same exam re-take requirement was implemented for the second exam in addition to the first exam.

The competency-based approach seems to result in improved performance, particularly for those students that would otherwise perform poorly due to a failure to grasp the fundamental concepts required for the remainder of the course. While the sequential nature of thermodynamics makes it particularly well-suited to this type of approach, a number of analogous approaches could be implemented in other classes. Rather than giving tests and assignments where students merely receive a grade, setting minimum scores and requiring

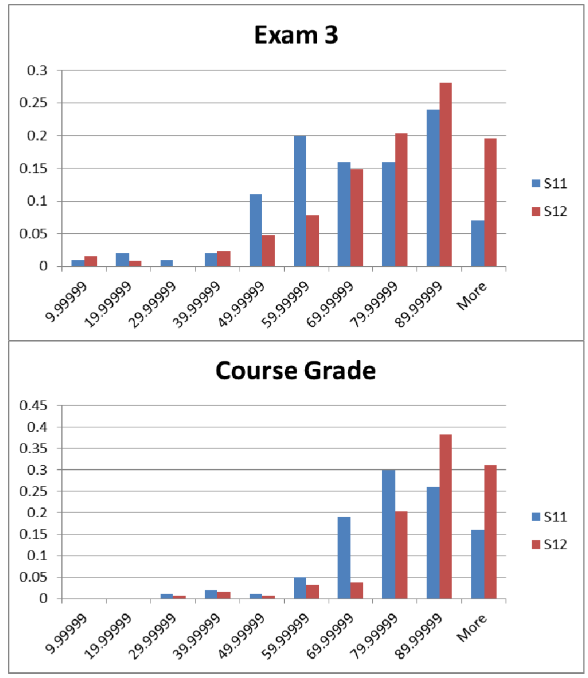

Fig. 1. Normalized grade distributions for the third exam (top) and overall course grade (bottom).

students to redo the assignments until they are proficient will enforce competence. While the repetition creates a higher workload for instructors or graders, online resources such as randomized quizzes that are automatically graded may enable such approaches to be more widely used.

Moving to a competency-based course structure forces students to review fundamental material that is necessary both later within a course and in subsequent courses. Such a format offers potential to improve student retention and student performance, aiding those that would otherwise allow themselves to continuously struggle through class after class, always remaining a step behind. Future work includes evaluating the impact of such an approach on performance in subsequent classes rather than just within a single class and expanding the approach to other engineering courses.

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Shared Note-Taking Using Electronic Enhanced Guided Notes: Peer-Review Activity, Performance, and Self-Regulated Learning Skills

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***Abstract*—Literature suggests that note-taking activity helps students in their learning process and successfully increases performance. Previous studies also have suggested that collaborative learning facilitates students to learn from different views of interpreting information. Although many studies have revealed positive correlations between collaborative learning and student performance, few studies have been conducted to investigate peer-review activity, students' performance, and self-regulated learning skills while engaged in shared note-taking using electronic enhanced guided notes. The main research question of the current study was to investigate how students' review frequency of peers' enhanced guided notes and learning performance reflected on their self-regulated learning skills. With regards to this question, we specifically explored differences among students according to their peer-review activity and performance and how the differences reflected on their self-regulated learning skills. Our findings revealed four groups of students based on those differentiation factors. Data analysis showed that while sixty percent of participants were willing to review their peers' enhanced guided notes regularly, sixty-eight percent of participants performed very well on the exams. Results also suggest that willingness to review peers' guided notes positively correlated with planning and cognitive strategies. Implications of the use of shared note-taking in an engineering classroom will be discussed.**

Keywords—electric circuit concepts; enhanced guided notes; self-regulated learning; shared note-taking

I. INTRODUCTION

Research suggests that students learn best when they take an active role in learning through discussion, practicing, games, and applying concepts and ideas (e.g., [1, 2]); however, these activities are often impractical to conduct, particularly in large classes. A recent study involving engineering students found that active learners achieved greater levels of learning and motivation than did their passive peers [3]. The use of guided notes can facilitate active learning in a more practical way. Guided notes are prepared by instructors and contain incomplete text, diagrams, and graphs. Students must listen to their instructor and think critically in order to answer the prompted questions and fill in missing parts of the information. The benefits of note-taking activities include development of higher-order thinking skills [4, 5] and improvement of an individual's concentration [6]. Literature also suggests that note-taking activities help students in their learning process and successfully increases learning achievement.

While the idea of note-taking is not new, studies regarding the use of an electronic or a handheld device to support note-taking is still in the preliminary phase. The rapid development of hardware, software, and the internet has impacted the innovation of technology and computer use in the classroom. Design of instructions has been adjusted by applying technology-enhanced applications for teaching and learning. Previous studies also suggested that collaborative learning facilitates students to learn from different views of interpreting information. Although many studies have revealed a positive correlation between collaborative learning and student performance, few have been conducted to investigate students' profiles on shared note-taking activity and learning performance reflected in their self-regulated learning skills. The main objective of this study was to investigate how students' learning performance and review frequency of peers' guided notes reflected on self-regulated learning skills while using electronic enhanced guided notes.

II. LITERATURE REVIEW

A. Shared Note-Taking Using Electronic Enhanced Guided Notes

Standard guided notes, which are also called seminotes or skeleton-notes, have been used in undergraduate teaching. Unlike the guided notes introduced in many studies (e.g., [5-7]), the enhanced-guided notes (EGN) used in this study include questions that prompt students to assess their self-regulated learning (SRL) skills (see [8]). This component is not present in the standard guided notes. The questions appear throughout the guided notes, including the introduction of each topic, elaboration of the theoretical concepts, and during

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problem solving. The EGN can be used as a tool to encourage students to plan appropriate strategies to solve problems, monitor their understanding, and adjust strategies when difficulties occur.

The electronic EGN is another format of our guided notes to facilitate students who have been using electronic pads such as an iPad or Android tablet. A network attached storage (NAS)-based online system was set up to enable students to complete and edit their guide notes and to facilitate note-sharing submission (see Figure 1; [9]). Student completion and editing of the EGN were performed on PDF-formatted files using an iPad 2TM device. Students could take as many notes as they liked on the EGN provided. When homework was due, the students submitted their group's copy of the EGN through a repository server.

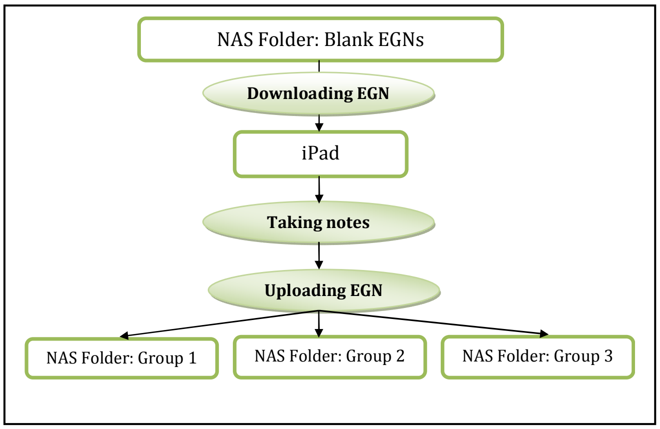

Fig. 1. System architecture of electronic-based EGN for shared note-taking using Network Attached Storage (NAS) and iPad.

The electronic shared note-taking was used as an approach to implement our enhanced guided notes in this study for three reasons: First, for each topic, there are aspects of the course materials that are not covered during the lecture. The materials may be part of the course materials, but insufficient time is available for detailed coverage during lectures. The second reason is to help students to become familiar with different views and clarify information with their peers. Collaborative learning is particularly important during several hours of study per course hour that is expected of engineering students. When the faculty is unavailable, access to information occurs through the shared note-taking activity. Third, electronic shared note-taking encourages new learning experiences for students. The students can take advantage of information and communication technology for learning.

B. Self-Regulated Learning and Student Performance

According to Zimmerman self-regulated learners are "metacognitively, motivationally, and behaviorally active participants in their own learning process" [10, p. 329]. While many theoretical perspectives of self-regulated learning (SRL) have been offered [11-14], this study chose Butler and Cartier's model of self-regulation. The model characterizes SRL as a complex, dynamic, and situated learning process [11, 15-17]. The model consists of eight features that interact with each other: layers of context, what individuals bring, mediating variables, task interpretation, personal objectives, SRL processes, cognitive strategies, and performance criteria. The current study will focus on three main features including task interpretation, SRL processes, and cognitive strategies.

Task interpretation is the heart of the SRL model insofar as it shapes key dynamic and recursive self-regulating processes. Students' interpretation of task demands is a key determinant of the goals set while learning, the strategies selected to achieve those goals, and the criteria used to self-assess and evaluate outcomes. Students manage their engagement in academic work by using a variety of SRL processes: planning, monitoring, and adjusting approaches (or regulating) to learning. Students prepare their learning activity, select strategies for task completion, self-monitor progress, and adjust goals, plans, or strategies based upon self-perceptions of progress or feedback and performance. These strategies are iterative and dynamic endeavors. Furthermore, the term cognitive strategies refers to students' cognitive activities employed as they engage in learning that is planned, monitored, and adjusted through self-regulating strategies.

Previous studies suggested that self-regulated learning strategies benefit students in their learning activities (e.g., [18, 19]). Zimmerman and Pons found that consistency in employing self-regulated learning strategies is highly correlated with student achievement [20]. When students engage in learning concepts or solving problems, self-regulated learning skills emerge. Schoenfeld argued that a lack of success in problem solving may result from the absence of assessment and strategy decisions [21]. Thus, our goal in this study was to investigate students' task interpretation, cognitive strategies, and self-regulated learning strategies and also their performance while learning using electronic-based shared note-taking.

III. STUDY

Thirty engineering students enrolled in the Fundamental Electronics for Engineers course participated in this study. The course covered the study and application of direct DC/AC and digital concepts including circuit fundamentals, theorems, laws, analysis, components, digital design fundamentals, and combinational circuits design, equipment, and measuring devices. Students worked in groups of three during the spring 2012 semester to complete the EGN using an iPad 2. Six student-completed EGN, from EGN #6 to #11, were collected to be evaluated. The use of these enhanced guided notes was intended to replace the one-way communication that was typical of class meetings. Students were asked to fill in the blank spaces found on the pages. The enhanced guided notes prompted students with what/why/how questions regarding the material covered to exercise their SRL skills.

A self-regulated learning survey instrument developed using Butler and Cartier's SRL model was used to capture students' task interpretation, SRL processes, and cognitive strategies. The SRL survey was adapted from the Inquiry Learning Questionnaire (ILQ) by Butler and Cartier based on their theoretical model [15-17]. Students were asked to rate themselves on a 4-point Likert scale (1 = *almost never*, 2 = *sometimes*, 3 = *often*, 4 = *almost always*). Five subscales were developed to capture students' SRL skills at end of semester. The subscales were task interpretation, planning, monitoring, regulating, and cognitive strategies. Subscales of the questionnaire had Cronbach's Alpha scores ranging from .637 to .870 (see Table I for samples of the SRL questionnaire items).

The cluster analysis technique was used to investigate differences among the participants based on their learning performance and review activities on peers' EGN. We evaluated students' learning performance in two regular and final exams. Review activities on the EGN were counted from a system log on a repository server. A hierarchical cluster analysis using Ward's method was used in the cluster analysis to find relatively homogeneous clusters based on measured parameters. Three phases of cluster analysis were conducted to come up with student groups. Phase 1 was conducted by running the cluster analysis using learning performance data, then review frequency on peer's EGN data. Phase 2 was the opposite, running the cluster analysis using review frequency on peers' EGN and learning performance data. Phase 3 was conducted by comparing the results from Phases 1 and 2, and excluded unmatched data. Five sets of data were deleted as a result of this process.

TABLE I: SRL FEATURES AND EXAMPLES

Features	Examples
Task Interpretation (*TI*)	• When I have to learn and solve math, science, or engineering problems involving new concepts, *I find important details or facts (e.g., symbols, units)*.
SRL Processes: *Planning Strategies* (*PS*)	• Before I begin the activity of learning and solving math, science, or engineering problems involving new concepts, *I start by choosing a method for completing the problems*.
SRL Processes: *Monitoring Strategies* (*Mon*)	• When learning and solving math, science, or engineering problems involving new concepts, *I check whether I can describe the main topic of the subject*.
SRL Processes: *Regulating Strategies* (*Reg*)	• When I have difficulties learning and solving math, science, or engineering problems involving new concepts, *I check to make sure I have completed everything required for the activity*.
Cognitive Strategies (*CS*)	• While I am learning and solving math, science, or engineering problems involving new concepts, *I pay attention to underlined or bolded words in learning resources, if there are any*.

Furthermore, nonparametric statistical analyses such as Mann-Whitney and Wilcoxon tests were used to analyze students' learning performance, peers' review activities, self-regulated learning skills, and supporting data from a system log on a repository server. Spearman tests were also carried out to investigate correlation scores between students' performance, review frequency, and self-regulated learning skills.

IV. FINDINGS

A. *Differences among Students According to Review Frequency of Peers' Enhanced Guided Notes (EGN) and Learning Performance*

Our findings revealed four groups of students named as Group 1 (high performance and review), 2 (high performance and low review), 3 (low performance and high review), and 4 (low performance and review). According our data analysis, Group 1 included students who reviewed their peers' EGN at least once per EGN and performed very well on their exams. Group 2 included students who reviewed their peers' very rarely and also had very high performance. Characteristic of Group 3 was students who reviewed their peers' EGN at least two times per EGN, but they did not perform well on their exams. Last, students who almost never reviewed their peers' EGN and had low performance on their exams were categorized into Group 4 (see Table II).

TABLE II: MEAN DIFFERENCES OF REVIEW FREQUENCY ON PEERS' ENHANCED GUIDED NOTES AND PERFORMANCE

Groups	Average Review per EGN	Average Performance
1 (*n* = 11)	9.91/6 = 1.65	91.64
2 (*n* = 6)	2/6 = 0.33	92.69
3 (*n* = 4)	15.75/6 = 2.63	69.54
4 (*n* = 4)	1/6 = 0.17	74.37

As shown on Table II, a majority of the participants were enthusiastic to participate in the shared note-taking activity. The system log on our repository server showed that more than half of the participants (15 students or 60 percent) frequently reviewed their peers' guided notes and only 40 percent of the students very rarely reviewed their peers' EGN. Furthermore, our analysis on students' learning performance in two regular and final exams showed that, on average, 17 students (68 percent) had very good learning performance (see Groups 1 and 2). We further evaluated students' learning performance of the four groups as we found before (see Figure 2). The findings revealed that, despite the increasing level of difficulty of the learning contents, Groups 1 and 2 showed a high performance and significant increase of their exam scores, from the first to second regular exams ($p < .05$). In contrast, no significant improvement was found for Groups 3 and 4 (see Figure 2 and Table III).

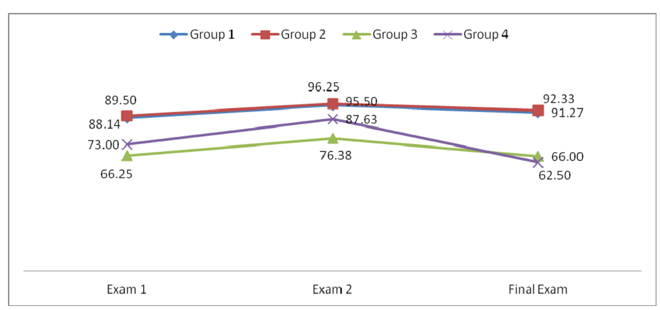

Fig. 2. Distribution of exam scores of Group 1 (n = 11), Group 2 (n = 6), Group 3 (n = 4), and Group 4 (n = 4).

TABLE III: SIGNIFICANT DIFFERENCES BETWEEN EXAMS SCORES

Groups	Exams 1-2	Exam 2- Final Exam
	***Z* (*Sig.*)**	***Z* (*Sig.*)**
1 (n = 11)	-1.852 (.032)**	-1.339 (.095)
2 (n = 6)	-1.890 (.029)**	-1.014 (.310)
3 (n = 4)	-1.604 (.054)	-.730 (.433)
4 (n = 4)	-1.604 (.054)	-1.461 (.072)

Note: ** Significant at $p < .05$ (1-tailed).

Furthermore, a series of Mann-Whitney tests suggested that Group 1 outperformed Group 3 on all exams ($p < .01$). Group 1 also outperformed Group 4 on the first exam ($Z = -2.070$, $p < .05$) and final exam ($Z = -2.866$, $p < .01$). The tests also revealed that Group 2 outperformed Group 3 on the first exam ($Z = -2.412$, $p < .01$), second exam ($Z = -2.096$, $p < .05$), and final exam ($Z = -2.574$, $p < .01$). Furthermore, Group 2 outperformed Group 4 on the first exam ($Z = -2.606$, $p < .01$) and final exam ($Z = -2.566$, $p < .01$; see Table IV).

TABLE IV: DESCRIPTIVE STATISTICS OF PERFORMANCE

Groups	Exam 1	Exam 2	Final Exam
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
1 (n = 11)	88.14 (10.89)	95.50 (5.32)	91.27 (8.06)
2 (n = 6)	89.50 (6.78)	96.25 (3.39)	92.33 (3.88)
3 (n = 4)	66.25 (10.71)	76.38 (14.87)	66.00 (11.66)
4 (n = 4)	73.00 (6.36)	87.63 (11.25)	62.50 (10.63)

B. *Self-Regulated Learning Skills of the Groups of Students*

Data from self-regulated learning (SRL) questionnaires were analyzed to investigate students' SRL skills during the semester. On the previous findings, we reported four groups of students according to their performance and review frequency of their peers' EGN. The mean value of each SRL skill was used to describe students' SRL profile that belonged to those groups. We were interested in understanding whether the groups had different levels of SRL skills at the end of semester. Differences between groups were interpreted based on mean differences. Since the number of data sets was very limited, we did not expect to find significant differences on data analysis. Descriptive statistics of groups' task interpretation, cognitive strategies, and SRL processes while learning electric circuit concepts using electronic EGN can be read in Table V below.

TABLE V: DESCRIPTIVE STATISTICS OF SELF-REGULATED LEARNING SKILLS

SRL	Group 1 (*n* = 11)	Group 2 (*n* = 6)	Group 3 (*n* = 4)	Group 4 (*n* = 4)
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
TI	2.98 (.29)[a]	3.30 (.24)[a,b]	3.15 (.50)	2.95 (.25)[b]
PS	2.66 (.45)	2.29 (.66)	2.81 (.38)[c]	2.25 (.35)[c]
Mon	3.12 (.24)	3.20 (.23)	3.39 (.36)	3.18 (.22)
Reg	2.95 (.49)	3.03 (.29)	3.04 (.44)	3.13 (.16)
CS	3.22 (.32)	3.10 (.44)	3.31 (.41)	3.06 (.13)

Note: (a) Group 2 scored significantly higher than Group 1 on TI ($Z = -2.031$; $p < .05$); (b) Group 2 scored significantly higher than Group 4 on TI ($Z = -1.901$; $p < .05$); (c) Group 3 scored significantly higher than Group 4 on PS ($Z = -1.845$; $p < .05$).

Three interpretations of findings are reported from the data analysis. *First*, students who regularly reviewed their peers' EGN reported higher scores on planning and cognitive strategies compared to other groups who rarely reviewed their peers' guided notes. Related to this finding, students' who performed very well on their exams and regularly reviewed their peers' guided notes (Group 1) reported relatively higher scores on task interpretation, planning and cognitive strategies than students who did not perform well and rarely reviewed their peers' guided notes (Group 4). *Second*, although Group 3 had low performance on their exams, they seemed to benefit from reviewing their peers' EGN as they reported the highest scores on SRL skills compared to the other groups. Group 3 also outperformed Group 4, students who had low performance and did not regularly review their peers' EGN, on planning strategies. *Third*, students who performed well on exams, but did not regularly review their peers' EGN, outperformed Groups 1 and 4 on task interpretation.

Moreover, Spearman tests revealed that performance had a positive relationship with SRL skills, although not significant ($r = .119$, $p = .286$). On the other hand, willingness to review peers' guided notes had significant positive correlations with planning ($r = .557$, $p < .01$) and cognitive strategies ($r = 364$, $p < .05$). These findings were supported by Mann-Whitney tests, that students who regularly reviewed their peers' guided notes reported significantly higher scores on planning strategies than those who did not engage in peer-review activity ($Z = -2.023$, $p < .05$).

Since our SRL questionnaire items captured students learning activities related to conceptual understanding and problem solving, we further investigated artifacts of student learning on a repository server's system log and copy of groups' submitted EGN: uploaded EGN to the repository server; downloaded EGN from the repository server; and completed the EGN. Uploading the guided notes reflected students' awareness of taking notes and sharing with their peers. Downloading EGN reflected students' awareness of learning from their own note-taking or making some revisions. Furthermore, completing the EGN reflected to what degree students' filled in the blanks on their guided notes. Either they completed the notes in class by themselves or after reviewing their peers' EGN. Our findings revealed that Group 1 was outstanding in uploading, downloading, and completing their own EGN. It is also interesting to note that Group 4 was below Group 1 in those activities (see Table VI).

TABLE VI: STUDENT ACTIVITIES WHILE USING THE SIX ENHANCED GUIDED NOTES (EGN #6 TO #11)

Groups	Upload EGN	Download Own EGN	Complete the EGN (%)
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
1 (n = 11)	15.91 (4.35)	14.45 (5.96)	86.91 (13.67)
2 (n = 6)	13.17 (5.74)	11.67 (6.02)	79.00 (12.34)
3 (n = 4)	5.75 (5.91)	5.75 (5.91)	52.25 (27.79)
4 (n = 4)	13.25 (4.86)	11.75 (7.59)	83.75 13.40)

V. CONCLUSION AND DISCUSSIONS

The majority of the participants were enthusiastic to participate in shared note-taking activity; our data analysis of the system log found more than half of the participants regularly reviewed their peers' guided notes (60 percent) and only 40 percent rarely reviewed their peers' guided notes. From the standpoint of learning performance, findings revealed that, on average, 68 percent of participants had very good learning performance in two regular and final exams in this context of learning activity. We were also interested in investigating how students' peer-review activity and performance while learning using electronic EGN reflected on their self-regulated learning skills.

In general, we found that shared note-taking activities benefit students in exercising their self-regulated learning skills. Groups 1 and 3 who regularly reviewed their peers' EGN reported higher planning and cognitive strategies than Groups 2 and 4 who very rarely reviewed their peers' guided notes. Spearman tests also revealed a positive correlation between frequency of review of peers' guided notes and SRL skills, in this case planning and cognitive strategies. However, it is interesting to note that although Group 3 regularly reviewed their peers' EGN and reported high scores on SRL skills, they did not perform as well as Group 1 on performance. Our supporting data showed that Group 3 had low frequency on uploading and downloading their own EGN from the repository server. They also scored a low percentage on completing their EGN. Furthermore, although Groups 2 and 4 had relatively low planning and cognitive strategies, their scores on monitoring and regulating strategies were relatively the same as Groups 1 and 3. We suspect that it happened because they regularly uploaded and downloaded their own EGN for review or learning purposes. Also, they completed the content of EGN more than 75 percent of them. These findings suggested that students may achieve greater benefits while using electronic EGN (i.e., gaining high scores on exams) if they do not only review their peers' EGN but also actively complete the EGN, review, and learn from their own EGN. These activities will enhance their skills in understanding concepts and solving problems.

Based on our findings, there are at least two implications from this current study. *First*, educators may need to persistently encourage their students to participate in a collaborative learning setting. Our evaluation found that willingness to review peers' guided notes significantly correlates to planning and cognitive strategies. *Second*, educators may need to encourage their students to regularly review both their peers' and own guided notes. Our findings suggested that students who balance the review of their peers' and own guided notes may achieve higher scores on their exams. They also reported a higher awareness on their self-regulated learning skills.

Since some of our findings were suggestive and this study included a limited number of participants, interpretation should be done with caution, and future work in this area is highly recommended. Three directions are proposed for the improvement of future work. *First*, studies should be conducted with a larger sample size to determine generalizability of the findings. *Second*, future research should compare shared and nonshared note-taking activities using an experimental research design. *Third*, having a better understanding about comparisons between electronic- and paper-based enhanced guided notes would be beneficial.

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Assessing Student Knowledge Transfer During Group Work

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***Abstract*— Successful group work requires that students transfer relevant prior knowledge to solve problems. This paper establishes a method to assess dynamic knowledge transfer in a group setting through analysis of a group project in a biomechanics class. Transcripts of student-student and student-instructor interactions were coded for evidence of target tools (students identifying relevant problem features), source tools (students activating prior knowledge), answers (stopping points), external inputs (resources and prompts from individuals or the instructor), and workbench explanations (student explanations of connections between source tools and target tools). Knowledge transfer was identified when a source tool and a target tool were coded within a phrase. The frequencies of codes were quantified to provide an overall picture of knowledge transfer for each group member throughout the project. Analysis for one group (a sophomore and junior bioengineering student, and a freshman engineering student) revealed that the junior was the largest contributor in the group, followed by the sophomore and freshman. The group mentioned source tools most frequently, followed by external inputs and target tools. The analysis provided evidence of knowledge transfer within the group through their identification of target tools and use of prior knowledge to explain their observations.**

Keywords— knowledge transfer; group work; prior knowledge

I. Introduction

Studies have proposed advantages to teamwork or group work-based methodologies with university students [1]. From work in group environments, students are able to acquire skills they will need in future jobs such as, leadership, communication, problem-solving, and time management [2–5]. Positive effects have also been shown in terms of students' academic performance, motivation, and attitudes toward learning [6], [7], especially for students who find group activities to be more interesting and engaging compared to traditional teaching [8]. While previous work has examined the effect of group work on cognitive performance and attitudinal changes, there have been few studies seeking to understand how group work influences students' use of prior knowledge when solving problems.

Traditional studies of knowledge transfer, or the application of prior knowledge to novel situations, have examined students in sequestered problem solving environments with students being expected to arrive at an expert's solution [9–16]. Results of these traditional transfer studies often show limited evidence of students' abilities to reach such solutions, resulting in failure to transfer. There has been an emphasis in the literature to move away from traditional transfer methodologies towards student-centered models. Student-centered transfer identifies what prior knowledge students *are* transferring [17–21] rather than *if* students can obtain an expert solution. Educators can use this student-centered approach to understand what students are transferring to problems, and take this information to further develop students' learning [22].

While various research studies have sought to improve group cognitive products and problem solving performance [23], [24] it is still unclear what prior knowledge students are transferring while working in groups [25]. An important factor in team success is students' ability to transfer relevant prior knowledge to aspects of the team project. This study seeks to understand what student interactions with resources, group members, and problem features may facilitate knowledge transfer. In order to address this need, a coding scheme was developed to assess the knowledge that students dynamically transfer into a group problem solving scenario, and what prompts transfer to occur.

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II. Theoretical Framework

Two models of transfer were adapted to this work: preparation for future learning [21], and dynamic transfer [26]. Unlike traditional models of transfer, Bransford and Schwartz [21] suggest an alternative perspective in which transfer is thought of as "preparation for future learning" (PFL). PFL shifts the focus from sequestered problem solving to understanding people's ability to learn when surrounded by resources. PFL was used as a basis to design a biomechanics course. This design was selected to encourage students' application of prior knowledge to a self-selected final project. The PFL framework allows us to examine students' learning trajectories and learning goals [21].

Rebello and colleagues [26] utilized the PFL framework to analyze how physics students worked with an instructor to solve physics problems and applied prior knowledge to problem features. Rebello's work uses a student-centered approach that examines what students do transfer into a learning environment, allowing for identification of what connections students have made to prior knowledge and how these connections are used [17–19], [21], [26]. This model for examining transfer is referred to by Rebello as dynamic transfer [26]. Using a dynamic transfer approach allows the researcher to identify mediating factors [26] that might provide insight into interventions to promote productive transfer. This method relies on the identification of similarities by the learner instead of similarities perceived by the researcher [19]. Rebello's coding scheme [26] was adapted for this work to assess the dynamic transfer of knowledge by group members working through a problem.

III. Research Methods

Audio recordings were collected during the final group project of a course entitled "Movement Science in Biomechanics," to determine how students utilized their prior knowledge in relation to the problem features. The students were instructed to use audio recording devices during any group work inside and outside of the classroom. These recordings were then transcribed and coded based on the dynamic transfer theoretical framework previously mentioned.

A. Course Description

Movement Science in Biomechanics was designed for undergraduate engineering students as part of a five-week study abroad program during May and June of 2010 in Brussels, Belgium. This five-week program incorporated six credit hours of instruction divided between a technical elective (Movement Science in Biomechanics) and a humanities course based on the culture and history of Belgium and the surrounding area. Two members of the research team taught the Movement Science in Biomechanics course. Twelve students attended this class for three hours a day, three days a week, usually between the hours of 9:00 am and 4:00 pm.

Based on elements of the PFL theoretical framework [21], this course applied principles and concepts of biomechanics, including statics, dynamics, and physics, to human motion analysis. Students were expected to utilize various bioinstrumentation tools to collect human motion and loading data, and apply biomechanics concepts to quantify and characterize these motions and loads. This active learning course was designed to give students the freedom to apply their prior knowledge, and make connections to new material concerning movement science and biomechanics. Throughout the course, students constructed and executed experimental designs based on conceptual information learned in class through problem-based scenarios. Students designed their final project around a research question developed within groups and approved by the instructor to synthesize learning objectives in the syllabus. These learning objectives included:

- Characterize the centers of mass and ranges of motion for the human body segments and their limitations in certain pathologies.
- Determine displacement, velocity, and accelerations from experimental measurements of human motion.
- Compute net forces, moments, power, and energy on joints based on reaction force measurements.
- Relate human motion to muscle recruitment using electromyography (EMG).
- Formulate design objectives and design experiments to measure and calculate different aspects of human motion.
- Evaluate experimental results and apply to current human motion pathologies.
- Defend conclusions in discussion based on experimental results and applicable human motion theories/principles.
- Develop a presentation culminating human motion principles learned during the class and apply to a current bioengineering issue.

B. Population of Students

For the purpose of anonymity, pseudonyms were used for all of the students in this study. Twelve students from Clemson University participated in Movement Science in Biomechanics (5 females and 7 males). Within the class, the majors included: 9 bioengineering students, 1 mechanical engineering student, 1 chemical engineering student and 1 general engineering student. Analysis of one of the four groups ("Frisbee group") is presented in this paper, whose members included Frank (a junior student who had completed two semesters of physics and statics, and two years in bioengineering), Andy (a sophomore student who had completed two semesters of physics, one semester of statics, and one year in bioengineering,) and Nancy (a freshman student who had completed one semester of physics and one year of a general engineering program). Frank was also on an Ultimate Frisbee team. This group compared kinematic and muscle activity parameters for a backhand, forehand flick, and overhead "huck" Frisbee throw. Data for wrist and elbow motion were collected via EMG and electro-goniometry.

C. Coding Scheme

Audio transcripts were coded and analyzed using R Qualitative Data Analysis (RQDA), a qualitative data analysis software program [27]. A codebook was established and constant comparative analysis was used to ensure consistent coding. Reliability of the knowledge transfer coding scheme was established by two researchers independently coding and comparing representative samples of audio transcripts. Agreement was considered when codes were identified by both raters within the same phrase. Inter-rater reliability was found to be 81% for this study, within acceptable qualitative research limits [28].

In this work, problem features identified by students were coded as target tools (Tt), while prior knowledge was coded as source tools (St). Connections between source tools and target tools are identified as instances of transfer, when occurring in the same phrase. Source tools are activated by students to make sense of the new problem scenario [26], [29], [30]. As seen in Fig. 1, students may not be able to independently make connections between source tools and target tools preventing them from moving forward when facing a problem, thus arriving at a stopping point. They may then seek *external inputs (Ei)* from another group member or the instructor, who can point out relevant target tools and/or source tools to help students transfer, or make appropriate connections between prior knowledge and problem features (prompts). These interactions are important to understand how students utilize external resources when they are unable to transfer.

Student explanations of connections between source tools and target tools are coded as a *workbench (W)*. This workbench explanation can lead to an *answer (A),* which is defined as a "stopping point in the reasoning process" [26]. Answers do not necessarily require a workbench explanation, and can take the form of a statement or question. Even stating "I don't know" would mark a stopping point in the reasoning process and could prompt the student to seek external input to move forward. Students may find themselves at a stopping point at any time while working through a problem.

Additionally, Redish observes that students can explain their work in common sense terms based on their "fabricated" experiences, in contrast to "propagated" knowledge that learned from an authoritative source such as an instructor, textbook or a prior class [31]. When evidence was present in the data, source tools were coded either as "fabricated" or "propagated" [32]. Certain source tools utilized both "fabricated" knowledge and "propagated," and were co-coded as such.

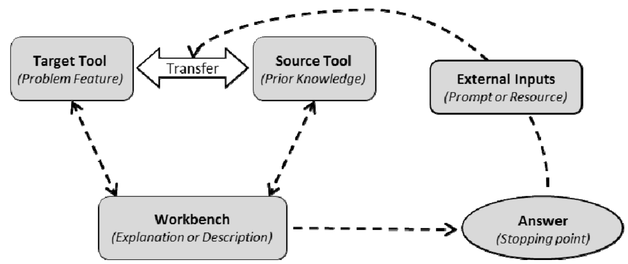

Fig. 1. Elements of the coding scheme showing how external inputs can prompt transfer through activation of target tools and/or source tools, leading to a workbench explanation and answer.

IV. Results

A. Quantification of codes

Although this case study is qualitative in nature, quantification of the codes within groups provides an overall idea of the contributions made by each member during their final project and the relative frequency at which the codes appeared in the group's transcript. Instances of codes for the Frisbee group are shown in Fig. 2.

It is evident that Frank is the largest contributor in the group across all categories, with Nancy and Andy evenly sharing the remainder of the contributions. The team mentioned source tools the most frequently, followed by target tools and external input prompts. This would indicate that they were discussing more of their prior knowledge than particular problem features during their work on their final project. This scenario would play out if they were discussing a particular target tool, such as the wrist motion during a particular Frisbee throw, and determining the appropriate source tools that would adequately describe that motion, for example angular displacement, velocity, or acceleration.

As can be expected during group work, group members prompt each other to notice target tools or use a particular source tool as part of a workbench explanation. For this group, the members had a fairly even distribution of prompts although Frank had the most prompts and the instructor had the least. Out of all of the coding categories, the instructor had the most contributions coded as external input-prompts followed by target tools and source tools. This would indicate that the instructor pointed out source tools or target tools to the group and prompted them less frequently with workbench explanations or answers. Also of note is that source tools were coded more often as "propagated" (coming from an authoritative source such as a textbook from another course). With that said, the group also had 125 instances of source tools coded as "fabricated" from their experiences during the class or outside of class. Specific instances are expanded upon in the qualitative analysis.

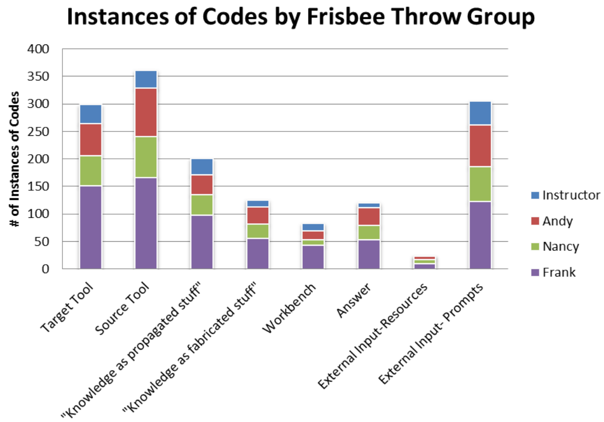

Fig. 2. Contribution of group members and instructor for the Frisbee throw group, demonstrated through instances of codes.

B. *Qualitative results*

Qualitative analysis of the transcripts was used to get a more comprehensive view of how the students interacted with each other and their instructor. From the transcripts, it was evident that the students typically identified several problem features (target tools) and then would discuss how their prior knowledge (source tools) explained what was happening. The students debated over source tools that would be appropriate to explain the motion of the wrist while throwing a Frisbee. Using data from electronic goniometers, students generated graphs to represent wrist motion in different planes (flexion-extension and radial-ulnar). Students used the generated graphs as target tools to grapple with and understand this wrist motion. Concepts of radial-ulnar and flexion-extension motion are "propagated" source tools because they were learned in class lectures. In contrast, descriptions of motion based on previous Frisbee throwing experiences are "fabricated" source tools, for example a forehand flick and "huck" (overhand throw).

During their data analysis, students began to comprehend that, although the motion of the Frisbee is in one plane, the wrist has two components of motion for the throw to occur. The following excerpt is an example of the students' discussion of what motion is occurring at the wrist during a forehand flick Frisbee throw. Codes noted at the beginning of phrases are represented throughout the entire phrase. Otherwise the codes are denoted immediately following the words of interest. Abbreviations of codes are provided in Table I.

TABLE I. CODE ABBREVIATIONS, USED TO REPRESENT CODES THROUGHOUT THE TRANSCRIPT EXCERPTS

Code Abbreviations	
Code	***Abbreviation***
Source Tool	*St*
Target Tool	*Tt*
Workbench	*W*
Answer	*A*
External Input	*Ei*

Frank: *(Ei,W)* "So the thing is that I think with this one, this is going to sound really weird, but I think the radial ulnar *(St,Tt)* and the flexion extension *(St,Tt)* were on the same plane *(St,Tt)* which I know sounds impossible."

Andy: *(Ei)* "That's impossible."

Frank: *(Ei,W)* "But I think what it is, is the radial ulnar *(St,Tt)*, … you turn your hand *(Tt)* and now it's flexion extension *(St,Tt)*."

Andy: "Ohhh."

Frank: *(Ei,A)* "I think they're in the same plane *(St,Tt)*; they're just not in the same …"

Andy: *(Ei)* "…so you're saying you're starting out radial ulnar *(St)* and then you completely…"

Frank: *(Ei,W)* "…Yeah. Yeah. Because if you look at this right here the peak for the ah, elbow *(St,Tt)* starts happening right here. The peak for the radial ulnar *(St, Tt)* starts happening right here and the peak for the flexion extension *(St,Tt)* happens right there. It's like there's one after another …

(Ei,St) Yeah, but it's like elbow starts, wrist starts and that starts…"

Andy: *(Ei,W)* "…No, no. For this graph *(Tt)* proves you wrong because it's showing that both of them, you're still, you're moving both at the same time *(St)* meaning that…"

Frank: *(Ei,Tt)* "…only for a very short period of time though."

This is an example of complex connections that Andy and Frank make, peeling back layer by layer to identify crucial ties between source tools and target tools. Before they can understand the data (graphs), they are reenacting a slow motion "flick" and what that means in terms of wrist flexion-extension, wrist radial-ulnar and elbow flexion extension motions. They are determining if there is enough significant contribution to include the elbow in their calculations. Frank argues there is definitely extension but Andy argues that because it is not in the same plane, it should not be included. Nancy, a freshman general engineering student, stays more to periphery asking questions, and observing the discussion between Andy and Frank. At a stopping point in their reasoning process, they consult the instructor to gain a better understanding of the connections between the source tools of slow motion reenactment, "propagated" planes of motion and the target tools of the graphical data.

Frank: *(St)* "…calculating velocity *(Ei)* so [instructor], is it possible with *(St,Tt)* the method you've been using with the [electronic goniometers], to calculate tangential velocity? *(A,W)* Is it possible to stay on the flick throw *(St)* to consider the contribution of both flexion extension *(St,Tt)* and radial ulnar *(St,Tt)* because they're not both on the same side – the elbow-wrist plane *(St,Tt)* …. This is the change in the angle *(St,Tt)*. So looking at this you can actually tell that the flexion-extension *(St)* is the yellow *(Tt)*. It's actually contributing because this right here *(Tt)* is …"

Instructor: *(W)*"…and then it's flipping through *(Tt)*. So vector analysis *(St)*… *(Ei,A)* So you're flicking *(St)*. So really your plane *(St,Tt)* is like this, right?"

Andy: *(Ei)* "Yes."

Instructor: *(Ei,St,Tt)* "So which is like you're basically doing some of this and some of this [demonstrates wrist motion]."

Andy: *(Ei,A,W)* "You're doing mostly [demonstrates wrist motion], because it's like a little of both."

Instructor: *(Ei,W)* "So the way you define an omega *(St)*…so call this like an X, Y [axes] *(St)* right? So this is your omega X, this is omega Y and so *(St)*… if you could tilt it you really have some arbitrary omega *(St)*. If you could you would have really just a rotation about the one point, right *(St,Tt)*? So in other words, like I'm doing some of this and I'm doing some of this [demonstrates wrist motion]."

Andy: *(Ei,A,St,Tt)* "And the resultant in that [plane]."

Instructor: *(Ei,A)*"And the resultant *(St)*, right. So basically what I want to do is find the resultant of this *(St,Tt)*."

Andy: *(Ei)* "Okay."

Instructor: *(Ei,A)* "So what I would do is take the two values *(Tt)* and um, you can do a vector sum *(St)* of that."

The instructor provides the missing source tool of "vector analysis" as a way of explaining how two different planes of motion (flexion-extension, radial-ulnar) can contribute to a "resultant". Although these are concepts students have studied in previous courses, such as physics and statics, they were unable to transfer this knowledge to the context of the wrist flicking motion. This is the type of discussion that is important according to the preparation for future learning framework upon which the course design was based [21]. Instruction is designed such that the same concepts are applied in contrasting cases (flick, backhand, overhead throws) so that students can learn to connect the same source tools (prior knowledge) to different target tools (problem features).

V. Discussion and Conclusions

Defining knowledge transfer as the ability to apply prior knowledge to new situations, and achieve a defined answer has led to more evidence of failure than success. This study utilized a revised definition of knowledge transfer that focuses on what knowledge students transfer into a new situation rather than if they transfer knowledge based on a prescribed expert solution. The long-term goal of this research is to understand what student interactions with resources, group members, and problem features may facilitate knowledge transfer in a group setting. To that end, a coding scheme was developed to assess the knowledge that students dynamically transfer into a group problem solving scenario, and what prompts transfer to occur. The coding scheme, based on Rebello's dynamic transfer framework [26], successfully allowed for assessment of individual group members' interactions with each other and external resources. The methodology presented here also allows for the assessment of both prior knowledge activation (source tools) and problem feature (target tool) identification by individual students within the group.

This methodology stands apart from other transfer methodologies in that students guide the instructor through problems forcing the researcher to take an actor-oriented approach [19]. Additionally, we have examined how students prompt each other to solve a problem in a more typical student group setting instead of how an individual solves a problem in a clinical or teaching interview [26].

This study focused on the interactions observed within a single group working on their final project in a biomechanics course. Recordings of the group's meetings were transcribed and coded using the coding scheme presented, identifying source tools, target tools, external inputs, workbench processes, and stopping points.

Quantification of the codes revealed that the group discussed their prior knowledge (source tools) more than they discussed problem features (target tools) or external input prompts. This quantification also showed that group members contributed in different ways. While the quantification of the codes only provided a limited view of the interactions that occurred within the group, it gave a useful overview of the interactions providing a general idea of the group dynamics. It can be assumed that different members of a group would contribute in different ways, and results confirm this assumption. This coding scheme provided evidence of which group members discussed their prior knowledge, mentioned problem features, and/or provided prompts.

As the quantification of codes does not take into account underlying reasoning behind the statements, qualitative analysis was used to gain a more detailed understanding of how student interactions with resources, group members, and problem features may facilitate knowledge transfer. Qualitative analysis revealed that the students often negotiated within their group about how their prior knowledge fit with the problem features they had identified. This analysis also showed that the students consulted their instructor, asking for guidance, when they were unable to move forward in order to gain a piece of knowledge they were missing. The students were able to transfer the information provided by the instructor to the problem statement. This allowed the students to continue working towards an answer. These are important evaluations that inform how a student will contribute to a group and what prior knowledge students activate in each other. As they work through a problem scenario, this analysis provides insight into how students utilize resources in a group environment to get beyond an intermediate stopping point, facilitating knowledge transfer.

VI. Implications for Instruction

From an instructor standpoint, the time to transcribe, code, and analyze each group to understand all the intricacies of these connections of knowledge and use of resources is typically not feasible. But if used as formative assessment, the instructor can evaluate in real time the source tools of the student in relation to the problem features they may be struggling with. Instead of providing assistance at the first opportunity, the instructor can evaluate how the student utilizes resources by their requests for guidance and also determine how their external input contributes to their connections between concepts. Based on this methodology, an rubric could be designed to assess group interaction and connection of knowledge.

Instructors often want feedback on the use of external inputs such as new technology and how it may hamper or enhance instruction. It is important for the instructor to evaluate meaningful interactions with the technology being used by identifying activated source tools and target tools in the problem solving process. As can be seen from the students' use of electronic goniometers, technology can be evaluated based on how it prompts students and instructors use of source and target tools.

Utilizing this methodology allows assessment of how students make connections to new scenarios while working in a group setting. Breaking down these complex interactions into understandable terms and concepts will provide evidence to inform pedagogy in ways that help students make the connections intended by instructors.

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Comparing Learning Styles Questionnaires

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***Abstract*— The study reported herein considered three questionnaires available for assessing learning styles, viz., Kolb, Honey-Alonso, and Felder-Soloman. The questionnaires were implemented in a spreadsheet with automated results, and distributed to subjects of both genders, and varying age, and academic background. The aim of the work was to determine which questionnaire, if any, would be preferred by respondents. The respondents were asked to answer all three questionnaires, examine the results and indicate their satisfaction by grading each result, using a scale between 0 and 10. While the results given by each questionnaire do not allow a complete comparison, partial agreement was possible to identify. Answers provided by 52 respondents have been processed, which show that, while there is no statistically significant difference among the preference of respondents regarding the three options, a slight preference for the Felder-Soloman questionnaire is discernible.**

Keywords*— *learning styles; Kolb; Honey Alonso; Felder Soloman

I. INTRODUCTION

Learning style assessment coupled with faculty mentoring has been found to help the development of effective study skills [1].

The use of learning style preferences for developing curricula has been supported in order to create an "effective, contemporary learning environment". The use of a variety of teaching approaches has been recommended to enable learning to occur for all learning styles [2].

Seventy-one apparently different approaches, or learning style models, were analyzed [3] and more than fifty were classified into five families:

- Constitutionally based, i.e., inherent to a person;
- Reflect a person's cognitive structure;
- One component of a personality type;
- Flexible learning preferences;
- Learning approaches instead of styles.

In the present work, it was decided to consider approaches in the "flexible learning preferences" family, since it has been reported [4, 5] that learning styles may change during a person's life.

There are several tools available for the assessment of learning styles, usually in the form of questionnaires. Thus, the work reported herein sought to identify a preferred questionnaire, based on user perception. It is assumed that users are sufficiently aware of their preferred modes of learning in order to be able to judge the assessment results provided by these questionnaires.

II. LITERATURE REVIEW

Kolb [6] observed that the process of learning is different among individuals. The varying psychological structures that govern learning, and their different combinations, allow the creation of unique individual adaptive processes. The author further defines learning based on experience as the process in which knowledge is created through the transformation of experience. One is not merely exposed to an experience, it influences attitudes, desires, and ultimately changes the objective conditions under which experiences are had.

According to Kolb [7] the study of knowledge is based on how individuals learn, assimilate information, solve problems, and finally make decisions. Stemming from this analysis and the experiential learning theory, he created a learning styles inventory (LSI) in order to identify individual learning styles. Experiential learning is conceived as a four stage cycle, composed of:

- Concrete experience (CE) or "feeling": learning through concrete experiences, getting involved. Abilities in this area include good interpersonal relations and sensibility towards personal values of all parties involved;
- Reflective observation (RO) or "observing": learning through observation, seeing, listening, and internalizing;
- Abstract Conceptualization (AC) or "thinking": learning through pondering, use of logic, concepts, theories, principles, and ideas. The systematic planning and consequent action is based on the intellectual comprehension of the given situation;
- Active Experimentation (AE) or "doing": learning by taking action, and making decisions. The strategy is to work with real situations and obtain practical results.

The LSI initially consisted of 9 questions in 1976, then was expanded to 12 in 1985. The questions which make up the inventory present the respondent with four different options each. Each set of four statements must be ranked by the respondent, from 1 to 4, in order of increasing preference.

After the questionnaire is filled, a score is given to the respondent for each learning mode, CE, RO, AC, and AE. Two combination scores are also generated by subtracting the scores for pairs of opposing styles, AC-CE and AE-RO, which indicate the extent to which the individual emphasizes abstractness over concreteness and active experimentation over reflection, respectively.

With these combined scores, a learning style type grid was created by Kolb, and four learning styles defined based on the quadrants results fall under. The four styles are the **diverging**, the **accomodating**, the **assimilating**, and the **converging**. The diverging (reflective) is situated in the first quadrant with low AC-CE and AE-RO. Individuals with this learning style prefer observing, listening to, and sharing ideas. They are skilled in observing situations from different perspectives and organizing a multitude of relations in one explanation. They perceive information through the impression it causes on them, sensorially (CE), and process it in a reflective manner (OR), without the need for actively experiencing it. These are creative and innovative individuals that recognize problems and propose alternatives, in addition to understanding their peers.

The opposite of the diverging is the converging (pragmatic), located in the third quadrant. People with this type of learning style can easily solve problems and make decisions. They use experience to find solutions to practical problems. Information is understood through abstract conceptualization (AC) and processed actively (AE). They tend to converge or make decisions quickly, searching for the correct answer or a crucial piece of information efficiently.

The assimilating (theoretical) is situated in the second quadrant. Individuals with this learning style are more interested in ideas and concepts, than people. They perceive information through intellectual comprehension (AC) and process it reflectively (RO). These learners distinguish themselves by their ability to create theoretical and abstract models, by analyzing, organizing, assimilating, and integrating different pieces of information in a concise and logical manner.

The opposite of this is the accommodator (active), situated in the fourth quadrant, who trusts intuition, and tends to act based on feeling rather than logic. These individuals understand information through concrete experience (CE) and process it actively (AE). They are drawn to new challenges and experiences, learning by practice, executing plans, and adapting to different circumstances.

Honey and Mumford [8] employed the theories proposed by Kolb to develop their own work with the four stage cyclic process of learning. Initially, they developed an instrument targeted towards the business setting, the "Learning Styles Questionnaire".

They propose a learning scheme composed of four phases: the individual realizes experiences while learning, reflects on them, elaborates hypotheses, and applies this learning in other situations. According to them, people's main characteristics can be summarized in four basic learning styles: active, reflective, theoretical, and pragmatic. In each individual, evidence of all styles can be found, yet there is one dominating style.

Individuals of the **active** style are sociable, open minded, enthusiastic about new experiences, constantly involved with others in group projects, usually at the center of activities, interested in challenges as well as solving problems, and, in general, quite impulsive. **Reflective** people observe experiences from different perspectives, using observation and analysis to reach conclusions. They prefer to listen more and act later, being focused on reflection and constructing meaning. Information is registered from their own experience as well as others', and they are more pensive than active. Constituting the **theoretical** style are individuals that tend to establish relations, deduce, and integrate observations from logical and complex theories. They strive for rationality, objectivity, and logic, enjoy analyzing and summarizing, are uncomfortable with subjective conclusions, and are generally perfectionists. Last, the **pragmatic** style, is characterized by people who enjoy putting ideas, theories, and techniques into practice. They tend to avoid reflection and become uneasy with long discussions, are more practical and their ultimate goal is functionality.

Alonso, Gallego, and Honey [9] modified the Honey and Mumford questionnaire, LSQ, for use by university students and translated it to Spanish, creating the "Cuestionario Honey-Alonso de Estilos de Aprendizagem" (CHAEA).

The CHAEA is composed of 80 questions, as is the LSQ, with four groups of 20 questions, corresponding to the four learning styles, which are randomly distributed.

Each of the learning styles was defined according to the concepts presented by Honey and Mumford [10] and further elaborated on [9] in order to clarify the concepts of each style. To each, a list of characteristics describing the associated skill set was added.

Individuals who are predominantly **active** may have traits or skills such as: liveliness, improvisation, innovation, creativity, renewal, spontaneity, adventurousness, experience, leadership, participation, competitiveness, risk inclination, desire to learn and change, problem solving, and idea generation. They like experiencing situations, as well as directing debates and meetings.

Characteristics more associated with **reflective** individuals include: pondering, observation, care, analysis, receptivity, patience, argumentation, detailing, investigation, assimilation, and prudence. They prefer to listen, observe, and think before acting, are extremely attentive to details, and create alternatives.

For individuals that are predominantly **theoretical**, main traits or skills are: objectivity, criticism, organization, logic, order, planning, discipline, systematization, and summarization. They are generalists, rational, and search for hypotheses, models, theories, concepts, questions, and clear objectives. They are questioning, enjoy feeling intellectually challenged, and search for connections between models, concepts, theories or whatever they have heard.

The primary characteristics of **pragmatic** learners are: practicality, effectiveness, experimentation, technique, being realistic, usefulness, organization, actualization, efficiency, decision making, knowledge application, problem solving, and planning. They prefer learning techniques that offer practical advantages, enjoy experimenting with what was learned, and experiencing simulations of real problems.

Felder and Silverman [11], concerned about the performance of engineering students, developed a learning model which consists of two successive phases: reception and processing of information. During the reception stage, external information (captured by the senses) and internal information (which arises introspectively) become available to the individual, which selects the information to be processed and ignores the rest. Processing may involve memorization, or inductive or deductive reasoning. The learning styles are, thus, characterized by the different means of achieving learning, receiving and processing information.

In order to determine the learning preferences of an individual, based on the four dimensions of the Felder and Silverman [11] model, the Index of Learning Styles (ILS) was developed by Richard M. Felder and Barbara A. Soloman [12], at the North Carolina State University.

In the ILS two learning styles were defined for each of the four dimensions: active or reflective, sensing or intuitive, visual or auditory, and sequential or global.

Processing, either active or reflective, is related to the mental operations through which information perceived is converted into knowledge, which can be active experimentation or reflective observation. **Active** individuals prefer to experiment with ideas, processing information during activities, whereas **reflective** ones would rather process information individually, thinking and reflecting about concepts [13].

Sensing or intuitive perception allows individuals to become aware of and interpret what happens around them. The **sensing** type prefers to abstract information through sensing, uses data, facts, experiments, and memorizes information easily. The **intuitive** uses imagination, speculation, and guesses, being partial towards dealing with theories, concepts, and principles, does not like repetition, is attentive to details, and is interested in challenges.

Input, either visual or auditory, regards how people receive information through channels that can be divided into three types: visual, auditory, and synesthetic. Each person has different preferences and tends to retain more information through one of the channels. **Visual** individuals assimilate more of what they see, such as figures, diagrams, pictures, flowcharts, graphs, movies, and demonstrations. **Auditory** ones prefer written or oral explanations, and can extract more information from a discussion.

Sequential or global understanding classifies how individuals prefer to address a new subject. The **sequential** person learns in a linear fashion, through sequential steps, in which the subject becomes progressively more complex. A **global** person assimilates information randomly, without finding connections, and can intuitively skip steps during the solution of problems, perhaps not being able to explain how she/he reached the solution afterwards.

Preferences in the four proposed dimensions are assessed through the Felder-Soloman ILS questionnaire. This tool defines a score on a bipolar scale of 12 points for each dimension. The authors define three result ranges, which determine the predominant or preferred style of the respondent:

- Scores between 1 and 3 indicate a balanced preference between the two opposite learning styles;
- Scores between 5 and 7 indicate a moderate preference for a certain learning style;
- Scores between 9 and 11 indicate a strong preference for a certain learning style.

Ortigosa, Paredes, and Rodriguez [14] developed an adaptive hypermedia (AH) questionnaire, based on the ILS, to determine learning style. They sought to reduce the number of questions needed to determine a person's preferred learning style, compared to the 44 questions of the Felder-Soloman questionnaire. Their goal was to develop a system capable of determining the learning style of a student with the least number of questions possible. They showed that each learning style dimension may be determined with 4 or 5 questions, with accuracy ranging between 95.7% and 98.6% depending on the dimension. Since the ILS examines 4 dimensions, the AH-questionnaire is able to reduce the number of questions to less than half the original 44.

III. METHOD

Several limitations have been identified [3] in the questionnaires employed to determine learning styles, especially with respect to the possibility of misinterpretation of questions by the respondent. The present work selected questionnaires which, in the opinion of the authors, were composed of clearly stated questions.

Thus, three questionnaires for assessing learning styles were selected, viz., Kolb [15], Honey-Alonso [16], and Felder-Soloman [12]. The questionnaires were implemented in a spreadsheet with automated results, and distributed to subjects of both genders, and varying age and academic background. These questionnaires were selected due to their widespread use as reported in the literature, and also due to their increasing number of questions, which might signal an also increasing diagnosing capability.

Kolb's questionnaire, or Learning Style Inventory, consists of twelve questions, each involving the analysis and classification of four alternatives. Thus, the subject needs to make 36 decisions, three per question, and fill 48 cells. The result is given as a preferred learning style among four possibilities: Active or Reflective or Concrete or Abstract. In order to take the Honey-Alonso test, the subject needs to make 80 decisions, and fill 80 cells. The result is given as a pair of preferred learning styles: Active or Reflective, and Concrete or Abstract. Answering the Felder-Soloman questionnaire, or Index of Learning Styles (ILS), requires that the subject make 44 decisions, and fill 44 cells. The results are presented as four preferred learning styles: Active or Reflective, Sensing or Intuitive, Visual or Verbal, and Sequential or Global.

The respondents were asked to answer all three questionnaires, examine the results and indicate their satisfaction by grading each result, using a scale between 0 and 10. Gender, age bracket, and academic background were also recorded. Most respondents were male (59.62%). Age brackets were defined in five-year intervals, and ranged from 11-15 to 66-70. The most populated bracket was the 46-50, with 10 respondents, followed by the 36-40, with 9 respondents, and 21-25 and 31-35, both with 6 respondents each. Questionnaires were distributed to present and past students of two authors, both undergraduate and graduate, colleagues and family members. Most respondents (82.69%) had finished an undergraduate program, 32.69% had finished a graduate program, and 36.54% were in graduate school. Science and technology graduates made up 42.31% of the respondents, while health and social sciences both had 15.38% representation each, with business graduates accounting for 13.46% of the total. A graduate degree in Environmental Management was most common (24 respondents), as expected, since the work reported herein was conducted by students and faculty of such a program, as part of their activities in a Faculty Development course [17].

The results for each questionnaire were presented as short answers indicating the learning style, and interested respondents were directed to detailed online descriptions of each possible result. The questionnaires were not supposed to be answered in any specific order, neither at one sitting, but it is likely most respondents did it in the order presented: Kolb, Honey-Alonso, Felder-Soloman.

IV. Results

Answers provided by 52 respondents, and summarized in Tab. I, show that, while there is no statistically significant difference among the preference of respondents regarding the three questionnaires, a slight preference for the Felder-Soloman questionnaire is discernible. This is evidenced by the higher average score and lower standard deviation observed in the assessment of the ILS by the respondents.

TABLE I. Average and standard deviation of scores assigned by respondents to each learning style questionnaire.

Questionnaire	*Average*	*Standard deviation*
Kolb (LSI)	7.65	2.28
Honey-Alonso (CHAEA)	7.56	2.37
Felder-Soloman (ILS)	8.58	1.13

Considering the possible results of the application of each questionnaire, as described above, Tab. II proposes a correspondence among the results of the three questionnaires considered here. The visual/auditory and sequential/global dimensions of the ILS were not listed since they do not have correspondences neither in the LSI nor in the CHAEA.

Comparisons show a 69% agreement between results of the Kolb and Honey-Alonso questionnaires, 47% agreement between Kolb and Felder-Soloman, 59% agreement between Honey-Alonso and Felder-Soloman in the active/reflective dimension, 45% agreement between Honey-Alonso and Felder-Soloman in the pragmatic/theoretical dimension. Full agreement between the two comparable Honey-Alonso and Felder-Soloman results was observed in 27% of the responses, and at least one agreement between corresponding Honey-Alonso and Felder-Soloman results was observed in 76% of the responses. Agreement in the results of all three questionnaires was observed in only 16% of the answers. Tab. III summarizes these comparisons.

TABLE II. Correspondence among the possible results of the three learning styles questionnaires tested.

Kolb (LSI)	*Honey-Alonso (CHAEA)*	*Felder-Soloman (ILS)*
Diverging / Reflective	Reflective	Reflective
Converging / Pragmatic	Pragmatic	Sensing
Assimilating / Theoretical	Theoretical	Intuitive
Accommodating / Active	Active	Active

TABLE III. Agreements among results of the different questionnaires.

Questionnaires compared	*Dimensions compared*	*Agreement in results*
Kolb and Honey-Alonso	Single Kolb result	69 %
Kolb and Felder-Soloman	Single Kolb result	47 %
Honey-Alonso and Felder-Soloman	At least one agreement	76 %
Honey-Alonso and Felder-Soloman	Active / Reflective	59 %
Honey-Alonso and Felder-Soloman	Pragmatic / Theoretical	45 %
Honey-Alonso and Felder-Soloman	Active / Reflective and Pragmatic / Theoretical	27%
All three questionnaires	Single Kolb result	16 %

Based on the scores respondents assigned to each questionnaire, their preferred resulting learning style was inferred, active or reflective, and theoretical or pragmatic. Thus, results given by each questionnaire were deemed correct or incorrect according to the respondents' preferred results. With these assumptions, 59% of the LSI results were correct, 71% of the CHAEA results were correct in the active/reflective dimension, and 69% were correct in the theoretical/pragmatic dimension. Similarly, 86% of the ILS results were correct in the active/reflective dimension, and 76% were correct in the theoretical/pragmatic dimension. Considering CHAEA and ILS results correct only when both active/reflective and theoretical/pragmatic dimensions are correct, 53% of CHAEA results are correct, while 73% of ILS results are correct. Tab. IV lists these results.

TABLE IV. RESULTS DEEMED CORRECT BASED ON RESPONDENTS PREFERRED RESULTS.

Questionnaire	*Results correct*	*Questionnaire*	*Results correct*
Kolb (LSI)	59 %		
Honey-Alonso (CHAEA) Active / Reflective dimension	71 %	Felder-Soloman (ILS) Active / Reflective dimension	86 %
Honey-Alonso (CHAEA) Theoretical / Pragmatic dimension	69 %	Felder-Soloman (ILS) Theoretical / Pragmatic dimension	76 %
Honey-Alonso (CHAEA) Both dimensions	53 %	Felder-Soloman (ILS) Both dimensions	73 %

Taking the rank assigned by each respondent to the questionnaires by means of the assigned scores, and noting that some ties did occur, the ILS figured in first place in 67% of the answers, while LSI and CHAEA topped the rankings in 49% and 43% of the answers, respectively. Conversely, ILS figured in last place in only 6% of the answers, while LSI and CHAEA did so in 24% and 22%, respectively. Tab. V shows these rankings.

TABLE V. RANKINGS ASSIGNED TO QUESTIONNAIRES BY RESPONDENTS

Questionnaire	*Ranked first*	*Ranked last*
Kolb (LSI)	49 %	24 %
Honey-Alonso (CHAEA)	43 %	22 %
Felder-Soloman (ILS)	67 %	6 %

Finally, it was looked at the learning styles of the respondents in an attempt to understand their stated preferences. LSI results showed 15.7% active; 29.4% reflective, 41.2% theoretical, and 13.7% pragmatic. CHAEA results indicated 5.9% active, 84.3% reflective, 7.8% active or reflective; 23.5% pragmatic, 68.6% theoretical, 7.8% pragmatic or theoretical. ILS results showed 51.0% active, 49.0% reflective; 74.5% pragmatic, 25.5% theoretical; 90.2% visual, 9.8% verbal; 41.2% sequential, 58.8% global. Thus, considering that most respondents (90.2%) were visual learners, the fact that ILS results were the most visual of the three, with the four dimensions represented as rulers, certainly contributes to its achieving the best results. Tab. VI summarizes these results, with blocks bordered by thicker lines indicating groups which should add up to 100% in each column.

V. CONCLUSIONS

Deciding which questionnaire to apply, if one must choose among the three options considered here, should also take into account the ease of understanding the questions, the time needed to complete the questionnaire, and how the results are presented. Considering the results reported herein, the authors are inclined to indicate the adoption of the Felder-Soloman questionnaire. The ILS was ranked first among the three by 67% of the respondents, and achieved the highest average score and corresponding lowest standard deviation. Also, the ILS's 44 questions are likely to take less time to answer than the CHAEA's 80 and the LSI's 12, since the latter require ranking four alternatives each.

TABLE VI. RESULTING DISTRIBUTION OF LEARNING STYLES AMONG THE RESPONDENTS.

Questionnaire → *Learning style ↓*	*Kolb (LSI)*	*Honey-Alonso (CHAEA)*	*Felder-Soloman (ILS)*
Active	15.7 %	5.9 %	51 %
Reflective	29.4 %	84.3 %	49 %
Active or Reflective	-	7.8 %	-
Theoretical	41.2 %	68.6 %	25.5 %
Pragmatic	13.7 %	23.5 %	74.5 %
Theoretical or Pragmatic	-	7.8 %	
Visual	-	-	90.2 %
Verbal	-	-	9.8 %
Sequential	-	-	41.2 %
Global	-	-	58.8 %

Once assessed, the learning styles of students may be used by instructors to devise teaching strategies. The results should also fuel self-analysis by students, and guide learning strategies. There is conflicting evidence in the literature regarding the efficacy of changes in teaching style to accommodate for different learning styles. Dinçol, Temel, Oskay, Erdoğan, and Yilmaz [18] considered the effect of matching learning and teaching styles, and concluded that it has no significant influence on student success. On the other hand, Iurea, Neacşu, Safta, and Suditu [19] hold that if a teacher adapts his/her teaching style to the students' learning styles, academic performance will rise.

McMillan and Dwyer [20] questioned whether students should adapt to teaching strategies, or teachers should cater to the learning styles of students. They cited Dixon [21], who recommended that teachers should create a learning environment which accommodates diversity, and students use the learning style information for better learning.

Arthurs [22] considered the challenges nurse educators face to manage the wide range of learning styles in a large group of students, and suggests teaching strategies to accommodate different learning styles.

Tulbure [23] showed that employing teaching strategies suited to learning styles produces better learning outcomes. It was shown that graphical organization of information is best for assimilators, cooperative learning and investigation work best for convergers, debate and problem solving suit accommodators best. Students with diverging learning style did not show exceptional performance for any teaching strategy tested, but did achieve better results when debate was employed.

Mixed results have been reported in the literature, with some authors despairing over the apparent chaos, such as Martin [24], who examined the results obtained with the application of LSI-2 (LSI modified by Kolb, Osland, and Rubin [25]) and LSQ, concluding:

> *"Teachers in these schools would have as much information if they assigned the learning styles randomly to students rather than using the Kolb test. They might have more confidence in the LSQ, but the factor structure shows there is still much cause for concern about this scale."*

Young [26] investigated the perception of language teachers and learners with respect to the usefulness and validity of learning styles in a multicultural classroom. Teachers were almost evenly divided, with most individuals on the negative side questioning the validity of the learning style assessment, and unsure about how to use the results. Learners, on the other hand, were satisfied with the profile given by the learning style assessment and considered it useful.

Theoretical psychological evidence has been sought to validate learning style assessment. Duff and Duffy [27] examined the psychometric properties of Honey and Mumford's learning style questionnaire and concluded that it had limited reliability and validity for the population analyzed, which was composed of undergraduate business and health students.

It must be noted that changes in learning styles have been reported. Nielsen [5] reported changes in learning styles of Business Administration and Psychology students over one, two, and three years of study. Thus, it may be concluded that periodical reassessment of learning styles is recommended for better design of instructional activities.

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Learning in Style

Correlation of Learning Styles with Problem Comprehension and Perceptions in an Introductory Chemical Engineering Course

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Abstract—**Learning styles are emphasized as being preferences for how an individual learns and indicators of how studying should be approached, rather than indicators of success. This has not, however, prevented researchers from exploring whether student performance can be dependent on matching question type to learning style. In a study of medical students, Cook et al. failed to establish such a correlation. However, small sample size and the inherently high inclination of the sample population to succeed were likely high contributing factors. Further, preferences are adaptable by education, and this study was conducted with advanced students. We are interested in the correlations between learning style preferences, task perception, and student performance in the context of an introductory chemical engineering material balances course. Assignments have a natural degree of learning style bias, and we are looking to see if student preferences correlate with their performance and perceptions when these biases are considered. Results will provide evidence regarding whether learning styles can affect student performance, as well as identify naturally occurring biases in chemical engineering problems that are translatable to other fields. A better understanding of student background and learning preferences is invaluable in developing improved curriculum, especially in the ever-changing modern classroom.**

Keywords—learning styles, ILS preferences, student performance, perception

I. Introduction

The validity of learning style indicators has been a point of contention in education since their establishment. While accepted as indicators of preference for specific learning practices, there is question of whether learning styles can also be a predictor of student success. Studies on learning styles have largely focused on the use of hypermedia, rather than traditional classroom lectures, as a teaching technique. We are interested in exploring the correlation between learning styles and student performance on, and perception of, tasks in the context of an introductory chemical engineering course taught in the traditional lecture format.

II. Felder-Silverman Learning Styles

In 1988, Felder and Silverman published their model of learning and teaching styles [1]. The Felder-Silverman model identifies five dimensions of learning styles: active/reflective, sensing/intuitive, visual/auditory (verbal), sequential/global, and inductive/deductive. While we will focus solely on the learning styles, Felder and Silverman also further proposed parallel teaching styles: active/passive, concrete/abstract, visual/verbal, sequential/global, and inductive/deductive, respectively.

A. Active vs. Reflective

As the words themselves suggest, active learners prefer actively doing something with and reflective learners prefer thinking about a new topic. Active learners are generally thought to prefer working in groups while reflective learners prefer working individually [1]. They are further described as approaching learning through "active experimentation" vs. "reflective observation" [1].

B. Intuitive vs. Sensing

This dimension correlates highly with the Myers-Briggs personality indicator dimension [1]. Learners with a preference towards sensing prefer facts and generally prefer concrete, numerical, practical problems over theory [1]. Intuitors, on the other hand, prefer to consider the possibilities and more abstract relationships rather than concrete facts [1]. They tend to dislike the traditional "plug-and-chug" type problems in favor of more theoretical questions [1].

C. Visual vs. Auditory (Verbal)

This dimension describes how students prefer to receive their information. Visual learners prefer to see diagrams, graphs, and cartoons, whereas auditory/verbal learners prefer words, be they written or oral [1]. In a June 2012 preface to the original publication of the Felder-Silverman model, Felder officially explains the change in terminology from auditory to verbal, to better encompass that these individuals learn better from words, auditory or written. From here forward we will refer to this dimension as visual/verbal.

D. Sequential vs. Global

Sequential/global is a dimension that describes how the students view the material in the context of the greater picture. Sequential learners prefer calculated steps and are able to focus and follow details without having to grasp the big picture [1]. Global learners tend to learn in a less stepwise

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fashion and need to grasp the big picture before they can focus on the details to see where those details fit [1].

E. Inductive vs. Deductive

Inductive vs. deductive describes the reasoning processes of learners. Inductive learners process information from details such as observations and measurements, and they construct generalities such as laws and theories from these details [1]. A deductive learner begins at the theoretical level and subsequently "deduces" the possible results [1]. In the preface of the June 2012 publication, Felder explains the reasoning behind later omitting the inductive/deductive dimension. Felder cites induction as the more natural human learning method, while deduction is commonly what faculty use in teaching. While he continues to believe that the two are distinct learning preferences, Felder explains that he has removed this dimension from his model to prevent instructors from being "able to determine somehow that their students prefer deductive presentation and use that result to justify continuing to use the traditional but less effective lecture paradigm in their courses and curricula" [1].

F. Index of Learning Styles (ILS)

The Index of Learning Styles (ILS) is a 44-question survey designed to identify student learning preferences in the four dimensions of the Felder-Silverman model [2]. The questions are spread evenly across dimensions, 11 for each, with two possible answers for each question representing the opposing preferences of the dimension [2]. Answers are scored on a scale from -11 to +11, where positive and negative correspond to the opposing preferences [2]. For example, for the active/reflective dimension, answers showing an active preference are considered +1, and answers showing reflective preference are considered -1. If a student answers 7 questions with the answer corresponding to an active preference, and 4 with the answer corresponding to a reflective preference their score would be [(+7) + (-4)] or a +3, which shows only a slight inclination towards active learning. A score with an absolute value from 1 to 3 is considered "balanced", 5 to 7 a "moderate" preference, and 9 to 11 a "strong" preference [2].

Studies done on the reliability and validity of the ILS have shown strong student agreement with results [2][3], and the instrument has been utilized in fields ranging from engineering and computer sciences to internal medicine [2][4] [5].

III. Learning Style Preference Vs. Performance

Learning styles are emphasized as being student preferences for how they learn and indicators of how studying should be best approached [6], rather than indicators of success [2]. This has not, however, prevented a few researchers from exploring whether or not student performance can be dependent on matching question type to learning style. In a study by Cook et al. 89 medical residents and students were administered a web-based learning module [5]. Some were presented with questions that matched their learning style, while others were given questions that were designed to be a mismatch [5]. The focus of the study was on the active/reflective dimension, and no statistical significance was found in student performance regardless of whether they were matched or mismatched for question type [5]. The authors offer a number of reasons why this study may have failed to establish a connection between learning style and performance, including small sample size and the inherently high inclination of the sample population to succeed regardless of circumstances [5]. Also of consideration is that this study was conducted with students in an advanced point in their educations, and preferences can be influenced (adapted) by prior education [2].

IV. Learning Styles in ChBE 2200

Chemical and Biomolecular Engineering (ChBE) 2200, Process Fundamentals, at The Ohio State University (OSU) is the introductory course in chemical engineering. Commonly known as materials and/or energy balances, this course is traditionally taken in the sophomore year of undergraduate study and determines whether students remain in the major. Since learning style preferences are adaptable (*i.e.*, they can change over the course of a student's career with repeated exposure to specific teaching styles [2]) we are interested in looking at students in this introductory course because of the inherent diversity of their educational backgrounds. Still relatively fresh out of high school, and having spent their first several semesters in a variety of elective and general science and mathematics requirements, these students have yet to be affected by their forthcoming shared chemical engineering curriculum. Thus, in theory, they have a greater potential for variation in learning styles. Further, 150-250 students take ChBE 2200 over the course of an academic year, providing a good sample size for study. A considerable fraction of these students (nearly a quarter) do not pass the minimum course requirements, and thus do not continue as chemical engineering majors.

A. Course Description

ChBE 2200 is a lecture-based course with assessment provided through homework, quizzes, and exams. Homework is completed both individually and through specifically assigned groups. Groups are randomly assigned by the instructor at the start of term and retained through the course. Homework problems are assigned as "individual" or "group problems", to be completed accordingly. Our study focuses on the individual work only.

B. Study Design

We are interested in the correlations between student learning style preference, academic performance, and perception of homework, quiz, and exam problems to identify any effects of problem bias. Data collected are student ILS responses (administered at the beginning of the term), grades (for individual work only), and surveys regarding self-efficacy to gauge perceptions of assigned problems.

1) Preliminary Work, Spring 2013: In the spring semester of 2013 we have worked with two sections of ChBE 2200 to gather preliminary data and develop a usable survey. Initially, we polled students about every problem they encountered.

However, this is difficult to do effectively in a short (*i.e.,* no longer than one page) survey. We have changed our approach to selecting the most distinct and representative problems from each assignment and asking more thorough questions. Questions include rating the student's confidence in their solution, ease of achieving the solution, and perceived fairness of the question. Positive and negative versions of the same question ("I am confident in my solution" and "I am uncertain I completed problem x correctly") are used to gauge consistency of answers. Comparative questions are also included to determine student preference when problems demonstrating a distinct bias within a learning style dimension are available on the same assignment.

2) Challenges Identified: The primary challenge identified, as with any research involving human subjects, is compliance. It is difficult to get students to voluntarily complete a task without incentive. Furthermore, while the study is designed to not effect course content or create additional work for the instructor, it is important to have the instructor involved in order to keep students engaged and completing perception surveys. Lack of compliance proved a great hindrance to the study in Spring 2013, as students completed the surveys too sporadically and infrequently to provide robust data. The responses received did, however, prove useful for insight into survey usability even if they are not sufficient for assessing the correlation(s) of interest. Thus, the preliminary work has provided us with ideas for an improved survey design and insight into protocol execution. In future semesters, we will (with instructor agreement) assign a small number of points to the survey completion. It is important here to note that, as IRB exempt research, this study is designed such that all students complete the same tasks (same homework problems, same surveys) regardless of participation. Only data from students consenting to participate is/will be analyzed. Teaching assistant or grader support is also critical in collecting grade data for individual problems.

3) Fall 2013 and Beyond: With the insight provided in the spring term, we look to conduct a more robust study in Fall 2013 and subsequent terms. The variables of interest are difference in learning styles, with each dimension considered separately. The study will be conducted during ChBE 2200. Each learning style dimension will be investigated through assignment biases and follow-up surveys. These assignments are part of the regular course homework and will thus be administered throughout the semester. This will allow for repetition of the study with different difficulties of assignments, as learning styles may be more significant as learning and problem solving demands become more complex. Student performance on these assignments will be the quantitative measurements obtained from the study, with each student's overall class performance and GPA taken into consideration when comparing across the class. The corresponding surveys will be a brief set of questions on a 1 through 5 Likert scale (strongly disagree to strongly agree), evaluating the student's response to the given task.

V. Desired Outcomes

The correlation between learning styles and student performance or perception is not well-established, especially in the context of engineering education. There is an understood degree of "discipline bias" in material that is accepted to also influence the "type" of person who enters each field. If such a bias is shown, and student performance seen to be correlated, this would open an avenue for more informed curriculum development in the context of chemical engineering that is translatable to other fields. By developing curriculum and respective materials that are adapted to a variety of learning styles, we can not only make our disciplines more diverse and inclusive with respect to learning styles in the students (later to become professionals) that they draw, but also develop students with an ability to process information presented in a greater variety of ways. This would help develop a generation of more versatile problem solvers.

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Identifying Misconceptions Held About the Engineering Design Process

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Abstract – **The primary goal of the research presented in this work-in-progress paper is to identify misconceptions held about the engineering design process. Identification is the first step in the development of a concept inventory, an instrument for assessing misconceptions. While there are several methods for assessing misconceptions, concept inventories are an excellent method for assessing a group of students. The distractor questions identify misconceptions and possible causes for them. Misconceptions coded from student responses to incomplete scenarios of the engineering design process include the idea that engineering is solution driven instead of problem/client need driven and that engineering is merely fabrication. Future work will develop, test, and validate a concept inventory for engineering design with questions based on identifying these misconceptions as well as misconceptions identified through follow-up work.**

Index Terms – Concept inventories, engineering design process, misconceptions, P-16 engineering education.

INTRODUCTION

A critical pedagogical task is the identification of learners' misconceptions. Instructors cannot assume that every student possesses correct conceptual knowledge regarding core and discipline-specific concepts, or that s/he can identify the correct relations among various concepts in a coherent fashion, at any point in a program of study. This assessment should be separate from traditional learning assessments, since it is well documented that students with hazy conceptual understanding can nonetheless develop strategies to perform well on tests using questions that rely on knowledge recall or elimination strategies for completion, such as true/false and multiple choice [see, for example, 1].

Without a clear understanding of the correctness of students' conceptual knowledge, it is difficult, if not impossible, to gauge comprehension and preparation for succeeding courses. Additionally, work in developing instruments and strategies for correcting misconceptions cannot proceed without knowing what the misconceptions are. The identification of misconceptions about the engineering design process is the main goal of the research presented in this work in progress paper. The overall research goal is the development of a concept inventory to identify student misconceptions about the engineering design process.

ENGINEERING DESIGN PROCESS

The engineering design process is at the heart of the discipline. ABET Student Outcome 3(c) directly addresses the need to know and apply the process. The cornerstone and capstone model, providing design education at the beginning and completion of the undergraduate engineering program, is widely used. Yet, we acknowledge that assessment of student learning in design classes is an admittedly difficult process and as a result, students may go through their undergraduate careers without having their misconceptions corrected, much less identified.

There are many models in use, but for the most part they have several features in common: engineering design is problem-based and starts with the identification of and research on an issue; a design space is defined; solutions are developed and evaluated; the best solution is selected for prototyping; an internally iterative cycle of build-test-evaluate occurs; and, when a stopping rule is encountered, the artifact is reviewed to determine if it meets, within tolerances, expectations or whether the design team needs to re-enter the process at a phase appropriate to the amount of redesign that needs to occur. Throughout, there is communication among team members and with client(s).

A representative model is displayed in Figure 1 at the end of the paper. It was developed based on my assessment of other models [see, for example, 2 – 5] and my experiences as an instructor of ENGR 1620, *Introduction to Engineering* at the University of Virginia and in K-12 outreach.

MISCONCEPTIONS AND METHODS FOR IDENTIFYING THEM

It is important to understand the process of cognition in developing definitions of concepts and misconceptions. The most basic definition of cognition is the "process of knowing…and the content of those processes." It is a **fundamental** concept in the science of learning, since learning is dependent on prior knowledge and the nature of changes students can make in both processes and content. (see, for example, [6]; emphasis added) The primary components affecting a person's level of cognition are declarative knowledge and procedural knowledge. Declarative knowledge can also be defined as "semantic information…(knowledge about ideas)" and procedural knowledge as the "complement" of declarative knowledge; together, they "represent categories for describing knowledge in general" [7, p. 28]. The interplay between the acquisition and application of sets of related declarative and procedural knowledge helps students identify and internalize

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underlying concepts. However, students may internalize concepts incorrectly for a variety of reasons, and the resulting misconceptions can be a factor in student disengagement and other negative (re)actions.

A concept, therefore, is a mental construct or model that helps a person organize knowledge. It is inductively built from interactions and experiences [8]. Misconceptions, also known as an alternative framework or invented theory, develop from a flawed development process and can be resistant to change [1, 8, and 9].

There are several validated methods for evaluating conceptual knowledge; the most commonly used are concept inventories, direct interview, and strategy writing.

Concept inventories, multiple choice tests used to assess misconceptions in a variety of subject areas in science, technology, engineering, and mathematics (STEM), were pioneered by physicist David Hestenes and his colleagues at Arizona State University beginning in the 1980s. The first concept inventory addressed student misconceptions with respect to Newtonian forces. A discussion of the history, development, reliability, and validity of concept inventories, accompanied by descriptions of engineering and related science concept inventories, is provided in [10]. ciHUB [11] and the Foundation Coalition [12] are repositories of concept inventories.

Streveler, *et al*. [13] presents an overview of the results of fundamental and applied research performed in the area of the development and application of conceptual knowledge in general and in science (more specifically, physics) in particular, with an acknowledgment of the range of topics for which concept inventories have been developed. Concept inventories are recommended for the rapid assessment of conceptual knowledge; however, the instrument's available answer choices may not truly reflect all misconceptions held by students and therefore may provide an incomplete assessment. The authors support the use of alternative assessment methods that are "research-oriented, in-depth studies of small groups of students, which explore prevalent patterns of thought or mental models of phenomena" – that is, directed interviews – to capture engineering science (mis)concepts as fully as possible (p. 281).

An application of these results is "strategy writing," a qualitative problem solving method in which a student's initial focus is on concepts instead of equations [14, 15]. The outcome is a written solution protocol with three main components: identification and discussion of the main concept(s) or principle(s) involved, arguments justifying the applicability of the concept(s) or principle(s) to the problem's issue(s), and procedures for using the concept(s) or principle(s) in solving the problem [15, p. 6]. In short, a strategy is a document containing the "'what,' 'why,' and 'how' of a problem's solution" [14, p. 1496].

METHODOLOGY

Course assessments are a rich source of qualitative data, as review of essay answers and reflections can serve as proxies for direct interviews. The code list is emergent, and is originally based on a review of the literature [see, for example, 16 – 19], classroom observations, and discussions with colleagues.

The data come primarily from students in ENGR 1620, *Introduction to Engineering*, at the University of Virginia (UVa). In 2011, I reviewed and coded answers, using an emergent code list, from seventy-five first year students (25 females, 50 males) to a midterm question that asked for a response to a scenario based on an incomplete description of the engineering design process, after [15]. The result – that 26 students (35%) perceive the engineering design process as solution, not problem, driven – is reported in [16]. By the end of the semester, the number of students holding that misconception dropped to six. Partial validation of these results comes from responses to a similar question posed to twenty-two students (3 female, 19 male) in EGR 120, *Introduction to Engineering*, at Piedmont Virginia Community College (PVCC) in Spring, 2013. A related observation is that almost all students felt compelled to try to fit every part of the process in their analyses even though it is clear that only parts of it are being addressed.

Additional data come from responses to exams questions and scenarios and end-of-semester reflections of eighty-one first year students (28 females, 53 males) in ENGR 1620 in Fall, 2012 and the 2013 EGR 120 students.

The questions are provided in the Appendix. Student demographics are reported in [16 and 20].

PRELIMINARY RESULTS

TABLE I
MAIN MISCONCEPTIONS ABOUT THE ENGINEERING DESIGN PROCESS

	Female	Male
Solution-based process / engineer as fabricator	7	18
Linear, one-pass process	4	12
Engineering is only math and science	3	7
No process or resource limits or boundaries	1	6

The main misconceptions regarding the engineering design process are listed in Table 1. Additional misconceptions include the levels of complexity, definition, and organization in the process, including the need to have a process; the engineer's role in the process and the interactions s/he has; the degree of value for soft skills engineers need to have in order to conduct a successful design project; and the role of creativity throughout the process. The term "misconception" is used instead of "misunderstanding" due to the former's importance in the constructivist philosophy of education, and anecdotal evidence points to students having built a flawed conceptual framework of what engineering is based on their experiences in K-12 formal and informal learning environments. Identifying and understanding these experiences is a future research direction.

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I am grateful to Teri Reed and PK Imbrie, the leaders of the Second Annual National Meeting on STEM Concept Inventories, sponsored by the National Science Foundation (DUE 0920589), for the opportunities to network with other researchers interested in concept inventories; to current and former first year engineering students for their ideas about the engineering design process; to Reid Bailey, Ali Bouabid, and Edward Berger for the opportunity to teach these courses; to Larry Richards for mentoring and guidance; and to the reviewers for their feedback and recommendations.

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FIGURE 1
A REPRESENTATIONAL ENGINEERING DESIGN PROCESS MODEL

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APPENDIX – EXAM REFLECTIONS, QUESTIONS AND SCENARIOS

UVa 2011 Midterm Scenario: You are a general consulting engineer. A prospective client asks for help in building a prototype of the device he's sketched out. You make a copy of the signed and dated sketch so that you can evaluate the situation and possibly draw up a project schedule and cost estimate if you think the project is a good fit with your skill set. Evaluate *wrt* the engineering design process.

UVa 2012 Midterm Q and PVCC Final Q: Revisit the IDEO Deep Dive video, and critique what you see in the video *wrt* the engineering design process.

UVa 2012 and PVCC 2013 Final Reflection: What are two ideas or conceptions about the engineering design process you had at the beginning of the semester? Have they changed? If not, state that. What process or project do you think helped most in either reinforcing or changing these ideas or conceptions?

PVCC 2013 Test 1 Scenario: You are a general consulting engineer. A prospective client comes into your office asking for help in building a prototype of the device he's sketched out. You build the prototype and deliver it to him. Refer to (an earlier version of Figure 1, above). What steps are involved in the above scenario? Which steps are not?

The Effects of Direct Observation on Student Responses in the Renewable Energy REU Program at Colorado School of Mines

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***Abstract*—The Cornell Office for Research on Evaluation (CORE) Systems Evaluation Protocol (SEP) is a step–by–step guide to evaluation, emphasizing systems modeling principles, facilitating the creation of evaluation plans with clear, specific and measurable outcomes. In 2011, CORE SEP techniques were applied to the Renewable Energy Materials Research Science and Engineering Center (REMRSEC) National Science Foundation (NSF) funded Research Experience for Undergraduate (REU) site and revealed two very different pathways leading to the critical outcome of students obtaining post–baccalaureate jobs in technical fields related to renewable energies. While the experiences within a student's research group defined a clear evaluation pathway, a second pathway characterizing student attitudes shaped by the REU community at–large also emerged. This created an interesting question on the effects direct observation has on evaluation data. In response the REMRSEC REU SEP evaluation plan saw different implementations from 2011 to 2012. While both employed similar measures, the 2012 evaluators intervened only digitally. In this paper we summarize the REMRSEC REU and its CORE SEP evaluation plan. We conclude with comparison of the two evaluation implementations and speculate on how evaluator role affects the gathered data. Lastly, we discuss plans to hybridize previous implementations into the 2013 cycle, which we characterize in terms of evaluator role theory.**

I. Introduction

Ideally, an evaluator's role within a given program is clear and accepted. In practice, however, this is rarely the case because roles are contextually dependent concepts endowed with complex dynamics [1], [2]. These tenets of sociological *role theory* have been echoed and incorporated into the evaluation discipline where evaluators no longer identify as sterile auditors but as participatory social scientists [3], [4]. Patton, in 1997, attempts to classify such roles with 14 roles, 19 styles and 46 characteristics [5]. Regardless of the reasons for this cultural shift, or the impact, its existence naturally raises the questions:

1. What shapes the *evaluator role*?
2. How does evaluator role affect their evaluation?

Assuming that an evaluator is subject to heavy *role change*, stemming from the influences of their many roles, we ask how an evaluator's role is created and shaped by the program. Upon arriving at a particular role, it is highly likely that the evaluator is member of a larger community that defines the program they seek to evaluate. That being the case, it makes sense to consider how a participatory evaluator affects the program and, in turn, the overall evaluation. Scientifically, evaluator integration generates a feedback mechanism where the system responds to itself or in other words, a nonlinear system. While it is hoped that one day these questions may be addressed by nonlinear feedback analysis, we do not attempt to do so in this paper. Instead, we seek to texture and advance the ongoing conversation on evaluator role and effect by an analysis of recent evaluations conducted on an ongoing research experience for undergraduates (REU) focused on renewable energies. Here changes in evaluator role are primarily due to refinements in the program's evaluation plan and can be reasonably quantified.

At the Colorado School of Mines (CSM) there exists an National Science Foundation (NSF) sponsored Renewable Energy Materials Research Science and Engineering Center (REMRSEC), which is focused on transformative materials science advances that greatly impact emerging renewable energy technologies. After a two–year pilot program, the NSF sponsored a ten–week, eight–student REU Site starting in 2011 and lasting for three years. The goals of this REMRSEC REU are twofold

i. provide participating students with high quality research experiences in renewable energy and
ii. increase undergraduate student's interest in pursing advanced degrees in the discipline.

To address the first goal, the REU introduces talented undergraduate students to vibrant research led by teams both from CSM and the nearby National Renewable Energy Laboratory (NREL). To support positive student attitudes and academic success in these endeavors, the REU contains programmatic elements focused on communal and professional development. The importance of community as a factor in student attitudes was identified, by the REU Director, during the pilot program. Upon NSF sponsorship, efforts were made by REU program managers to better understand these aspects through the use of a more comprehensive evaluation plan.

The Cornell Office for Research on Evaluation (CORE) Systems Evaluation Protocol (SEP) is a step–by–step guide meant to support evaluators in their assessment endeavors. Through the application of systems modeling principles, the

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SEP seeks to facilitate the creation of thoughtful evaluation plans. In 2011, CORE SEP techniques were applied to the REMRSEC REU Site. As part of the planing process, program stakeholders were interviewed and a functional flow diagram, or logic model, of the site was produced. From this model, it was concluded that there were two very different logical pathways leading to the overarching outcome of students obtaining post–baccalaureate opportunities in technical fields related to renewable energies. It was expected that a student's experience within their research group would have a strong affect on their attitudes towards academic research. The emergence of a second pathway characterizing student attitudes shaped by the REU community at–large was reasonable but unexpected. In particular, the evaluator found the theme of community to be central in all stakeholder interviews. Moreover, this pathway created an interesting question of evaluation scope and nonlinear feedback. That is, the evaluator may be an obvious member of the at–large REU community and, as such, affects the system which they seek to evaluate.

Since the REMRSEC REU was well established by 2011 and knowing that previous evaluations characterized the student research experience as high–quality, the 2011 and 2012 cycles sought to understand how the program evaluator affects aspects of evaluation implementation. Consequently, the SEP plan saw different implementations from 2011 to 2012. While both employed similar quantitative and qualitative assessment methodologies, the 2011 cycle incorporated evaluators in REU program elements, which is in contrast to 2012 where evaluators intervened only digitally. The outcome of this is two sets of evaluation data, consistent with one SEP plan, whose primary difference is in the role of the evaluator within programmatic elements. A comparison of these data indicate that when the program evaluator is incorporated as a communal member, the respondent participation increases while other characterizations stay relatively the same. From this perspective, it seems, an important communal function of the evaluator is to facilitate participant self–reporting. This conclusion provides some closure to the previous sociological questions, at least as it relates to the REMRSEC REU, we outline plan to further investigate this role in the 2013 cycle.

In the following we first summarize the REMRSEC REU and its implementations from 2011–2012. Next we consider CORE SEP modeling of the REMRSEC REU and present salient features of the associated evaluation plan. In addition we compare and contrast the two evaluation implementations in an effort to understand how the incorporation of evaluation personnel affects evaluation results. In particular, we study the participation rates, and volume of a subset of evaluation data gathered by each implementation and from these data we draw conclusions about the effect of "evaluator presence." We conclude by discussing how these results find application in third–year CORE SEP REMRSEC REU evaluation implementation.

II. THE CONTEXT: REMRSEC REU

In 2008 the NSF awarded CSM a six–year grant to establish REMRSEC, which consists of an interdisciplinary team of CSM faculty from Departments of Chemical Engineering, Chemistry and Geochemistry, Liberal Arts and International Studies, Metallurgical and Materials Engineering and Engineering Physics, in addition to faculty from Academic Computing and networking; Center for Assessment of Science, Technology Engineering, and Mathematics; Center for Engineering Education; and the College of Engineering. REMRSEC faculty collaborate closely with scientific staff at the National Renewable Energy Laboratory (NREL) and also with Center for Revolutionary Solar Photoconversion (CRSP), a research center of the Colorado Renewable Energy Collaboratory, which involves NREL and Colorado universities in an industrial consortium with approximately 15 companies with business interests in alternative energy technology [6], [7]. The center consists of two Interdisciplinary Research Groups (IRGs):

TABLE I. DEMOGRAPHIC DATA 2011–2012

	2011	2012
Total	20	21
Male	9	15
Female	11	6
International	2	2
Underrepresented	3	6
Non–Traditional (age $>$ 25)	1	2
Different Home Institutions	14	13
Different Majors	8	6
Freshman	3	3
Sophomore	6	9
Junior	9	7
Senior	2	2

- Photovoltaic IRG: Specializes in research and development of future generations of photovoltaic and opto–electronic materials.
- Advanced Membrane IRG: Emphasizes micro–structural design of ion–transport membranes and composite membranes with improved stability, operational range, impurity tolerance, and transport efficiency and selectivity.

To support the research missions of REMRSEC and these IRG's the REMRSEC REU solicits exceptional undergraduate students to participate in a ten–week summer interdisciplinary summer research program focused on material science issues related to renewable energy. While the delivery of a high–quality research experience, which increases student interest in renewable energy fields, is a primary goal of the REMRSEC REU, a secondary goal is to increase the participation of underrepresented groups. Table I provides demographic data for all participating students, NSF funded or otherwise, during the 2011 and 2012 cycles. These data show the existence of a socially diverse undergraduate collective that when coupled to the 40–50 CSM faculty and staff forms an ad–hoc community for the duration of the REU.

In addition to their involvement in research projects led by CSM/NREL faculty and staff, the REU students are asked to attend various functions focused on professional, academic and communal development. Table II provides a listing of the events and their frequency associated with the 2011–2012 cycles. The goals of the aforementioned programmatic elements are to provide a construct in which students gain a breadth of understanding on post–baccalaureate opportunities in the field of renewable energy science and also the professional tools for successful pursuit of them. That said, the overarching theme of all program elements is the bringing together of members of the ten–week ad–hoc community. That is, beyond their proposed function, they are social in nature. This was noticed

TABLE II. PROGRAMMATIC DATA 2011–2012

	2011	2012
Technical Seminars	9	9
Professional Development Sessions	5	9
Student Snapshots	4	2
Laboratory Tours	3	2
Laboratory Safety Training Programs	1	1
Social Activities	8	3
Poster Sessions	1	1

by REU programmers and led to several post–pilot changes emphasizing communal engagements, which are reflected in the programs evaluation plan.

III. THE EVALUATION: CORE SEP

During 2011–2012 the author participated in Phase I and Phase II training offered by the Cornell's Office for Research on Evaluation (CORE) Evaluation Partnership (EP) sponsored by the Cornell University Cooperative Extension and the NSF. The EP seeks to develop and extend the capacity to make good choices about evaluation, which will ultimately lead to improved programs, and facilitates this with in–person and web–based training on their System Evaluation Protocol (SEP) [8]. The SEP is a standard procedure that an assessor uses to construct a thoughtful evaluation plan for arbitrary systems (Phase I) and implementation methodologies (Phase II). The result of application of CORE SEP to a system yields a logic diagram, consistent with stakeholder opinions, that connects activities to clear, specific and measurable short/medium/long–term outcomes. This informs the creation of sensible evaluation questions and data collection strategies for various time–scales that triangulates the affect of a program on its participants.

The emphasis of CORE SEP is on program modeling. The CORE SEP is organized into three broad phases which are further subdivided into smaller stages:

- Phase I (Evaluation Planing): Stage 1 – Preparation, Stage 2 – Modeling, Stage 3 – Evaluation Plan creation
- Phase II (Evaluation Implementation): Stage 1 – Implementation Preparation, Stage 2 – Data Collection and Management, Stage 3 – Data Analysis
- Phase III (Evaluation Utilization): Stage 1 – Reflection and Plan Revision, Stage 2 – Reporting

A more detailed discussion of the application of CORE SEP Phase I to REMRSEC REU can be found in our previous work [9]. In summary, the program evaluator interviews key stakeholders and from their input constructs a rough outline of the overall program. This outline is then distilled into a *logic model*, a set of activities and outcomes central to the stakeholder view of the program that, when supplemented with interdependencies, creates a *program pathway model*. A pathway model is a visual representation of the program and informs the evaluation by highlighting critical programmatic elements relevant to a programs current life–cycle. The SEP logic and pathway models for REMRSEC REU are given in Figures 1 and 2, respectively. On the logic model we see a listing of program elements, as gathered from the stakeholders, with the condition that activities must lead to short–term outcomes, which then lead to medium–term outcomes and so on.

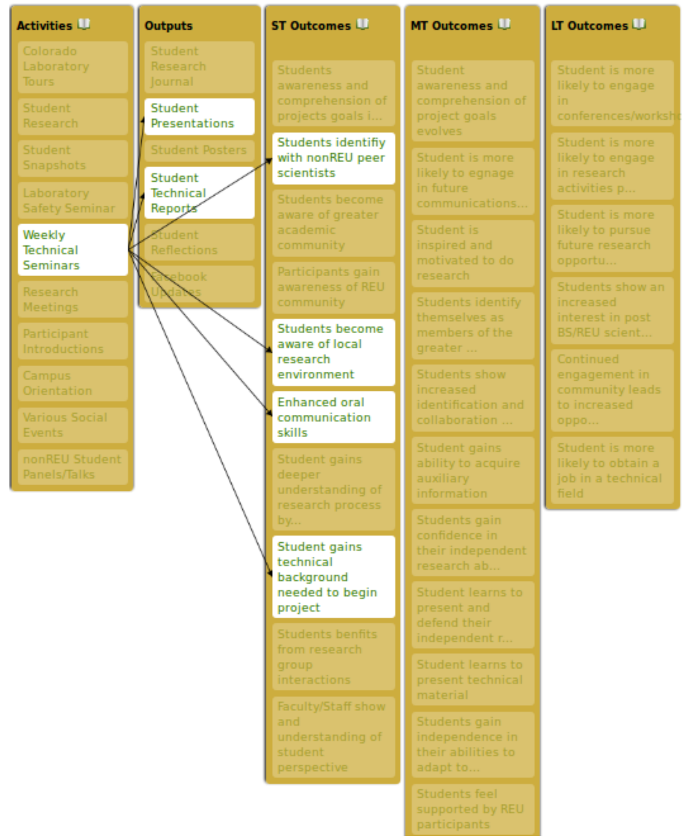

Fig. 1. CORE SEP Logic Model of REMRSEC REU

Through the Evaluation Netway (EN), a web–based utility created in conjunction with the EP, a system of interconnections can be made, which is highlighted in Figure 1 where we see that the Weekly Technical Seminars influence several student outputs/deliverables as well as some initial outcomes. Once this data is encoded, the EN can generate a Pathway Model, see Figure 2. While the interconnections/arrows may be somewhat difficult to untangle, the EN groups program elements based on causal relationships and what results is visually distinguishable paths that connect elements with thematic commonality.

In the case of REMRSEC REU there are two dominant paths, which we will call an upper–path and lower–path. The lower–path begins with activities such as laboratory training, student research and research meetings. That is, they are all academic in focus and are natural precursors to the stated medium–term outcome, "Students gain independence in their abilities to adapt to evolving research," which is related to a high–quality REU experience. However, what we also see in the pathway model is that this outcome is related to several other activities that generate an upper–path. In this upper–path we see that various social aspects, some of which are academic in nature, of the REU community lead to participants identifying with each other as well as a broader community of renewable energy scientists. It was the existence of this upper–path that evolved the REMRSEC REU evaluation, in 2011, to include methodologies that would help the evaluator better understand the effect of communal interactions on student attitudes.

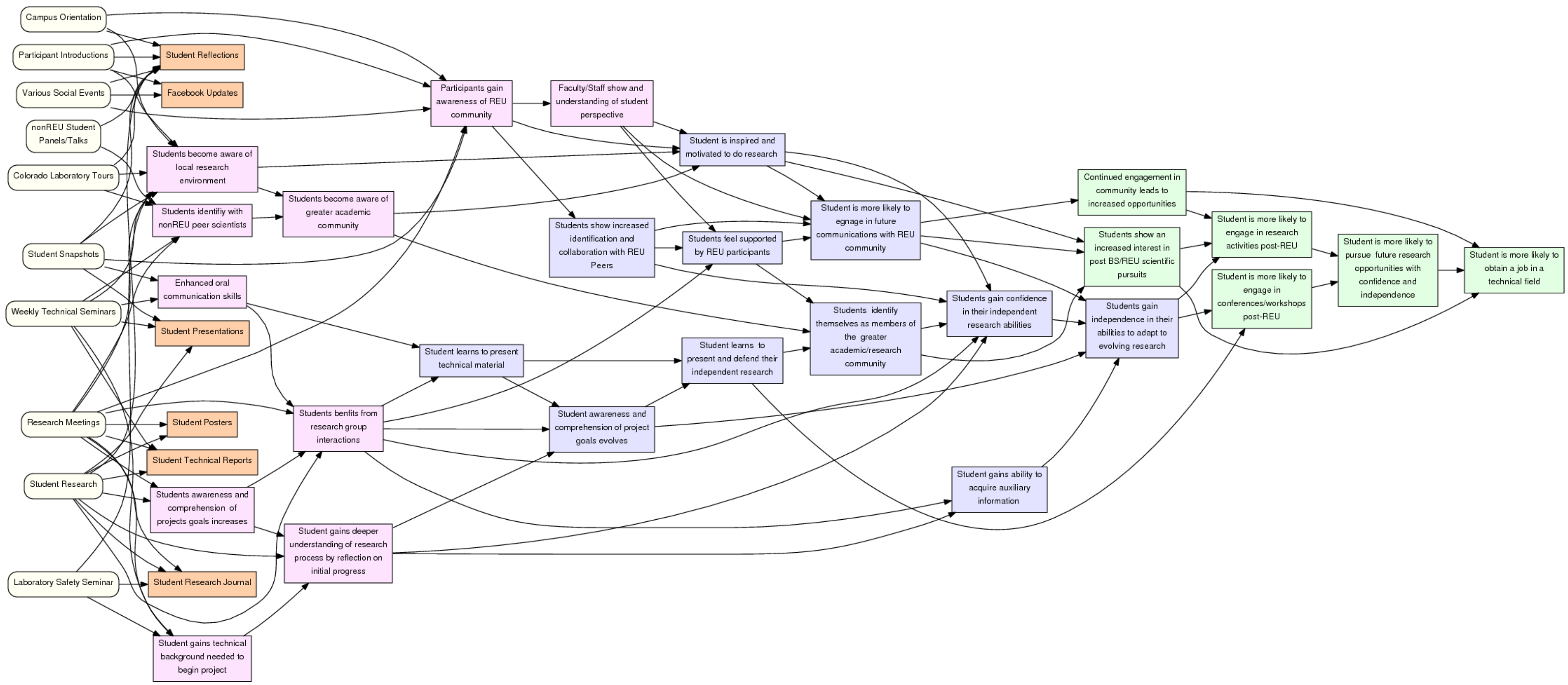

Fig. 2. CORE SEP Pathway Model of REMRSEC REU (Color Online): White represents activities, orange represents outputs generated by participants, pink are short–term outcomes, blue are medium–term outcomes and green are long–term outcomes.

A. Evaluation Implementation: 2011

In 2011 the author in conjunction with EP training in the CORE SEP created an Evaluation Plan for REMRSEC REU that exposed the existence of a pathway of outcomes which are nontrivial factors in facilitating independence in undergraduate research. This pathway starts with activities that are social in nature and are felt to lead to participants who increasingly identify renewable energy scientists as professional role models. It is expected that these attitudinal changes combined with suitable research training contributes to long–term outcomes associated with the placement of students in renewable energy fields post–baccalaureate. The success of the lower–pathway associated with those outcomes related to a high–quality research experience have been well–studied during the REMRSEC REU pilot phase, 2009–2010. The 2011 evaluation implementation sought to solidify these findings and move towards evaluating outcomes associated with communal activities. To this end we posed the following evaluation questions on the topic of community:

a. How do REU participants characterize/describe their experience in their CSM research group?
b. What is the effect of CSM research group interactions on the students research experience?
c. How does the frequency and/or quality of research group meetings relate to the students attitudes about research?
d. How does the frequency and/or quality of research group meetings relate to the students research experience?
e. How often do REU participants interact with their peers throughout the duration of the program?
f. What is the nature of the peer–to–peer REU participant interactions, i.e. voluntary or mandatory, professional or personal?
g. To what extent are REU students identifying with each other?
h. To what extent are REU students identifying with the local scientists?

To answer the previous evaluation questions we have chosen four measures. Currently, not all of the measures are fully implemented. However, we provide a detailed explanation of each in the following and conclude this section with a description of their 2011 implementation.

1. Frequency Charts: Student engagement can be characterized by the quantity and quality of their various interactions. These interactions form a shared construct for multiple evaluation questions. We plan to quantify these interactions through the use of frequency charts, which will be taken to measure student–student and student–research group interactions. In detail, we plan to have a third–party record types and frequency of interactions during social engagements and a have a group member do the same for research engagements. This, which will partially address evaluation question (e).
2. Internal Surveys: If the frequency charts are meant to measure the quantity of student interactions then the internal surveys are meant to measure their quality. We will survey key members of the students research group to characterize the perceived attitude towards and independence of student research. Specifically, we will ask these research group members how their interactions with a student contributed to the completion of a given task. This measure, will address evaluation questions (b) and (f).
3. Student Journals: In order to triangulate these previous measurements we will ask students to keep journals chronicling their REU experience. Prompts will be supplied to encourage student self–reporting consistent with the evaluation questions. These journals will then be sampled periodically and analyzed for important statements, themes and use of technical vocabulary. Of particular importance will be responses concerning evaluation questions (a)–(d) and (f), which can be compared against data from measures #1 and #2. However, the information found within the journals will go beyond these evaluation questions giving the REU organizers deeper insight into the student experience, which will be invaluable to future incarnations.
4. External Survey: The first three measures are primarily concerned with determining the nature of the dynamic REU experience as seen through peer/mentor interactions, student attitudes and research abilities/achievements. The Student Assessment of Learning Gains (SALG) is a standard online post–measurement evaluating student outcomes of REU. This self–report will end–cap the REMERSEC REU and provide both qualitative and quantitative data that will be used to both determine the REU outcomes as well as provide comparison to measures one through three on evaluation questions (b)–(d) and (g).

The 2011 cycle saw the implementation of measures #2 and #4 as well as aspects of #1 and #3. Our current goal is to further explore measure #3 because of its ability to provide rich and textured information. In conjunction with these mixed–method measurements, the evaluator was introduced at the start of the REU and attended several REU functions. For the most part these functions were driven by survey administration and interaction observation. Beyond this "presence" the evaluator attended a purely social function early on in the REU timeline. In the 2012 implementation, many of these measures would be used again but everything would take place in a purely digital format.

B. Evaluation Implementation: 2012

In the 2012 cycle the REMRSEC REU Evaluation would take a slightly different evaluation and because of this we can attempt to understand how evaluator role affects an evaluation. Specifically, this implementation saw continued use of measures #2–#4 from the 2011 cycle but now all data acquisition was handled electronically and the evaluator was known to the participants only digitally. Interestingly, that this comparison can be made is because of both a role change in the evaluator and the REMRSEC REU participants.

The evaluations conducted from 2011–2012 acquired a vast amount of data, some of which is still being processed. In the following we offer a snapshot of some simple data that motivates further discussion of evaluator role and effect. Later, in Section IV, we compare these data and offer some interpretation before discussing the implications on future evaluations. First, however, we summarize some results from the SALG standardized post–test in Table III where we see that, with the exception of response rate, students responded roughly the same, to questions about both their research and social experience from 2011 to 2012. In terms of response rate

TABLE III. STUDENT ASSESSMENT OF LEARNING GAINS: 2011–2012

	2011	2012	%–Δ
Response Rate	57%	35%	−39%
The research experience overall (4–Excellent, 1–Poor)	3.5	3.57	+2%
Pursue graduate study in materials science or engineering? (5–Extremely More Likely, 1–Not More Likely)	3.35	3.57	+6.6%
Overall program organization or logistics (4–Very Satisfied, 1–Very Dissatisfied)	3.21	3.43	+6.9%
Group social activities (4–Very Satisfied, 1 – Very Dissatisfied)	3.07	3	-2.6%
Average % (Total): Here a percentage is given where 100% would indicate a completely favorable view, on average.	79.1%	82.1%	+3.2%

TABLE IV. REMRSEC PRE/POST TEST RESPONSE DATA: 2011–2012

	2011	2012
Average Words Used Per Pre–Test: Q1	71.3	67.2
Average Words Used Per Pre–Test: Q2	55.2	58.6
Average Words Used Per Pre–Test: Q3	43.1	58.2
Average Words Used Per Post–Test: Q1	36.3	41
Average Words Used Per Post–Test: Q2	30.5	32.3
Average Words Used Per Post–Test: Q3	27.6	22.5
Percent Response Pre–Test	100%	85%
Percent Response Post–Test	66.7%	40%

TABLE V. BI–WEEKLY STUDENT UPDATES (STUDENT JOURNALS): 2011–2012

	2011	2012
First Collection Response Rate	61.9%	82.5%
Second Collection Response Rate	52.3%	77.5%
Third Collection Response Rate	52.3%	71.6%

we see a dramatic decrease from 2011 to 2012. Turning our attention now to Table IV we consider a comparison between a pre–test and post–test given to the students concerning their perceptions of scientific research. In particular we asked students to respond to the open–ended questions:

i. Describe what academic research is and what academic researchers do.
ii. What skills and resources are needed to successfully conduct academic research?
iii. What skills and resources do you possess that are aligned with those needed to successfully conduct academic research?

With these data we consider both the response rate as well as the average response length. The results of this are recorded in Table IV. Lastly, we consider the response rate associated with responses to three prompts given to participants for their journals:

I. Describe your current understanding of your research project.
II. What are your goals, associated with your research project, for the next two weeks.
III. What are you planning on doing to meet these goals?

Responses were gathered three times throughout the course of the REU. The response frequency is recorded in Table V.

IV. DISCUSSION AND CONCLUSIONS

Considering these data from Table III–V we notice a significant drop in response rate during the course of each REU. We expect that there are two reasons for this. First, as students get farther along in the REU they become more invested into their own research and less interested in program evaluation. Second, as surveys become repetitious, a certain fatigue sets in an consequently response rates drop. That said, a comparison between the two data sets shows:

- Table III indicates that while the overall response rate is dramatically lower from 2011 to 2012, responses concerning participant overall experience were roughly the same.
- Table IV shows that the response rate again favors the 2011 implementation, by 20.9%, while at the same time the 2012 participants tended to be a few words more verbose.
- In contrast to the two previous response rates we have data from Table V, which shows that the total number of 2012 participants in student journaling greatly exceeded those in 2011 by an average difference of 21.7%.

These data show that respectable response rates are possible through purely digital methodologies but, at the same time, there is not overwhelming evidence to conclude that evaluator presence is the dominant factor in low response rates. This does not preclude the notion that the evaluator facilitates participant response and it could be that a lack of communal engagement contributed to the substantial decrease in response rate for the 2012 post–test. In order to better understand this effect, the 2013 evaluation implementation will by a hybridized version of previous implementations. Specifically, we plan to introduce the evaluator at the onset with a brief discussion of evaluation plan/implementation and its purpose. After this the evaluator will again assume an entirely digital presence but facilitate increased collaboration and community through the use of web–logging tools. Journals will be collected digitally and anonymous content will be posted which, we hope, generates increased interest and relevant discussion points. This evolution of evaluator role can be characterized in terms of Patton's taxonomy pgs. 128–129 [5]:

- 2011 Cycle [Roles 5,7]: A collaborative evaluation facilitator who is available and involved reporting to diverse stakeholders and program staff.
- 2012 Cycle [Roles 2,3]: A investigative researcher who is independent and appealing to funders and academics.
- 2013 Cycle [Role 8]: A empowerment facilitator who is a resource person to program participant and community members.

Essentially, we hope to realize, in the 2013 implementation, an evaluator role that non–invasively facilitates participant self–reporting and is largely independent of program context. If such a role can exist then it is believed that the goals of CORE EP can diffuse more rapidly into the STEM disciplines.

ACKNOWLEDGMENT

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More Graph Comparison Techniques on Mind Maps to Provide Students with Feedback

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Abstract—**One of the limiting aspects in education research is the techniques available for determining if a student has learned something. In this work, the goal is to extend our exploration of how mind maps can be automatically analyzed using their graph properties to reflect student learning. In particular, a set of student mind maps are created three times during a class in both 2011 and 2012 on digital system design using a common technical vocabulary. These mind maps are analyzed by extracting graph metrics by comparison with a criterion mind map, which is an expert created mind map. The metrics are derived from traditional graph metrics (average degree and graph density), three sets of difference metrics analyzed with a internally created tool, and a graph metric invented for comparing proteins. The results of this exploratory analysis is that five of the six metrics can be used to evaluate if a student is learning and connecting the vocabulary in a given subject over time. Additionally, these five metrics are correlated to one another. This result is promising, but we emphasize that these metrics do not correlate directly to class performance based on student grades over the course, and therefore, the current goal for this measurement technique is to be used to provide the student with automated feedback on their mind maps as related to the technical vocabulary of a course.**

This work extends our original work by increasing the number of graph metrics that are used to automatically analyze student maps to a criterion map. The idea is to find a number of graph metrics that can then be combined to help analyze a students mind map and provide them with useful feedback. Even though our results show that compare 5 metrics and each metric can be used to observe student improvement, each of these metrics differs in how the metric can be interpreted and related to the process of learning. Therefore, our goal is to find a number of these metrics so that they can be combined to provide the student with a variety of feedback results to help them understand their errors in terms of the structure of their mind map.

I. Introduction

One of the limiting aspects of educational research is the techniques available for measuring if a student has learned something. Engineers and their respective research fields, however, are skilled at finding and using measurements to help improve a system. For this reason, it is the author's belief that the community might be best suited for providing more measurement tools to help in improving student learning.

Concept maps [1], [2] and mind maps [3] are useful tools in education, and they can be used both in lectures as classroom assessment techniques (CATs) and outside the classroom for the learner to express ideas in a visual form. Mind maps are words/concepts connected by lines where a line indicates a relationship between the words, and concept maps have similar structure except the connecting lines tend to have directionality (indicated by arrows) and have associated prepositional phrases that indicate how the words are related. For this work, maps are mathematically called graphs, and therefore, this research can be leveraged in the understanding and characterization of graphs to automatically analyze mind maps.

The two overarching goals are, one, to create tools so that learners can receive automatic feedback on their understanding of a topic, and two, to provide researchers with measurement tools that can be used quantitatively evaluate if an intervention is improving learning beyond existing tools such as tests and surveys. To quantify learning in a map, either the map can be evaluated by an expert, or the map can be compared to a golden map generated by an expert (also known as the criterion map). In this work, the later is used since the first of these evaluation options is very difficult for computers to perform at present. However, this work is a precursor to evaluating open maps.

Over a semester course on digital design, student mind maps were collected at three intervals during the course (course beginning, post exam I, and post exam II). These mind maps were CATs where students had 10 minutes to create mind maps that consisted of 20 technical terms, where these 20 terms are introduced throughout the semester. Each student's mind maps was then digitally encoded and analyzed using various tools. These tools calculate a number of metrics that might reflect learning including:

- A metric based on average degree in a graph
- A metric based on graph density
- A metric based on direct comparison between the two maps for missing and extra connections and words
- A metric of similarity, called Relative Graphlet Frequency distance (RGF-distance)

A more detailed description of these metrics is described including what they are, how they are calculated, and how they might relate to learning within a student's mind map.

The exploratory results show that two of these metrics are highly correlated with each other and that three of these metrics can be used to measure if a student is learning and developing a deeper understanding of the vocabulary over the time of a course. These metrics are checked for correlation

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with student grades, but results show that correlation is low and not statistically significant. This is, likely, due to the fact that course grades and deep understanding of the course's vocabulary are not closely related in the chosen course, and a student can perform well in this course independent of vocabulary knowledge.

Some of these ideas were first presented last year at FIE'2012 [4]. This work has been extended to include more data as well as more graph metrics of comparison. The analysis presented in this work shows only the 2012 subjects as the conclusions from the analysis are roughly the same for both 2011 and 2012.

The remainder of this paper is organized as follows. Section II reviews scoring techniques and technical vocabulary. Section III introduces the metrics of measurement in more details and relates how these metrics might be related to student understanding in a mind map. Section IV describes the experiment, and Section V shows results. Finally, Section VI concludes the paper and suggests future work.

II. Automated Map Scoring and Technical Vocabulary

As a precursor to automated map analysis, various methods of scoring a map have been proposed by researches, and a brief list of scoring methods in the literature include the following:

- Concept map - count the number of valid propositions, levels of hierarchy, examples, and crosslinks [1] where weights can be introduced to each count ([5], [6])
- Concept map - a measure of *hierarchiness* which relates hierarchy in the map [7]
- Mind map - compare the scores on tests to the technique [8]
- Concept map - the more important a concept, the closer it is to the top of the tree [9]
- Mind map - have two independent experts score (sometimes with a rubric) the mind map on a scale two times with one week delay and compare correlation of ratings [10]

The scoring of maps has been challenged by many researchers in the literature [11], [12]. Kinchin and Hay [13] criticize the shortcomings of strict scoring of concept maps as a motivation to propose qualitative analysis of maps. Interestingly, one of their key contributions in this qualitative approach is looking for *spoke*, *net*, and *chain* like structures in a map, and these structures are internal graph structures that are captured by what will later be described as graphlets.

Early attempts at automating the analysis of maps and providing feedback focused on hint like mechanisms. A criterion map (called a scaffold in these works) provides student creators with hints for their maps on what is missing and what does not belong [14], [15]. Conlon [16] built a system that used Novak's scoring mechanism and other artificial intelligent concepts to build an open concept map creation system that provided feedback to students. Our goal is study modern graph analysis tools for similar purposes.

A. Technical Vocabulary

In our previous work we reviewed what mind maps and concept maps were and how these maps can be classified and evaluated. For the sake of space we guide the reader to our previous paper [4].

A body of work has focused on the vocabulary and its importance to reading and learning. In this work, there is no attempt to cover this literature, but we provide a short discussion on technical vocabulary. Nation [17] and Coxhead [18] report that the technical vocabulary in a field consists of approximately 5% of the words used in related publications. Chung *et. al.* [19] elaborate on the calculation of this number. Technical vocabulary is more specific than academic vocabulary, and a number of researchers have investigated the impact of specificity and academic vocab on student learning [20], [21], [22], [23].

Though there is a connection between concept and mind maps to vocabulary, there is a limited number of research papers that link or research the combination in any major detail. Beyer *et. al.* [24] describe there work of using concept maps to help new teachers learn and understand the technical vocabulary of education.

III. Graph Analysis and Relation to Learning

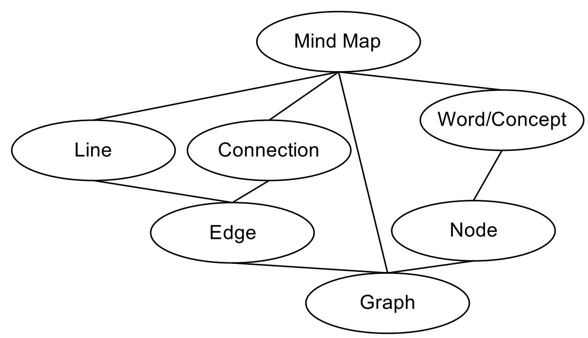

Fig. 1. Example of a mind map on the relationship between mind maps and graphs

Mind maps [3] are a visual tool that can be used to represent the connections between a number of concepts. Figure 1 shows an example mind map that expresses the author's understanding of mind maps and how they relate to mathematical graphs. The words/concepts that are in a mind map are the nodes of a graph (circled bubbles), and the connecting lines between these words are called the edges of a graph. Mind maps are classified as undirected graphs, which means that the edges do not have a direction, normally indicated by an arrow. In the rest of this section, the graph metrics are discussed including some discussion on why and how each metric captures student understanding. Note that mathematical formulas and definitions are provided in graph notation, but the reader does not need to understand this notation to understand this work.

The first metric is related to *average degree*. The degree of a node is the number of adjacent nodes, or the number of edges that connect to other unique nodes. For example, in figure 1 the degree of the "Mind Map" node is 4 and the degree of the "Connection" node is 2. The average degree is the total number of edges ($|E|$) divided by the total number of nodes ($|V|$). For this example, the graphs average degree is 9 divided by 7 or, approximately, 1.29. The greater this metric, the more connections on average a node has to other nodes. To make this into a metric of comparison against the criterion map, the following equation is used:

$$AverageDegreeSimilarity = \frac{AverageDegreeStudent}{AverageDegreeCriterion} \quad (1)$$

The *density* of a graph is defined as the total number of edges ($|E|$) divided by the maximum number of edges that a graph could have ($.5*|V|*(|V|-1)$). For the graph in figure 1, the maximum number of possible edges is 21 and the number of edges is 9, so the density is 9/21 or, approximately, 0.43. The greater this value, to a maximum of 1, means the more connectivity between the nodes within a graph. A value of 0 means there are no connections, and a value of 1 means the graph is a fully connected graph. This metric of comparison is similar to the previous and follows:

$$DensitySimilarity = \frac{DensityStudent}{DensityCriterion} \quad (2)$$

These first two metrics are measures of how much connectivity there is between the two compared graphs. In terms of relating this to mind maps, the hypothesis is that the more connected a mind map is then the more tightly related the topics are. Comparing student maps and criterion map based on how close the metrics are to one another is an expression of similar global connectivity. The problem, however, is the structure of the mind map is not captured with simple metrics and students might be making wrong connections that somehow make the comparative metrics more equal. Similarly, if a map varies between densely connected areas and sparsely connected areas, then the density and average degree metrics do not capture this and only show the average connectivity.

The third metric is a edge by edge comparison between the student mind map and the criterion map. Since the nodes in both graphs are identified uniquely by a label (the word that the node represents is the unique label), the two graphs can be compared in linear time and record statistics about the missing edges ($MissE$), missing nodes ($MissN$), extra edges ($ExtraE$), and matching edges ($MatchE$) for the student map compared to the criterion map. If the two graphs are the same, then these statistics will show this since all edges will match and nothing will be missing. These statistics are combined in the following equation:

$$GranularSimilarity = \frac{MatchE}{MissN + ExtraE + MatchE} \quad (3)$$

The idea of this equation is it is a number that has the value between 0 and 1 where the closer the value is to 1 means that there are less missing and incorrect edges. At present, missing nodes are not included in this equation, but it might be added to the denominator to decrease the similarity factor.

The last metric in this exploration is the RGF-distance, but before defining RGF-distance, graphlets are introduced. Graphlets, formally, are "a connected network with a small number of nodes" [25] and these small graphs are non-isomorphic induced subgraphs of a larger graph. Figure 2 shows all the graphlets of size 2, 3, and 4. Note that the graphlet of size 1 is a single unconnected node and is not that useful.

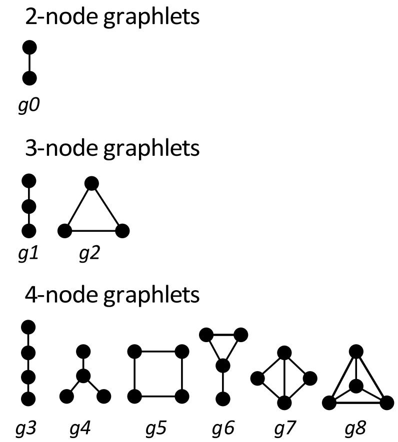

Fig. 2. Graphlets of size 2, 3, and 4

The power of the graphlet is how it can be used to analyze a graph. The procedure developed by Przulj *et. al.* [25] is to search for all graphlets of size 3, 4, and 5 in a given graph. Based on the count of each type of graphlet, a signature is constructed in the form (g1, g2, g3, g4, g5, g6, g7, g8, ..., g28, g29), where g1 is number of the first type of graphlet of size 3 shown in figure 2 and g29 is the count for the last graphlet of size 5. This signature can be compared to another graphs signature to get a measure of similarity, and Przulj *et. al.* used their technique to compare graphs representing biological structures such as proteins.

RGF-distance is a measure of the difference in frequency of graphlets of g1, g2, g3, ..., g28, and g29 appearing in the two graphs being compared. A detailed equation is presented in Przulj *et. al.* [25] and the reader can find the details on the calculation of RGF-distance. The reader should understand that GraphCrunch II will calculate this metric, and the smaller this metric gets means the more similar the two graphs are.

A. Hypotheses on How each Comparison Metric Relates to Learning

Given each of the metrics described above, a set of hypotheses are made to why each metric might capture student understanding in a mind map. Note that it is not expected that any of these metrics can perfectly quantify learning, and the order in which they are presented relates directly to our hypothesis on which metric is, likely, the best choice for measuring learning.

The $AverageDegreeSimilarity$ is a connectivity metric that extracts how much connectivity is in the graph on average for both the student and expert generated mind maps. Considering the student mind map, then there are three situations that might emerge as it relates to the criterion map: under-connected, over-connected, and equally connected. In all cases, the average connectivity reflects a student understanding of how the words are related to each other as measured by an average, but this metric does not extract specifics of individual connections. For example, even if this metric results in "equally connected" (a value of 1), it is possible that the two mind maps are still different, and therefore, this metric only captures a rough estimate of the similarity between student and expert. Note, neither over-connected nor equally connected occurred in the results.

$DensitySimilarity$ is a similar measure of connectivity compared to the first metric. It captures a rough measure of student understanding for the same reasons as described above. In both cases, if these two metrics are considered as feedback tools to a student, then a student might just add or remove edges in their mind map until the metrics equaled one. This is not a true reflection of understanding.

The $GranularSimilarity$ metric is created based on an edge to edge comparison between two mind maps, and the breakdown of the metric (as in the instances where an edge is missing or is not needed) would be useful for giving direct student feedback. As a single combined value, the metric reflects a measurement of learning in terms of correctness divided by errors. Both the correct and incorrect edges are valued in terms of one-to-one matching where the measurement reflects how many one-to-one connections have been made correctly. This metric, hypothetically, is better than the previous two, but it does not reflect deeper ideas where the connectivity of a number of words suggests deeper understanding of how these ideas are interrelated.

Finally, $RGF - distance$ captures the comparative structure of two graphs, and in terms of comparing student mind maps to the criterion map, the hypothesis is that the lower the RGF-distance means that students better understand the relationships between concepts/words since their maps have more similar structure compared to the expert's criterion map. Consider the G2 graphlet; this graphlet is a triangle that shows the interconnection between three words, which is a deeper level of understanding then knowing that their is a one-to-one mapping between these words.

IV. Semester Mind Map Experimental Setup

For this work, the goal is to analyze student created mind maps over a semester long course and test the respective metrics to see if they quantify how these students are learning the course vocabulary. The focus course for this experiment is a digital design course offered at the 200 level. The course starts with how transistors can be organized to make basic Boolean gates and ends with designing finite state machines using a hardware description language (HDL). From a perspective, the most challenging aspect of the course for most students is the application of HDLs to design hardware as this design language differs significantly from sequential programming languages that students are much more familiar with. However, mind maps only play a small part in understanding how to use HDLs.

These mind map experiments are on closed mind maps. Specifically, a list of 20 technical terms are provided that are introduced in the course. The list consists of 20 terms introduced over the course, but the displayed words are randomized when the students see them.

During the second lecture in the course, mind maps are introduced using an illustration of constructing mind maps for countries. It is demonstrated how a mind map can be constructed differently depending on if we are treating it as about geographical location, oil supply, or military alliances and enemies. After this basic training, the list of 20 terms is shown and the students have 10 minutes to create their first mind map. This is repeated after exam I and exam II with the same terms and the same amount of time. This means each student who has chosen to participate (IRB approved protocol allowed students to remove their participation agreement any time in the semester before final marks were released) could have created up to three mind maps over the semester.

V. Experimental Results

Three mind map exercises are done over a semester to compare the metrics and analyze how they can measure learning based on three questions. First, do any of these metrics have a strong correlation to grades? Second, is there any correlations between the metrics themselves? Finally, in the last section, how do the metrics change on a per student basis over time as a reflection of learning?

A. Metrics Correlation to Grades

The first hypothesis is that vocabulary understanding measured by the proposed graph metrics will have a correlation with grades.

TABLE I. Correlation results between comparison metrics and grades

	Correlation Values			
Metric	Exam I	Exam II	Exam III	Final Grades
	$AverageDegreeSimilarity$			
Pre	0.04	0.04	0.14	0.22
Post Exam I	0.03	0.04	0.04	0.01
Post Exam II	0.02	0.18	0.04	0.04
	$DensitySimilarity$			
Pre	0.01	0.10	0.05	0.21
Post Exam I	0.02	0.00	0.19	0.06
Post Exam II	0.01	0.12	0.09	0.04
	$GranularSimilarity$			
Pre	0.07	0.23	0.07	0.25
Post Exam I	0.09	0.18	0.06	0.11
Post Exam II	0.05	0.09	0.07	0.00
	$RGF - distance$			
Pre	0.16	0.12	0.09	0.20
Post Exam I	0.19	0.13	0.01	0.01
Post Exam II	0.11	0.19	0.13	0.06

Table I summarizes the results of the correlation data between comparison metrics and grades. The first column contains the labels for each metric calculated with the mind maps from Pre, post Exam I, post Exam II. Columns two through five contain the correlation coefficient calculated between the comparison metric and the students grade on Exam I, II, III, and their final grade. The bold values are statistically significant for $p < 0.01$ where the populations are n = 41 for Pre, n = 39 for post Exam I, and n = 36 for post Exam II (two-tailed test).

From these results, there are no statistically significant points. In general, we state that there does not appear to be a strong correlation between the comparison metrics and grades. These results suggest there might be some deeper connection that might need more investigation if the technical terminology is directly related to course grades.

Since the course studied does not have a strong dependence on technical vocabulary and is graded based on the performance of the students in designing and solving problems, we don't think there should be a strong correlation. However, we are, presently, looking at other courses where there is a stronger connection between grades and understanding of technical language to see if there is stronger correlation between our metrics and grades.

B. Correlation between Comparison Metrics

In this section, the question is how do the different measurement metrics relate to one another. Earlier discussion described how average degree and density are similar graph metrics in terms of connectivity. Here, any close relationships between all the metrics is explored.

Table II shows the correlation of each of the four metrics to each other as compared based on the same mind map creation time. Column 1 contains the time when the mind map was created, and columns 2 and 3 contain the label of the measurement metric being compared. Finally, the last column contains the correlation value where bold values indicate the correlation is statistically significant for $p < 0.01$. The population values are the same as the previous analysis.

The results show that there are a number of statistically significant correlations, but to consider that two metrics are closely related to one another we would expect correlation over all three time points. This happens in the three way relationship between $AverageDegreeSimilarity$, $GranularSimilarity$, and $RGF - distance$, which suggests that these three metrics are capturing similar results.

C. Per Student Metric Analysis

Since there is no strong correlation between grades and our comparison metrics, quantifying learning might be viewed from the perspective of an improvement in individual performance. In this analysis section, we plot the metrics for each student's map over time with the hypothesis that the metric will change for the better as the student progresses and learns in a course. Since there is a significant amount of data for this analysis, we will only show students who finished our course with a grade between 80% and 90% who did all three mind maps (n = 15 students). These results have similar behavior for all students in the class and demonstrates some interesting trends.

Before looking at the results we must make an assumption to interpret them. The assumption is that students will, on average, create mind maps that are more similar to the criterion map as the course progresses. This assumption is debatable, but from our qualitative experiences with student mind maps we believe this assumption is true.

Figure 3 shows the four graphs, one for each comparison metric, plotting a line that represents a students performance over time related to the respective metric. In each case, the x-axis is time in terms of when the mind map was created (Pre, Post Exam I, and Post Exam II), and the y-axis is a scale for the respective metric. The values on this scale on not very important, but we briefly describe how the change of a metric reflects improvement relative to the criterion map. In other words, how should the metric change to show that the student mind map is more similar to the criterion map. For $AverageDegreeSimilarity$ and $DensitySimilarity$ plots (upper left and lower left in Figure 3) an improvement in understanding happens when the metric approaches 1, but the value can be greater or less than 1 since the metric is a ratio between student and criterion maps. For $GranularSimilarity$ plot (upper right in Figure 3), an improvement in understanding happens as the metric approaches 1 (where the value can only be less than 1). Finally, for $RGF - distance$ plot (lower right in Figure 3) an improvement in understanding happens as the metric decreases in value.

Of the four metrics, the two plots for $GranularSimilarity$, and $RGF - distance$ show that on average these students are learning as the students respective metric measurements show improvement. This can be observed quite clearly for $GranularSimilarity$.

$AverageDegreeSimilarity$ and $DensitySimilarity$ do not follow this clear pattern of improvement, and from the results, we conclude that this metric do not offer an easy visualization of learning. For the graph $DensitySimilarity$, it appears that the trends are random, and we can conclude that this metric, as yet, can not capture learning. On the other hand, $AverageDegreeSimilarity$ has some trends (and as previously shown, correlates to the good metrics), and therefore, this metric should be further studied to be used as one way of reflecting improvement.

Another interesting observation from the two most appropriate graphs for visualizing learning ($GranularSimilarity$, and $RGF - distance$) is the shape of a students line. In some cases, the student has made a more similar mind map compared to the criterion map after exam I then to after exam II, and this might be phrased as the student seems to have lost some of their knowledge. For example, student 12_11 and 12_37 show this behavior. Their are a number of hypotheses that could be made. For example, the mind maps created after exam II included more vocabulary, which the student was unsure how to connect with previous vocabulary. This is a question for future work.

VI. Discussion and Conclusion

The last analysis shows that three comparison metrics can show that a student is learning the technical vocabulary from automated analysis. However, as discussed in earlier sections we believe that both the $GranularSimilarity$ and $RGF - distance$ metrics are the most useful in terms of giving students automatic feedback about the quality of their mind maps and as a visualization tool it seems clear that $GranularSimilarity$ may be the best visualization tool.

From the perspective of using this tool in educational research, at present the three metrics can be used to provide a true/false answer on whether a student's understanding of concepts as reflected by their mind maps has improved. As of yet, there is no quantity that can be associated with this improvement as in percentage improvement. In the future, as we increase the data sets and improve these metrics, we may be able to provide such quantities. At present, though, we believe that these techniques should be used to validate if students are improving, but these techniques should neither be used for

TABLE II. CORRELATION BETWEEN METRICS

Time	Metric 1	Metric 2	Correlation
Pre	$AverageDegreeSimilarity$	$DensitySimilarity$	0.27
Post Exam I	$AverageDegreeSimilarity$	$DensitySimilarity$	**0.86**
Post Exam II	$AverageDegreeSimilarity$	$DensitySimilarity$	**0.95**
Pre	$AverageDegreeSimilarity$	$GranularSimilarity$	**0.58**
Post Exam I	$AverageDegreeSimilarity$	$GranularSimilarity$	**0.70**
Post Exam II	$AverageDegreeSimilarity$	$GranularSimilarity$	**0.76**
Pre	$AverageDegreeSimilarity$	$RGF - distance$	**0.82**
Post Exam I	$AverageDegreeSimilarity$	$RGF - distance$	**0.84**
Post Exam II	$AverageDegreeSimilarity$	$RGF - distance$	**0.83**
Pre	$DensitySimilarity$	$GranularSimilarity$	0.07
Post Exam I	$DensitySimilarity$	$GranularSimilarity$	**0.56**
Post Exam II	$DensitySimilarity$	$GranularSimilarity$	**0.73**
Pre	$DensitySimilarity$	$RGF - distance$	0.11
Post Exam I	$DensitySimilarity$	$RGF - distance$	**0.66**
Post Exam II	$DensitySimilarity$	$RGF - distance$	**0.83**
Pre	$GranularSimilarity$	$RGF - distance$	**0.59**
Post Exam I	$GranularSimilarity$	$RGF - distance$	**0.64**
Post Exam II	$GranularSimilarity$	$RGF - distance$	**0.63**

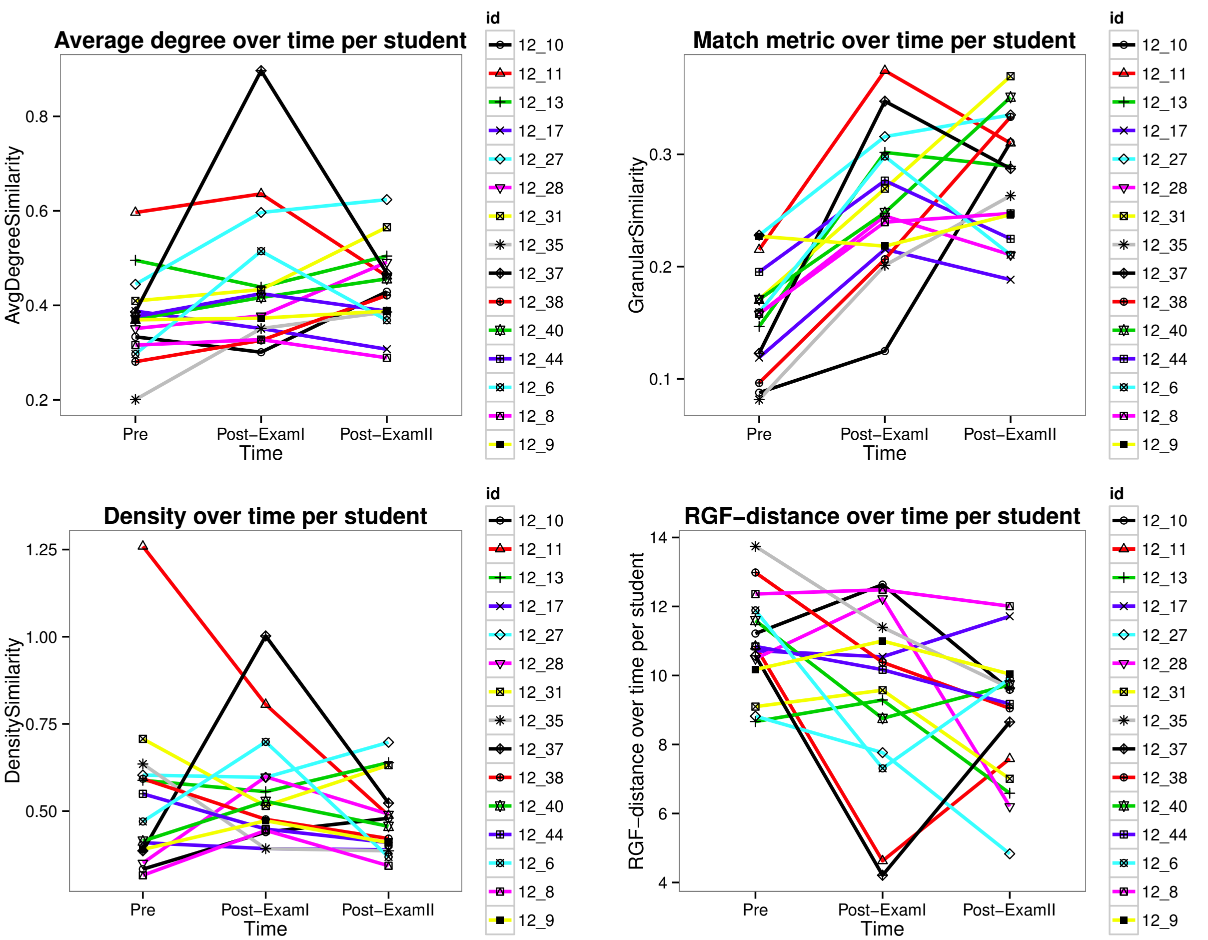

Fig. 3. Line graphs for student mind maps RGF-distance over semester for each comparison metric.

formal assessment of grades nor a quantitative value of how much has been learned.

A. Conclusion

In this work, an exploration of the value of four comparison metrics was studied that could be used to automatically analyze student's mind maps compared to an expert's criterion mind map. Each of these metrics was described including how they might be related to learning. Student mind maps were analyzed from a class to understand if these metrics provide any useful measurements.

The results show that there is no strong correlation between grades and any of the metrics. Additionally, there is some relation between all of these metrics as shown by correlations between them. Most importantly, it was observed how these metrics change over time on a per student basis. These results suggest that three of these metrics, $AverageDegreeSimilarity$, $GranularSimilarity$, and $RGF - distance$ can be used to determine if a student is improving their understanding of the relationships between vocabulary.

For future work, we are extending this experiment to other disciplines and their respective courses as we can find interested faculty members. In this process and with our new matching metric, we have learned that one of the key issues for further research is how to select the technical vocabulary to include in an experiment. Our plan is to further investigate this question and learn to provide a good methodology for teachers to select their vocabulary among other additional questions identified in the paper.

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Assessment of problem solving in computing studies

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***Abstract*—The assessment of learning outcomes is a key concept in the European Credit Transfer and Accumulation System (ECTS) since credits are awarded when the assessment shows the competences which were aimed at have been developed at an appropriate level. This paper describes a study which was first part of the Bologna Experts Team-Spain project and then developed as an independent study. It was carried out with the overall goal to gain experience in the assessment of learning outcomes. More specifically it aimed at 1) designing procedures for the assessment of learning outcomes related to these compulsory generic competences; 2) testing some basic psychometric features that an assessment device with some consequences for the subjects being evaluated needs to prove; 3) testing different procedures of standard setting, and 4) using assessment results as orienting feedback to students and their tutors. The process of development of tests to carry out the assessment of learning outcomes is described as well as some basic features regarding their reliability and validity. First conclusions on the comparison of the results achieved at two academic levels are also presented.**

Keywords—Learning outcomes assessment, higher education, competence based education, assessment of learning, problem solving

I. INTRODUCTION

The assessment of learning outcomes is a key concept in the European Credit Transfer and Accumulation System (ECTS) since credits are awarded when the assessment shows the competences which were aimed at have been developed. ECTS is the credit allocation system for higher education used in the European Higher Education Area (EHEA), which involves all the countries engaged in the Bologna Process, 47 at this point in time. Its main role is to make higher education systems transparent and comparable, thus helping to bring to reality some crucial EHEA concepts such as mobility, student centered education, employability or educational quality among others. Most Bologna countries have adopted ECTS by law for their higher education systems [1]. In Spain, additionally, a decree passed in 2007 [2] establishes the generic competences which any student with a university degree must have developed; these include understanding basic and gradually more advanced scientific texts; problem solving; looking for, selecting and using information to solve problems or making decisions and, finally, the capacity to learn independently, all of them in the students' specific fields of study. But more generally, basing higher education on the development of key competences and measuring them is a strong international trend in higher education as, for instance, the OECD funded AHELO study shows [3].

This paper describes a study which first was part of the project of the Bologna Experts Team-Spain (http://www.expertosbet.es/) and then evolved as an independent study. It was carried out with the main goal of gaining experience in the assessment of learning outcomes and, more specifically to: 1) designing some procedures for the assessment of learning outcomes; 2) testing some basic psychometric features that an assessment device with some consequences for the subjects being evaluated needs to prove; 3) an issue of special interest for us was testing different procedures of standard setting; 4) finally, we were interested in using assessment results to give feedback on competence development to students, their tutors and the institution which holds them.

In order to achieve our goals, participants from degrees representative of different fields of knowledge (Biology, Psychology, Computing, Economy and History) were invited to take part in the study. In this paper we shall focus on the work done in the degrees of Computing and Mathematics & Computer Science. The sample of students includes 1st and 3rd year students from three different schools with a degree in computer science and we shall report specifically on one of the competences, namely problem solving at the level of university studies. We shall describe the process of development of the test and discuss some measures taken to guarantee an acceptable level of objectivity and validity of the data. Then, we shall report some results of data analyses carried out regarding results achieved at the two participating academic levels. Finally, we shall discuss our experience in the use of these procedures as well as the implications for the development of this kind of tests and its crucial role in higher education reform.

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II. CONTEXT AND BACKGROUND

In the context of higher education, a competence may be understood as the combination of skills, knowledge, attitudes, values and abilities that underpin effective and/or superior performance in a professional area. In this way, when we try to assess student performance, we are interested in assessing not only knowledge, as has been the case in traditional education, but also what the student is able to do using this knowledge (and how). By how, we understand adhering to disciplinary methodological standards and values. Thus, competence or learning outcomes assessment includes the assessment of knowledge, but is not limited to it. It is normally assessed through complex, representative disciplinary tasks that imply knowledge and are often complemented with students' reflections whereby students justify the decisions they have taken on a theoretical and/or disciplinary base, and take into account their consequences or the values that inform them.

The starting point for this study were the basic transferable competences which, according to the Spanish Decree 1393/2007 [2] every higher education graduate should have developed by the end of his or her studies. They were selected since they are common to all degrees although every discipline is expected to further introduce its own particular coloring and nuances. For this reason, they were considered to be at the same time a good basis for independent work and also for making interesting comparisons related, for instance, to fairness. On the one hand, we could learn about the particularities of the assessment of learning outcomes regarding different disciplines; on the other, if the structure used for the tasks was similar, we could explore to which extent assessment criteria and standards were used in similar ways.

III. RESEARCH QUESTIONS

As mentioned above, our aim was to design assessment procedures to assess the basic competences which all graduates must have mastered by the end of their undergraduate academic life according to the Spanish law. This should be complemented by the development of assessment criteria that would allow enough objectivity when correcting and eventually grading students' work. We also tried to validate the tasks as appropriated for the measure of these basic competences in various ways.

Some additional questions arose from a pilot study performed previously to the work reported in this paper. This pilot showed to us many valuable things such as the importance of correctly wording the questions, since light nuances in language can make dramatic changes in how students understand them; how to test administrations procedures need to be very clear and strictly followed if we want to work together and compare or sum up results from different schools or teachers; or how rating criteria for open questions need to be very carefully developed if a basic level of objectivity is to be assured. As a starting point, we deeply believed in constructed responses for the assessment of competences, since they usually represent more complex tasks. However, we were also aware that open questions are more difficult and costly to rate, so we opted for a mix of both kind of questions so their results could be summed up and eventually compared. As a means to assure some basic common conditions, we also opted for computerized tests.

IV. METHOD

A. Objetive

This paper presents the process of development of a procedure to assess a transferable competence basic for learning and academic life: problem solving. It further describes how basic objectivity and validity data were assured and finally adds some results on how the two academic levels participating in the study compare. Other comparisons of interest are internal consistency of the test, as well as closed vs. open questions.

B. Development and nature of the task

In order to develop the appropriate tasks to measure in a comprehensive way the learning outcomes associated to these transferable competences, they were in the first place analyzed it their facets or components. The various questions included in the tests were then mapped on this scheme, as can be partly seen below for problem solving:

- Problem identification
- Come up with a strategy to solve the problem
- Determine additional information if necessary
- Applying knowledge needed for problem solving
- Evaluating adequacy of solution and, if not found acceptable, re-start cycle.

In the second place, computing science teachers elaborated a task to assess this competence. When designing this task we had in view that first year students should have some difficulties in solving this task but it would be easier for third year students. The goal was to measure improvement in performance when the two academic levels were compared. Of course the task should include the facets mentioned above for problem solving.

After the presentation of the problem, the task contained two types of questions: 9 open questions which implied a constructive response and 11 closed multiple choice questions which required choosing from 4 alternatives. Table I contains examples of these two types of questions.

TABLE I. SOME SAMPLES OF OPEN AND CLOSED ITEMS

Open question:	What is recursivity? What aspects should a definition of recursivity include? Or how can the concept of recursivity help in solving this problem?
Closed question:	To differentiate between an iterative system and a recursive system the key if to identify: (options a, b, c & d follow)

C. Developing scoring criteria

As a first step to develop clear scoring criteria for open questions, 2 teachers prepared the best possible response to each question, discussed them and agreed on the criteria which make a highest scoring response. Then second best, third and unacceptable responses to the same questions were described. Finally, these criteria were validated against 10 exercises from the pilot sample which were scored separately by the two judges. All disagreements were taken as a basis to refine the scoring criteria. Next, they validated the new criteria against a new sample of 20 exercises until perfect agreement was reached. These were subsequently considered expert ratings.

In this process, examples of each of the 4 alternative ratings for each open question were also selected and included along the scoring criteria.

D. Experts' judgments on content validity of the assessment task

In order to estimate the content validity of the task, it was given to experts who had to answer two questions: 1) which one of the basic competences the task measured? And 2) which facets covered by the task analysis did each questions measure? This last question was meant to address whether all relevant facets of the competence were covered by the task in a comprehensive way.

Two judges participated in this stage. Both of them were specialists in higher education and had experience in competence based education.

The results of this phase were as the follows. The judges reached a 100% agreement regarding the competences we were trying to measure by means of the test. However, one of them also mentioned other competences which we thought were marginal for the task at hand. The same was true for the facets we identified in our tasks: 100% of the facets we identified were also found by the judges who, whoever, introduced some additional ones. We can thus conclude these results essentially validate our task analysis regarding this test.

E. Administering the task to students

The student sample who took the test is described in Table II. Although the size of the sample is not very large, its varied nature should be emphasized, since it makes it more representative. However, unfortunately the size of both academic levels it is not well balanced at this point in time.

TABLE II. DESCRIPTION OF THE STUDENT SAMPLE

UNIVERSITY	Gender (N, %)		Age (mean)	Year (%)	
	Male	*Female*		*1*	*3*
UAM	n= 9 (75)	n=3 (25)	21.5	41.7	58.3
UCLM	n=21 (87.5)	n=3 (12.5)	20.21	66.7	33.3
UPM	n=26 (74.3)	n=3 (8.6)	18.31	82.9	17.1
TOTAL	N=56	N=9	20.06	70.42	29.57

F. Training human judges to rate open questions

Once the expert scoring criteria were agreed upon as described above, we needed to train the judges who would rate the students' work. Of course, this was also an opportunity to observe how objectively these criteria could be learned and used by other raters. The raters were 2 master students who, in the first place, and before any rating, answered the test in order to understand its demands. Then they started rating the same exercises used to develop the expert ratings. They first received 10 of them together with the assessment criteria they were asked to use and their ratings were compared to the expert ratings, discussing any difference that was encountered. In a second stage, they received a new set of 22 exercises and the agreement of their ratings with that of the experts was calculated using Cohen's kappa coefficient in order to remove random agreement. The process continued until the agreement was satisfactory. This was usually reached in all tests with 20 to 30 exercises.

Following this procedure, inter-rater reliability for 2 judges and 22 exercises, using Cohen's kappa [4] was found to be 0.497. The SPSS statistics software was used for the calculation of this coefficient. According to Landis and Koch [5], we can conclude this is a moderate level of agreement.

Once a fair level in the objectivity of ratings was achieved in this way, the judges were given the exercises of the whole student sample. Throughout the whole grading process, they were aware of the fact that some exercises, unknown to them, were randomly distributed to all judges and their reliability was being continuously monitored.

V. DATA ANALYSIS

A. Open and closed questions and total score

As mentioned, the test consisted of a section with constructed or open questions (OQ) and another one with closed or multiple choice questions (CQ). The total score of the test is the sum of the two parts. The maximum score for the whole test is 38. The mean and standard deviation for the two academic levels are shown in Table III.

Constructed response items, or OQ, seem to reflect better the nature of the competences but they are also more costly to score in a reliable way. So, it was interesting for us to compare the OQ with the CQ and find out what each of them adds to the whole test. The OQ section includes 9 open questions which may be valued 0-3 by human judges. So, the maximum score is 27 and the minimum 0. Regarding the CQ section, it contains 11 questions with 4 alternatives with a value of 1 each; the maximum score is thus 11 and the minimum 0. Table III shows the results we found for our sample.

As can be seen these means increase from the 1st to the 3rd year, but in both cases leave ample space for improvement, especially in the case of the OQ and Total scores. Moreover, there is an indication that OQ would seem to be more difficult, since their mean is far from the mid-point of the score range (19), while the CQ questions seem easier since they come somewhat closer (6). However, this question will have to be postponed to more specific item difficulty analyses.

TABLE III. RESULTS FOR 1ST AND 3RD YEAR STUDENTS

	1st year students	**3rd year students**	**Score range**
Total Test Score	Mean:4.76 SD: 2.34	Mean: 8.90 SD: 4.04	0-38
Open questions	Mean: 0.96 SD: 1.31	Mean: 2.90 SD: 2.45	0-27
Closed questions	Mean: 3.80 SD: 1.81	Mean: 6.00 SD: 2.30	0-11

B. Internal consistency

When we look at the internal consistency of the total test, that is, the way in which the items seem to measure the same construct, we found a value for Cronbach's alpha of 0.689 for the whole test (0.622 for the OQ and 0.520 for the CQ). The meaning of this index depends on the kind of test and in our case it seems to be a medium value which seems to confirm the reliability of the test.

C. Comparison of results in two academic levels

When we compare the results of the 1st year students with those of the 3rd year, our results seem to be in line with our expectations, since they seem to reflect a development between these two academic levels from the 1st to the 3rd year when we look at the mean total score and also when we compare the different sections of the test (see Table III).

When we performed a t test for independent samples, in order to ascertain whether these differences were significant we found they are indeed for the whole test ($F= 13.63$, $p < 0.005$) as well as for the open ($F= 15.57$, $p \leq 0.002$) and multiple choice questions ($F= 2,14$, $p \leq 0.005$). So, we can state the test discriminates very well between the two academic levels.

VI. DISCUSSION

Competences and learning outcomes really seem to play a pivotal role in higher education reform. In this regard, the quote by Resnick and Resnick [6] "you get what you assess" seems in order. No matter how much we strive to help students develop the competences they will need in their professional lives, it is difficult to achieve them, al least in a general sense if we do not take the pain to assess them. Assessment determines the real goals that must be achieved by students to be successful and at the same time is a rich opportunity for learning if criteria are clearly understood and shared by students and can be worked upon. In other words, educational reform can be a void effort if it is not reflected in the way assessment is performed.

The main achievement of this project seems to be that indeed we have succeeded, at least in a first phase, in the development of a procedure to measure learning outcomes and more specifically problem solving which in light of the present results can be considered reasonable and can be taken as a sound base for future developments. However, it must be acknowledged this process takes much time and effort, as shown in this paper, and is probably best approached as a multidisciplinary endeavor.

Of course also many difficulties arose along the way. Maybe the first worthwhile mentioning are the difficulties found in the administration of these tests to natural groups of students. Teachers as well as authorities did not seem to be clear about the benefits of this administration and at times simply considered it a loss of time. The practical result of this is that, despite our efforts to the contrary, they were taken mostly by students who volunteered and the sample size was below what we expected. Moreover, since this procedure usually selects the best students, it may be considered that these results represent an overestimation. This is interesting considering the modest mean we found in a very basic competence for engineering such as problem solving.

No doubt the process of developing learning outcome assessment devices, as described in this paper is long and costly. However, it seems efforts of this sort need to be done in order to guarantee that students are assessed by means of procedures which have proved their objectivity and measure what they are supposed to measure. This is especially so when important decisions are taken based on this information, as is the case when they are used for certification purposes.

Several lines of reasoning seem to be relevant in this respect. Of course, once procedures of this type are developed and adopted by an institution they do not need to be so costly for subsequent use. Maybe the crucial question is whether they need to be developed at each institution, taking into account its costs and multidisciplinary nature of the effort needed, or they should be developed elsewhere, maybe for more general use at least in some specific cases [7]. We are aware this second option raises the question of the limitations of standardized tests vs. more open, qualitative and situated alternatives [8-11]. It also raises the question of the fact that, if the procedures have not been developed at an institution, its members do not feel ownership over them. Indeed, some of the resistance we found in tutors seemed to be related to the use of results for external evaluation and control.

It must be emphasized the experience of development and use of the procedures described was most enriching for all participants and it was a great opportunity for teachers' professional development and prompted them to use similar procedures for developing competences. For students alike, it was an opportunity to understand in a practical way what competences are about.

To summarize our experience to date, this work has been long and costly, but also very rewarding for those who directly participated. In fact, they readily used the tasks and others developed following this example in their daily activity. In this sense, the tasks seem to be very intuitive and stimulate educational activities geared to develop valuable competences.

Finding a balance between the effort needed to develop this kind of assessment devices and the possibility of not measuring them or doing so in less reliable and valid ways is something the academic community will need to consider seriously.

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A Systems Approach to Managing Learning based on Bloom´s Revised Taxonomy to Support Student Assessment in PBL

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Abstract—**The dynamism and intensity of the adoption of practical learning problems (PBL) provide adverse effects contrary to traditional learning approaches. The difficulty in defining clear educational objectives aligned to appropriate forms of assessment is also a recurring challenge in the management of learning environments. As a response to this state of affairs, this paper presents an approach to a system for managing learning based on PBL that makes use of Bloom's revised taxonomy to support planning and assessment activities. The model was implemented using prototypes with low-fidelity screens and its applicability with regard to the conduct of teaching using PBL was found to be valid.**

Keywords—PBL; Systems for Managing Learning (SML); Bloom´s Taxonomy – Revised; Planning and Assessment Processes.

I. Introduction

The dynamism and intensity of problem-based learning (PBL) [1] provide adverse effects in the teaching method, especially about teaching practice. On the one hand, a lack of control over teaching activities, the essential elements of which are processes (i.e. managing the application of the teaching methods), people (especially new roles involved) and tools (the teaching environment itself and the availability of the technology needed), can negatively affect the PBL approach and its principles. On the other hand, the difficulty in defining clear educational objectives aligned to appropriate forms of assessment can undermine the perception and evaluation of the results of teaching and learning.

Therefore, it is believed that many of the challenges that PBL presents are linked to new ways of "teaching" and how "assessment" is aligned to PBL principles. The dynamism inherent in teaching method keeps focus on solving problems, and owing to this argument, more appropriate ways to assess students should be considered. For possessing a subjective feature, assessment in PBL has been a constant point of discussion [2]. The flexibility and unpredictability present in practices lead to control being lost over the planning and monitoring of tasks and the results of teaching and learning.

As a response to this state of affairs, this paper presents a systems approach to managing learning based on PBL that makes use of Bloom's revised taxonomy to support planning and assessment activities.

This approach argues that Systems for Managing Learning (SMLs) can be used to determine what resources need to be used to facilitate how teaching activities are managed, especially the planning of teaching and the assessment of students. Besides directly aiding faculty in their teaching practice, SMLs are powerful tools because they facilitate collaboration and communication between those involved in this process.

Even though the use of SMLs has been little explored as a support to the PBL method, the literature has already recorded some advantages of implementing and using them, especially with regard to the ease with which they can be used to oversee and monitor learning. In the context of PBL, support to the monitoring of group tutorials is "better" via a SML [3], because less time requires to be spent on facilitating in addition to which an SML provides faculty with the means to monitor and offer guidance by making observations and giving feedback continuously. However, as is well-known, the success of management systems heavily depends on the processes thus implemented being regarded as effective.

One of the most critical processes in PBL is to align educational objectives to assessment. As these objectives are statements that express changes to be brought about by learning, checking whether such objectives have been achieved can be ensured by ensuring that appropriate assessment instruments are applied.

It happens that in practice, the assessment process has been used inappropriately with a view only to classifying knowledge. In addition, it has been established that these elements are incompatible. The real point of assessment is to assist teachers to identify what difficulties students have when they are learning. It is to seek to meet these objectives that the definition of processes within the systems approach is based on Bloom’s revised taxonomy [4], the purpose of which is to support teaching practice. The idea is to ensure that educational

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objectives are aligned to assessment during the planning of teaching in the real environment of learning, thus contributing to the planning and monitoring of teaching processes being conducted continuously.

To evaluate its applicability, the model proposed was implemented as an extension to the Amadeus SML by prototyping a technique that uses low-fidelity screens.

Since the teachers involved agreed to implement the model and accepted the results obtained from doing so, this showed that aligning educational goals and assessment can be achieved. This made teaching practice in this environment easier and therefore given that the results were positive this shows that this approach is effective.

II. TECHNOLOGY APPLIED TO PBL EDUCATION

A process inherent to learning in PBL is to tackle problems which have a complexity that is similar to real situations. This fosters students´ motivation as well as their developing the skills and attitudes needed to solve them [5]. Learning tasks which are primarily functional ones keep students immersed in practices which are always supported by content. By considering themselves to be active agents in the process [6], students focus on solving problems through collaborative learning by debating with each other and expounding their ideas.

The dynamism, flexibility and unpredictability associated with this approach to learning require greater attention from teachers, mainly to ensure the approach is being effective. Because its essence is to be strongly oriented to processes [6], it becomes necessary to consider how to manage them. Thus, adopting this approach to teaching can only be effective when teaching is planned and monitored such that the alignment between the content (theory) and the problem (practice) may be guaranteed. In addition, assessment must be appropriately applied.

Just like learning, assessment in PBL takes different forms. Self-assessment and constructive peer assessment are considered important for the metacognitive process, because this enables a student to undertake an assessment of his/her perceptions, strengths and weaknesses, as well those of his/her peers [7]. Furthermore, the possibility of assessing how the student applied his/her knowledge and performed during the resolution process is stressed. Besides these, authentic assessment [8] as a strategy inherent in PBL aims to stimulate critical thinking and insight during problem solving, and to train students to reflect on different ways to solve a problem.

Therefore, this article argues for the idea that the effectiveness of the approach depends on its processes being managed efficiently. Similarly, management of the conduct of teaching practice should consider the relationship that exists between the educational objectives, procedures and assessment in order to ensure the quality of a degree course in PBL. In this context, the application of appropriate technology to support these processes could be make a great difference.

Technology is ever present today and this includes new teaching practices being driven by it. However there is only a small number of studies on learning that refer to the use of management systems as support to learning based on problems. According to [9], computational tools and computers have not been explored extensively for PBL. Therefore, this section briefly presents studies that evidence there are systems that target the application of PBL.

A collaborative learning environment deemed a PBL-VE, the acronym for Problem-Based Learning Virtual Environment, is presented in [9]. This system enables PBL tutorial sessions to be supported both face-to-face and at a distance. The participants in the initial applications, which aimed at improving the development of the environment, were Computer Engineering students from the State University of Feira de Santana (UEFS).

The "PBL Manager" is a support system for education on the Web which sets out to provide a teacher with the facility of storing problems in a shared database [10]. With a view to computerizing the process of drawing up problems, the system also allows editing, searching for and sharing information.

In [11], a proposal is put forward for an environment based on PBL principles and on the CBR (Case-Based Reasoning) approach and which, by using the DUMBO system, seeks to facilitate the teaching of Computer Networks. The AAERO (the acronym in Portuguese for a Learning Environment for Teaching Computer Networks Oriented towards Problems) considers functions that are basic to the actors of the teaching and learning process. In addition to supporting student learning and the PBL process, by making various resources available, the environment provides such functions as "developer of the problem", "tutor" and "assessor" to the teacher. Its construction draws on the researcher's analysis of other environments specific to PBL, such as BELVEDERE, CROCODILE, CALE, CoMMIT and Munics.

The thesis of [12] puts forward a strategy model of teaching and strategy based on PBL and was applied in a virtual learning environment. The model is integrated with different resources that can be customized to the different actors of the process as a means to facilitate their interacting with each other in the environment. In addition to the collaboration tools, in which what prevail are activities using forums, chats and discussion lists, there is "My Space", "Support" and "Help". The first relates to managing and organizing information and provides the "Personal Library", "Notes" and "My Data". As for the support, this supplies resources to search for data cataloged in the environment as "ABP Bank", "Solve APB", "Guide Bank for solving APB" and "Guide to resolution."

The results of these studies showed support activities that involve teaching practice were superficial, especially regarding the planning of teaching and consequently the assessment process. To ensure effective with the adoption of the PBL method with LMS, the alignment between planning and evaluation should be considered. The management systems as support to learning presented do not contemplate the possibility to establish educational objectives aligning them into the most appropriate forms of assessment. Even though it was confirmed that performance was being monitored in order to support the assessment, there is no means to ensure that performance is being defined and monitored appropriately in these environments.

Therefore, this article emphasizes the importance of encouraging planning in the management system itself by clearly defining the educational objectives in addition to aligning these to the different forms of assessment. It is evident there is a need to develop management systems for a total PBL application, i.e. systems that can support not only student learning but also teaching practice. Towards an appropriate model to set this aim, the revised version of Bloom's taxonomy is adopted with a view to seeking to ensure that the model that sets this aim is appropriately designed. This tool is suited to PBL education because the philosophy behind is broad, ranging from metacognitive aspects to constructivist theories, as required by PBL, and emphasizes the relationship of knowledge with awareness of how the individual learns.

III. Bloom´s Taxonomy – Revised Version

Bloom´s taxonomy [13] is a classification scheme that enables educational objectives to be formulated and organized at cumulative and dependent levels, as shown in Fig. 1.

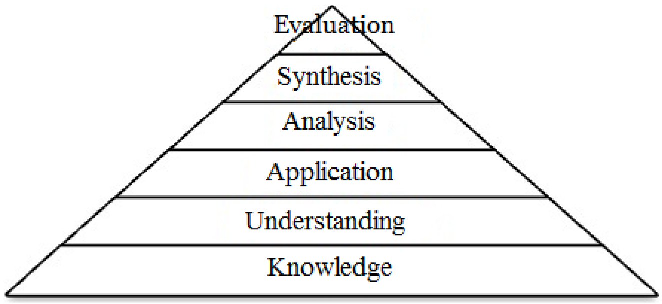

Figure 1. Bloom´s Taxonomy of Educational Objectives.

The educational objectives are represented by statements that express what the student can be expected to achieve, and makes modifications to learning explicit for the teaching and learning process [13].

When considering metacognition and self-learning, the taxonomy undergoes considerable changes and is deemed the "revised" version [14]. Having been made to fit the new forms of learning, including PBL itself, the taxonomy aims at "knowing how to" deal with the procedures in solving problems rather than "knowing what" to do on what content.

A very noteworthy change in its structure, with regard to cognitive processes and knowledge processes, can be represented by a two-dimensional table (see Fig. 2).

	Dimension of the cognitive process				
Dimension of Knowledge	**Remember**	**Understand**	**Apply**	**Analyse**	**Create**
Effective/ Factual					
Conceptual					
Procedural					
Metacognitive					

Figure 2. Bidimensional Table of Bloom´s Taxonomy Revised.

From the cognitive point of view, each one of six verb forms has a specific meaning and is associated with verbs in the gerund:

- *To remember*: to recall, to recognize or to reproduce ideas and contents. Associated verbs: Recognizing, Reproducing.
- *To understand*: to explain an idea, concept in one´s own words. *Associated verbs*: Interpreting, Exemplifying, Classifying, Summarizing, Inferring, Comparing and Explaining.
- *To apply*: to apply a piece of knowledge, a procedure to a new concrete situation. *Associated verbs*: Carrying out, Implementing.
- *To analyze*: to divide information into parts and to understand the inter-relationship between them as well as in the overall structure. *Associated verbs*: Differentiating, Organizing, Attributing, Concluding.
- *To evaluate* (representing of Assessment): to undertake judgments based on criteria, standards and norms. *Associated verbs*: Checking, Critiquing.
- *To create* (representing of Synthesis): to reorganize elements in order to create a new vision, solution, structure and coherent model, from knowledge and skills previously acquired. *Associated verbs*: Generalizing, Planning, Producing.

From the knowledge point of view, the model has four dimensions:

- *Effective/Factual:* This type of knowledge is very useful for enabling familiarization of a discipline to be gained by using the basic contents. *Subcategories:* Knowledge of the Terminology; Knowledge of specific details and elements.
- *Conceptual:* Knowledge related to more elaborate contexts. The students can explore / discover the interrelationship between elements. There is evidence of explicit knowledge regarding classification and categorization as well as knowledge of theories and structures. *Subcategories:* Knowledge of classifications and categories; Knowledge of principles and generalizations and; Knowledge of theories, models and structures.
- *Procedural:* Knowledge related to the use of techniques, methods, criteria and algorithms. This type of knowledge refers to "how to do something." Use of criteria of "how" and "when" to use a specific procedure. *Subcategories:* Knowledge of the skills specific to the disciplines and algorithms; Knowledge of specific subjects with techniques and methods; Knowledge to determine the criteria needed to show that procedures are being used appropriately.
- *Metacognitive:* Knowledge related to interdisciplinarity. To use previously assimilated (interdisciplinary) knowledge to solve problems and / or to choose the best method, theory or structure.

Subcategories: Strategic Knowledge; Knowledge about cognitive tasks, including contextual and conditional knowledge; Self-knowledge.

The idea of a two-dimensional table is to interpolate the categories when educational objectives are drawn up, by combining the type of knowledge to be acquired with the cognitive process (skill to be performed). In this case, it is considered that it is essential both to understand and differentiate between cognitive and knowledge processes.

IV. Aligning Educational Objectives and Assessment

With the purpose of supporting PBL teaching practice, an alignment model seeks to ensure that the educational objectives and assessment remain aligned throughout the teaching and learning process. Based on the revised taxonomy along with the two-dimensional table, the model facilitates the planning of teaching as it supports defining the educational objectives, in addition to checking the alignment of these components. The following sections describe the alignment steps defined in the model, including a framework for defining the educational objectives, which relates cognitive processes to those of knowledge and associates a form of assessment with this. In addition it applies this model to the Amadeus SML.

A. Stages of Alignment

To guarantee alignment in the PBL approach, the model was structured into four distinct stages: (1) Defining educational objectives; (2) Defining assessments; (3) Providing inputs for the two-dimensional table (Fig. 2) and; (4) Checking the alignment and identifying points for improvement.

Given that educational objectives are statements that express expected changes in learning, they should be structured by joining "verbs" and "nouns" as shown in Fig. 3.

Figure 3. Structure of an Educational Objective.

The structure of an objective is initiated by a "verb of mental activity". These verbs express the intended action more efficiently, so what they enable to be defined is what cognitive process is expected to be reached by the educational objective, assuming the levels of "to remember", "to understand", "to implement", "to analyze", "to evaluate" and "to create". After determining the intended action, a "noun" is added which enables an item of content to be associated with the action. Then, the "verb in the gerund" clarifies "how" it is expected that this objective may be achieved and concludes with the "noun" which associates the gerund with one of the categories of the knowledge process, thus concluding the description of the objective. There still remains the relationship of the verbs of action and their associated verbs, in the gerund, as shown in Section III. When defining an objective, the choice of the verb of mental activity is crucial to defining how the objective will be achieved, and is always associated with the verb in the gerund.

Fig. 4 illustrates an example of an educational objective as per the structure proposed. Note that the verb of mental activity "to remember" is associated with "recognizing", a gerund, which shows the real intention of the educational objective.

> To remember + the terms most used to define problems common to the functioning of a software program + by *recognizing* + the distinction between them during the tests.

Figure 4. Example of an Educational Objective.

The step "To define assessments" aims to associate a form of assessment with each objective. In addition, the teacher should predict the time needed to do it, by setting a time befitting its complexity. In order to solve problems, for example, it is considered that the more complex the problem is, the more time should be set aside to resolve it and to conduct the assessment itself.

The step "To provide inputs for the two-dimensional table" aims to fill in the cells of the two-dimensional table, the inputs being the elements "Objective, Assessment and Time". Since the cells are formed by the intersection of the dimensions of the table, they can be filled in with two or more educational objectives. Similarly, the educational objective can occupy two or more cells in the two-dimensional table (Fig. 2).

The step "To verify alignment and points of improvement" aims to guide the teacher as to his/her planning. After having completed the entries in the table, the teacher can verify and assess the alignment and/ or misalignment of the elements mentioned by means of the "macro" vision provided by the two-dimensional table. The idea is to identify areas for improvement, such as "where" and "how to" improve the choices of planning actions in addition to reflecting on learning opportunities lost because of the presence of empty cells.

It is believed that these steps guide teaching practice, especially regarding how the structure defines the educational objectives. This enables the object to be adequately associated with the contents and the assessment. Since the table reflects a dual perspective, an argument is thereby made about the importance of teachers using it because this enables a) the impacts of the assessments and the consistency of the curriculum to be examined; b) help to be given to aligning the objective elements and assessment; and c) the activity of the objectives to be differentiated [4].

B. Application of the Model in the SML

The alignment model was implemented in Amadeus SML by using prototypes with low fidelity screens. It was noticed that Amadeus does not have a module that allows teaching to be planned based on defining educational objectives and monitoring these. In this context, the prototypes presented in this section propose *Planning* and *Monitoring* activities in PBL as per the latest version of this system. Since the prototypes were originally written in Portuguese, they were adapted to this study so as to emphasize only the actions of planning. What mainly stands out is how to set educational goals and to integrate them into an assessment, besides checking that these elements have been aligned when planning teaching.

Planning is structured into three integrated steps. Planning begins by creating a "learning module", into which subjects can be put, activities defined and problems set up. After this has been drawn up, the teacher should establish educational objectives and relate them to the module (Fig. 5). The structure, as per Fig. 3, assists the teacher in this action and enables "what students need to do" to be associated with the content, as well as how this will be acquired and the type of knowledge.

Planning is effectively concluded when the teacher defines the actions regarding assessment. The form of assessment for each defined objective should be selected, as should the criteria and time, as shown in Fig. 6. A problem may still be associated with the assessment stage after the objective has already been created, which means that the proposed problem, in a way, is related to the objective that the teacher wishes to achieve.

Having defined these actions, the teacher should check if the elements are aligned and/or misaligned (Fig. 7). After the terms "objective, assessment, and time" have been filled in, the two-dimensional table enables a teacher to identify cognitive processes that have not been explored, which makes teachers reflect on their planning. Because of the flexibility of the revised taxonomy, note that the educational objectives are located in two or more cells (Fig. 7) i.e. what is most expected from a student in terms of the mental activity he/she is expected to acquire.

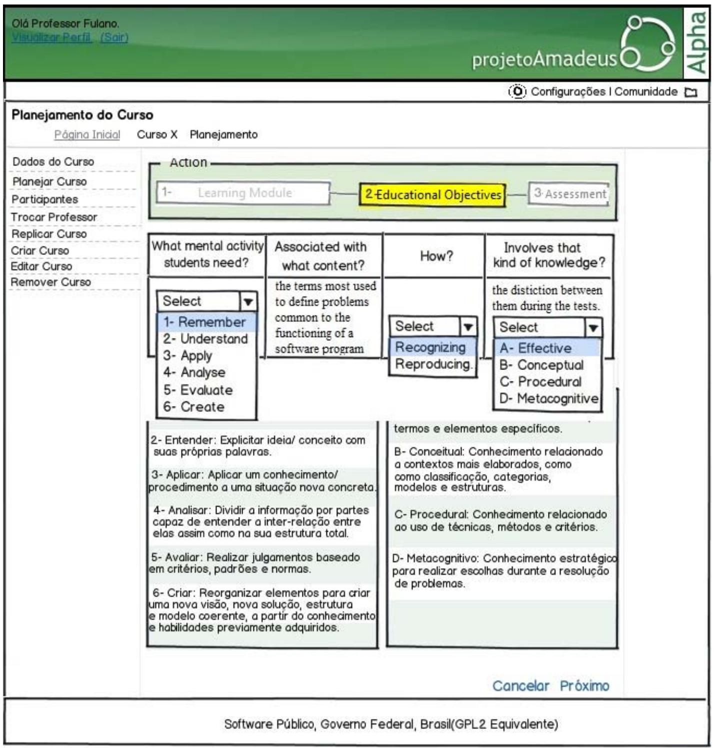

Figure 5. Screen for drawing up educational objectives.

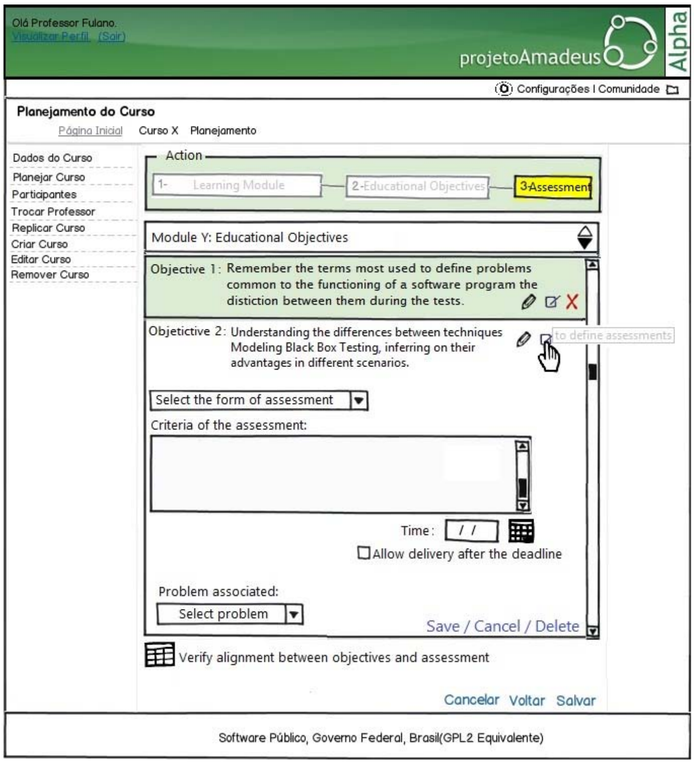

Figure 6. Screen for defining assessment.

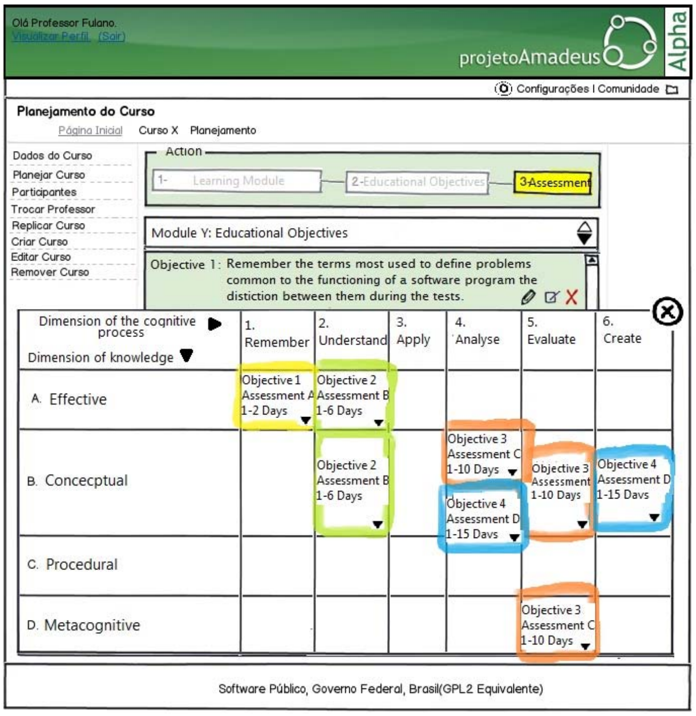

Figure 7. Screen for verifying alignment.

V. VALIDATING THE MODEL

The validation of the model was based on interviews and supported by a questionnaire the purpose of which is to assess the suitability of the model. The screens that were designed served as an instrument of analysis in this process. In the questionnaire, besides the objectives of the screens, two assertions were associated with each of the objectives, with predefined values, using the Likert scale (1 – "I strongly agree"; 2 – " I agree"; 3 – "I´m undecided"; 4 – "I disagree"; 5 – "I strongly disagree"), followed by a question for comments. To make this clearer, the assertions of the screens shown in Figures 5, 6 and 7 are summarized in Table 1.

TABLE I. EXAMPLES OF ASSERTIONS PER SCREEN.

Screens	Assertions
1. To define Educational Objectives	1. The definition of an educational objective in planning, of the form proposed, is presented sufficiently intuitively. 2. A lot of understanding is needed to establish an educational objective in planning.
2. To define Assessment	1. It is possible to define clearly and objectively elements associated with assessment in each objective proposed. 2. The relationship of the elements of "objectives", "problems" and "assessment" are established coherently.
3. To verify Alignment	1. The table provides ways that guide planning. 2. The alignment/misalignment between the actions established can be identified visually

Validation involved the participation of seven experienced teachers, mostly at undergraduate level and who had basic knowledge of the Amadeus SML and basic knowledge (3), intermediate knowledge (3) and advanced knowledge (1) of the PBL approach.

To define educational objectives, for the first assertion, five of the total (7) strongly agreed that the proposal is intuitive enough for the teacher. Excerpt from the conversation during interviews can be highlighted:

E5: "Strongly agree, I think it's pretty clear why this question is here (referring to the column "what mental activity students need?") and the answers that you can choose. This is also easy (referring to the column "associated with what content?") because the teacher will know what content is going to associate to the goal and relate".

Considering the second assertion, five participants agreed (I strongly agree (3), I agree (2)) with the ease of understanding in this action. Those who disagreed with this statement emphasized:

E2: "I disagree (...) is an educational objective and you need to understand about this and not fill anyway";

E7: "I noticed which is necessary to distinguish the verbs of cognitive process and relate these verbs to the knowledge. And that don't represent the low understanding. Maybe the first few times that teacher go set targets he has some difficulty (referring to use of the verbs and types of appropriate knowledge) and gradually he learns".

Considering the assertions to define assessment, both have prevailed in total agreement (I strongly agree (4), I agree (3)) considering the clarity and consistency of the objective elements, objectives, problems and assessments.

To verify the alignment, all the participants strongly agreed with the assertion that the table helps the teacher for direction of planning. For the second assertion, the participants agreed with (I strongly agree (6), I agree (1)) to visual form which facilitates verification of the alignment or misalignment of planning actions (i.e. goals aligned to a proper evaluation), defined by the teacher in the SML. Some excerpts highlight the participants' opinion for this action:

E2: "It has a macro view, because it has the objectives and assessment, then you ask: - That's what I want to accomplish?";

E3: "When you see the screen, it makes clear the connection of cognitive process with the knowledge process. And it is a way to organize the planning. (...) I think it was easier to understand visually. Was organized because then if I want to see the objectives I can see the detail of it";

E4: "When are you going to use the table as a representation, helps a lot the understanding of people";

E5: "It's great because this screen has a broad view of everything".

Table 2 summarizes the evaluation of the participants per each screen of the prototype. Due to limitations of space, the other subjective comments have been omitted.

TABLE II. SUMMARY OF THE VALIDATION RESULTS.

Screens and assertions		Likert scale				
		I strongly agree	**I agree**	**I´m undecided**	**I strongly disagree**	**I disagree**
Access to Amadeus	1	42.9%	42.9%	14.3%	0%	0%
	2	71.4%	14.3%	0%	0%	14.3%
Registering the course	1	28.6%	28.6%	14.3%	14.3%	28.6%
	2	14.3%	14.3%	28.6%	14.3%	28.6%
Planning the course	1	42.9%	0%	0%	14.3%	42.9%
	2	71.4%	0%	14.3%	14.3%	0%
Defining problems	1	71.4%	14.3%	14.3%	0%	0%
	2	14.3%	51.7%	0%	0%	28.6%
PBL Process	1	71.4%	28.6%	0%	0%	0%
	2	100%	0%	0%	0%	0%
Defining the Ed Objectives	1	71.4%	28.6%	0%	0%	0%
	2	42.9%	28.6%	0%	0%	28.6%
Defining assessment	1	57.1%	42.9%	0%	0%	0%
	2	57.1%	42.9%	0%	0%	0%
Checking alignment	1	100%	0%	0%	0%	0%
	2	85.7%	14.3%	0%	0%	0%
PBL monitoring	1	85.7%	14.3%	0%	0%	0%
	2	57.1%	28.6%	0%	0%	14.3%

It is believed that, although static, the prototype allowed the information from the model to be expressed by means of representing the design conceptually via arrangement of the contents, buttons, flow of the screens and support to planning activities.

In summary, the results obtained present in their totality the teachers' acceptance and/or satisfaction with the screens and their goals. When considering the screen for setting educational goals, the teachers agreed that the structure is intuitive and that a coherent relationship is established between the elements. Besides understanding the proposed action, the teachers report they were able to relate the essential elements to their definition. Moreover, they also managed to identify the dependency of the objectives to the assessment on the "planning / defining the assessment" screen and they confirmed that the fields were clear and that it was easy to undertake the action. As to verifying the alignment, the teachers agreed that the two-dimensional table not only guides planning but also enables the alignment between the objectives and the assessment to be visualized.

VI. Conclusions

The purpose of this article was to present a management systems approach to education in PBL based on Bloom's revised taxonomy. With an emphasis on teaching activities, what stands out is the alignment model and the possibilities for defining clear and coherent educational goals associated with the learning module and the assessment itself. The implementation of the model proposed as an extension to the Amadeus SML was performed by using the prototyping technique. Since the teachers involved accepted both how to implement the model and the results obtained from doing so, this showed that aligning educational goals and assessment can be achieved. This made teaching practice in this environment easier and therefore given that the results were positive this shows that this approach is effective.

As to future actions, the functionalities of all the screens of this model are being incorporated into the new version of Amadeus after having been approved by its managers who did so based on this study.

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Towards an Adaptive System for the Evaluation of Network Services

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***Abstract*—This paper presents a new educational system to automatically adapt the evaluation activities to the students' needs in the context of Higher Engineering Education. As an example, a subject focused on the configuration of network services has been chosen to implement our proposal. Therefore, the system will be able to guide each student through the learning process based on his/her particular knowledge-level. In addition to this, specific techniques are needed to dynamically evolve the system depending on the students' progress. In our case, this is analyzed by using data mining techniques. Finally, we show survey results, which illustrate the ease of use and usefulness of the system.**

Keywords*—Assessment and Evaluation Strategies; Educational Adaptive Systems (EAS); Distance Education; Learning Analytics; Data Mining;

I. INTRODUCTION

New issues related to the teaching/learning process in the field of higher education, especially on-line or distance evaluation, are currently a hot topic of research, and it is of a great interest due to the growing use of the Internet [1]. In particular, the evaluation procedure is a key element within the learning process. Basically, it allows faculty to check whether educative objectives are accomplished, not only by students, but also by all the participants involved in an educative program [2]. As a consequence, lecturers must make pedagogical decisions to adapt the curricula to students' needs or level of knowledge, enforcing or extending it if necessary, and following the framework of the European Higher Education Area (EHEA) [3]. The importance of evaluation is even more important at distance Universities, as our case is, since students are more independent and self-demanding, they have no strict schedules. By means of evaluation, faculty is able to select the most suitable evaluation criteria and dynamically adapt the content resources to students [4].

As a consequence, some specific techniques are needed for defining the students' knowledge-level and analyzing their interactions with the educational platform to be used during the process of customization. One of the most recent research areas for these types of learning experiences is *Learning Analytics (LA)* [5], [6]. Its main goal is to discover and organize the existing information in order to extract useful knowledge during the teaching/learning process. An interesting general approach that uses LA for monitoring the learning activities occurring in a student personal work-space can be found in [7]. Within the area of LA, our work focuses on the field of evaluation by using data mining techniques. In this case, the process of LA will be focused on the information gathered from the educational system. In order to perform the evaluation process more efficiently, it is desirable to develop customized systems that ease the automatic selection and adaptation of the assessment resources to students' needs. Each of them has to be created with different levels of difficulty.

Therefore, this work presents an educational system for the automatic adaptation of the evaluation resources to the students' needs in the context of Higher Engineering Education. As an example, a subject focused on the configuration of network services has been chosen to implement our proposal. The system includes three types of roles: *administrator*, *lecturer*, and *student*. Administrator basically manages the activation or deactivation of users. Lecturer specifies the knowledge base by choosing the most relevant pedagogical resources and assesses the students' activities. From the student's perspective, the proposed system will automatically adapt evaluation contents to each student's knowledge-level and have perfect knowledge of the students' progress, since all the information is registered in the tracking tools. That is, the system will contain quantitative and qualitative information about the students' level of knowledge and skills. In particular, some data mining techniques from the Weka libraries [8] were adapted and calibrated to our purpose of adapting the evaluation criteria. Finally, a satisfaction survey was completed by a group of students belonging to a post-degree subject in Computer Science, as a proof of concept. The system was found easy to use and useful.

The rest of this paper is organized as follows. In Section II,

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the motivation of this work is described. Section III presents our proposed adaptive system for the evaluation of network services. The evaluation results of the system are detailed in Section IV. Finally, Section V highlights our final remarks and suggests guidelines for future work.

II. Motivation of our Work

Over the last years, adaptive hypermedia has been widely used for the development of customized Web-based courses in the field of Education [9]. Therefore, the students' learning process was guided, adapting both pedagogical resources and learning ways to specific user's features. Since lecturers (or automatic systems) adapt course materials to students' skills and usage data dynamically [10], they were able to acquire more knowledge in less time. ELM-ART [11] and TANGOW [12] are some examples of traditional educational adaptive systems. The students' interaction in these types of architectures is different from face-to-face students [13]. On-line students have to be able to adapt their communication way to the user interfaces of the adaptive systems. Additionally, it is essential to ensure that the proposed activities within the system are correctly adapted to the students' needs [14], so that they feel comfortable interacting with the educational environment.

On the other hand, it is also convenient to adapt collaborative issues taking into account the students' behaviors. The most relevant research works related to adaptation in Computer Support for Collaborative Learning (CSCL) systems are COALE [15], WebDL [16], and COL-TANGOW [12]. COALE is a collaborative environment where different exercises are recommended to students. However, students are free to choose the next exercise to be performed. The main goal in WebDL is to facilitate user access to services. It focuses on adaptive support for navigation. COL-TANGOW is also a system that supports the dynamic generation of adaptive Web-based courses. These courses are generated at run time by selecting, at every step and for each student, the most suitable activities to be proposed.

Nowadays, the evolution of the Web 2.0 allow us to develop more sophisticated techniques to analyze more efficiently the students' learning process, so improving the learning contents and structure of a course. One of the most recent research areas is *Learning Analytics (LA)* [5] in order to discover and organize the information contained in the educational platform. Figure 1 depicts all the phases which follow this process, as described in [6]:

1) *Data Capture*. The existing information must be captured in order to perform an intelligent data selection. Computer theories can be used, such as algorithms for clustering, collaborative filtering, Bayesian networks, etc.
2) *Data Processing*. At this stage, computational techniques for analytic processing are usually employed, such as associative rules, decision trees, neuronal networks, or machine learning.
3) *Knowledge Application*. From the processed data, new knowledge must be acquired and applied in order to improve the educational process. In addition, the new knowledge must be used as a starting point at the first phase of this process.

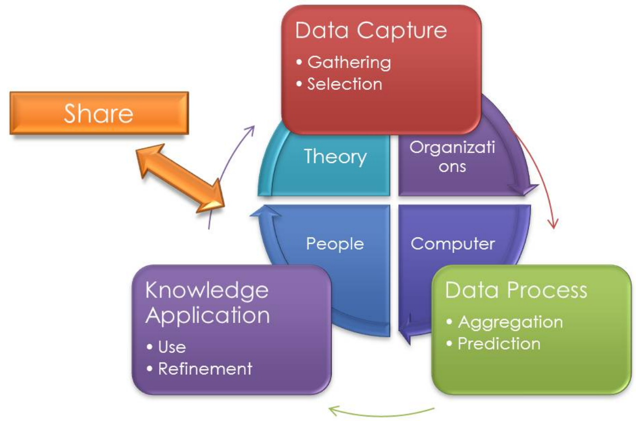

Fig. 1. The Process of Learning Analytics.

4) *Sharing*. The new knowledge extracted from the captured data and applied to the students' necessities may be shared to other contexts. As before, the new data can be used as a starting point at the first phase.

Within the area of LA, our work focuses on using data mining techniques in the field of evaluation. Data mining techniques [17] have led to a gradual replacement from data verification to knowledge discovery. These techniques can be divided in two groups: *supervised* and *unsupervised*. The supervised (or predictive) techniques are based on predicting the value of an attribute from a set of data, by using other known attributes. They are composed of two phases: training and testing. On the other hand, when predictive techniques are not enough to infer new information, unsupervised (or knowledge discovery) techniques could be employed in order to discover patterns or trends in the current data.

The most recent proposal related to assessment and customization can be found in [18]. The system proposed, named *askMe!*, supports and compensates deficits in students' individual learning by considering the students' strengths and preferences. In this work, the system core and the adaptation model employ rules in order to guide them in the evaluation process. Its main drawback is that it does not consider both the students' knowledge level and progress in order to adapt the evaluation resources to students. Additionally, this system has not been tested yet by a set of students. In contrast to this, our proposed system automatically includes both criteria and, also, it has been tested by a set of students in terms of ease of use and usefulness.

III. The Proposed Adaptive Evaluation System

The principal objective of this paper is to present a new service-oriented educational system for the automatic adaptation of evaluation activities to each student's knowledge level and progress. The Adaptive System, *AdaS* (*in Spanish*, named Sistema Adapta), will be able to guide students during their evaluation procedures. This fact can become useful since it is more difficult to dynamically keep track of the students' progress at a distance University, as our case is. In particular, we detail the architecture and user interfaces of our proposal and, then, the requirements and user models of this approach with a particular example.

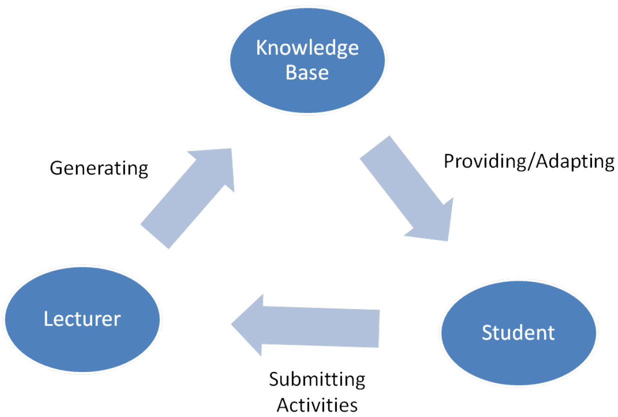

Fig. 2. Main Components of an Educational Adaptive System (EAS).

A. Adaptation and Levels of Proficiency

As shown in Figure 2, an educational adaptive system (EAS) must be composed of three main components: *knowledge base*, *lecturer*, and *student*. The knowledge base contains all pedagogical resources necessary to make possible the process of adapting the course to students. In our case, we define the evaluation resources to be included in *AdaS*. Note that, in order to adapt these resources for several levels of knowledge, each activity has been created with different grades of difficulty, so that one version or another is offered to students depending on their knowledge and particular progress in the course. Students can also rate the usefulness of each performed activity in order to improve the quality of the system.

Our system implements several user models for the customization of the evaluation criteria. To achieve this, some data mining techniques from the Weka libraries [8] were adapted and calibrated for our purposes. We use two combined ways to perform this adaptation, which are complementary:

1) The initial information for the students' customization is provided by themselves based on an initial survey. Each student is classified as *low*, *low-medium*, *medium*, *medium-high*, *high*, and *expert* according to his/her level of knowledge for each required skill and competence of the learning syllabus. Clustering techniques are used in order to establish the students' classification depending on their level of proficiency. We have employed the Expectation Maximization (EM)) [19] algorithm to make this classification possible. This statistic algorithm calculates the probabilities of each element to belong to a particular group of elements.
2) The information is automatically obtained from the previously performed interaction with the evaluation activities. Associative rules are employed to modify the student's knowledge level and, in this case, his/her skills (in terms of experience gained in the system). To make this possible, the OneR [20] algorithm have been chosen, as a first approximation of other works based on the use of rules to make user adaptation [18].

A new knowledge base is built and tested as follows. First, lecturers have to determine the pedagogical contents to be included in the knowledge base depending on the students' skills and competences to be gained for a particular context. After that, they must design the evaluation activities for each set of competences. For each activity, lecturer includes several statements with different levels of difficulty. So, a particular statement will be shown to the student taking into account how he/she was initially classified.

In our case, when students are activated in the system, they must answer a survey of initial knowledge, which contains several questions for each competence of the subject. As a result, students are established a personalized level of knowledge for each pedagogical competence. Each question will be weighted by lecturers depending on its quantitative importance to acquire the competence (or skill) in the context of the EHEA.

As a consequence, the system will offer a range of evaluation exercises based on students' particular knowledge. Note that, a student can be classified with a different level of proficiency, depending on the competence or skill to be gained. After that, they can download and perform the proposed activities for their submission. After the submission of some activity, students are required to indicate their grade of preference with regard to it. Therefore, the system will be able to adapt the evaluation exercises to students depending on their level of knowledge, progress, as well as the quantitative learning outcomes of students (from the evaluation activities rated in the system by lecturers).

Finally, lecturers will grade each activity and check the students' preferences as for the pedagogical evaluation resources offered to them. From these information, they can test and tune the system in order to improve the knowledge base.

B. Architecture of the System

Figure 3 depicts the architecture of our Web-based system. Users can access the system and perform their role-specific tasks using a web browser. The web gateway to the clients is provided by the Apache Tomcat [21], an open source application container. Additionally, the Tomcat server together with STS (Spring Source Tool Suite) [22], an open source framework for building Java-based applications supporting the Model-View-Controller (MVC) design pattern, hosts our Web application. In particular, the web application is implemented with the Grails [23], which is a framework fully-supported by Spring, and it uses Groovy as a programming language. Groovy is a high-level language based on Java.

The MVC pattern allows us to separate the architecture of the proposed system in three different layers: *Controller*, *View*, and *Model*. The Controller in the MVC pattern handles the HTTP requests from the client side, and gives information for further processing to the business logic of the application. The View compiles and presents results dynamically retrieved from the business logic. In our case, Groovy Server Pages (GSPs) are implemented. Also, some JavaScript functions are performed in the Web Client for validation purposes.

On the other hand, the Model in the MVC design pattern represents the business logic. In particular, it manages user data and roles. This component also handles evaluation resources, and controls the automated adaptation to students' needs. For the purpose of persistent storage of data and states, the open source framework Hibernate [24] was used. The underlying data are managed by the free available database system MySQL [25].

Figure 4 shows the diagram of the principal use cases for *AdaS*. Users can access the system and perform their role-specific tasks using a Web browser. The system considers three profiles: *administrator*, *lecturer*, and *student*. Administrator manages users' information, by activating or deactivating users as desired. Previously, both lecturers and students must register in the system, with the option of modifying their profile as necessary. The application has a private area for lecturers where they are able to create, modify, and remove the knowledge base with different pedagogical evaluation resources to be used. In addition, lecturers can evaluate the activities submitted by students. Also, they may communicate with students through the application.

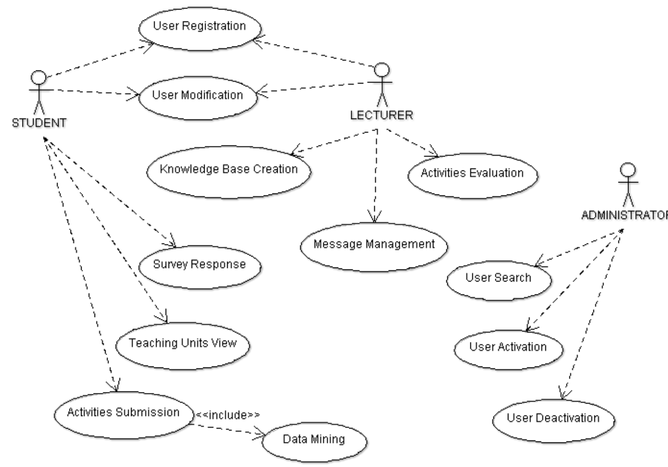

Fig. 4. Diagram of Use Cases in *AdaS* (Focuses on the Main actions of Student, Lecturer, and Administrator).

C. A Network Services' Example at UNED

The chosen subject to illustrate our approach is named "Management of Network Services in Operating Systems" (NetServicesOS), and it belongs to the "Communication, Networks, and Content Management" post-degree program in the Faculty of Computer Science at Spanish University for Distance Education (*in Spanish*, Universidad Nacional de Educación a Distancia, UNED) [26]. The scope of our proposed system is much broader, since this system has been designed and implemented as a modular system, which is independent of the design and implementation of specific activities. Therefore, it is not difficult to transfer the system to other contexts (e.g. Health, Humanities...).

Our NetServicesOS subject provides students with an advanced knowledge on the configuration of the network services provided in a local environment. The UNED University has a virtual campus [27], named aLF, with more than 220,000 students. This on-line campus is based on the dotLRN platform [28]. All subjects belonging to degrees and post-degrees at UNED are also adapted to the context of the EHEA [3], [29]. Its maintenance is a task that not only implies the deployment of sophisticated hardware and software, but also allows the inclusion of new application services, in our case, new procedures for evaluation.

Next, some of the user interfaces of our proposed system will be shown. Graphical interfaces have been developed in

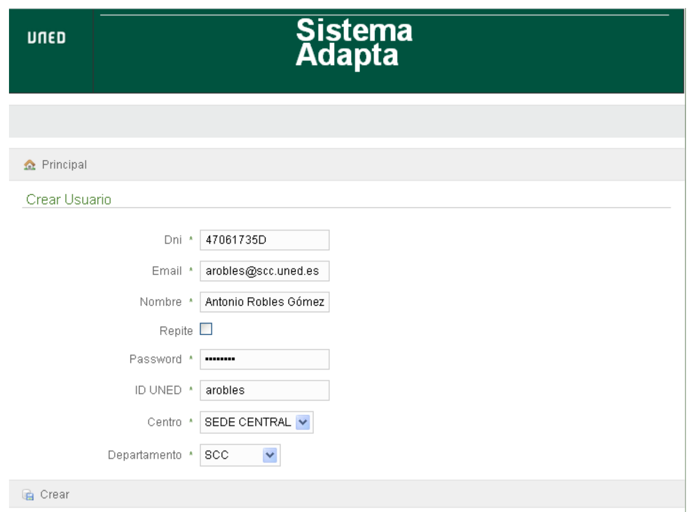

Fig. 5. Interface for the User Registration.

order to interact with the system easily. As first example, Figure 5 shows the interface of a user registration (both lecturer and student). Here, the user role is selected, apart from other parameters, such as name, surname, identification number, e-mail, and so on. Once the user submits this form, the administrator will receive a message requesting the activation. After the administrator accepts this request, the user can access the system.

From the lecturers' view, lecturers can organize the evaluation resources. For instance, as Figure 6 shows, they can create a new resource to be added to the knowledge base. In this screen, the most relevant parameters of each activity for the students' adaptation are selected. From the students' view, as we can observe in Figure 7, they must answer in an initial survey, so that the system analyze their initial level of knowledge. Additionally, the system is able to adapt its evaluation activities to each student' progress in the course in terms of new acquired knowledge and experience, as observed in Figure 8. In our example, knowledge is related to the

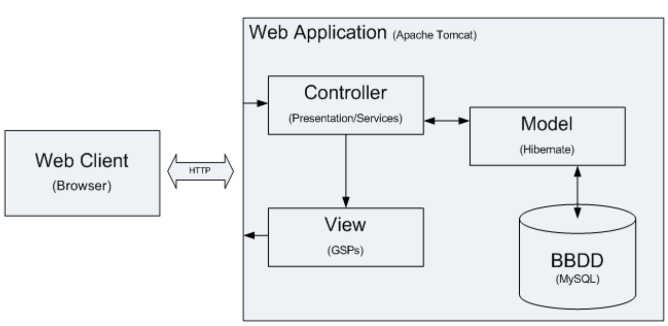

Fig. 3. The Proposed Architecture.

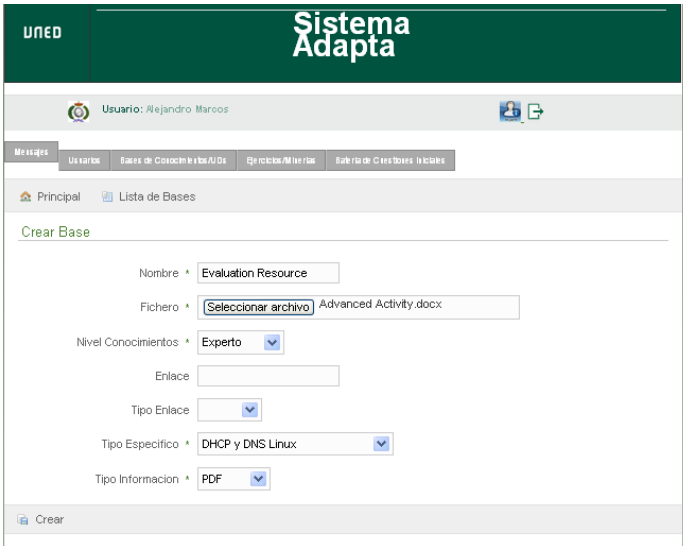

Fig. 6. Interface for the Creation of an Evaluation Resource for the Knowledge Base.

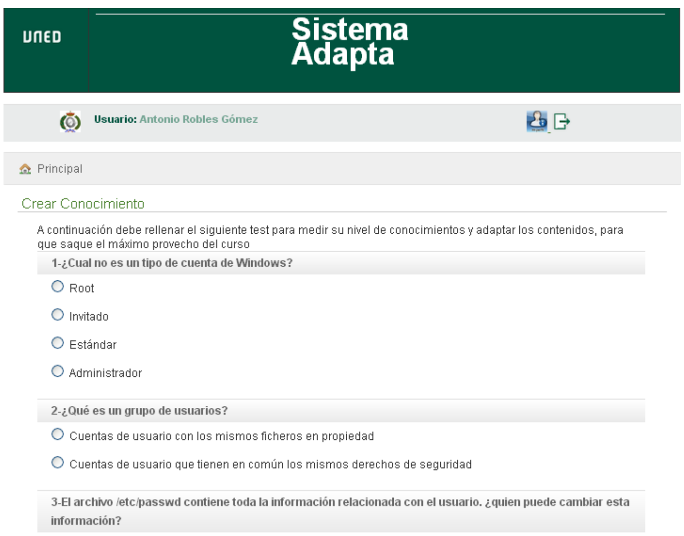

Fig. 7. Interface for the Students' Knowledge Survey.

configuration of network services on two of the most widely used platforms, namely Windows and Linux operating systems.

IV. Survey Results

In this section, the results from surveys conducted among students are presented. This has been done in order to obtain feedback from the students about the proposed *AdaS* in terms of the ease of use and usefulness of the system. The criteria used to choose the survey questions follows traditional guidelines as seen in other previous studies, such as [30], [31]. The survey has been conducted on 10 students of the NetServicesOS subject during the current 2012-2013 academic year. Each question has a five-point Likert-type scale, being 5 the best and 1 the worst.

Table I shows the questions of the survey along with the results we obtained. It can be observed that students are highly satisfied with the system and its user interface – 60% of

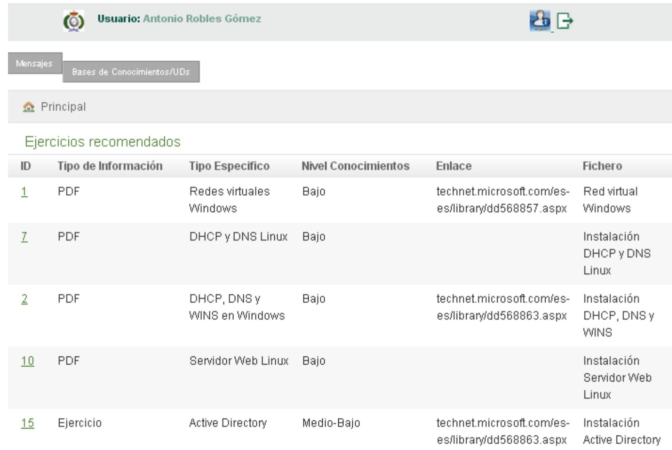

Fig. 8. Interface for a Student's Evaluation Activities.

students totally agree with their general satisfaction, and the rest of them agree. In this sense, only the 40% of students had strong previous experience on the use of this type of systems (they answered 5 to question 1). Furthermore, 80% of students are totally satisfied with the students' interface of the system. The rest of them partially agree with this issue.

As for the usability of the system, students think the system is useful; the 90% of students totally agree and the 10% of them partially agree. Also, 60% students partially agree about the ease of use of the system, and the rest of them totally agree. On the other hand, when students are questioned about the suitability of their interaction with the system, the 40% of students totally agree, and the rest of them partially agree (answered 3 o 4 to question 6). Finally, the 80% of students think these types of systems are very interesting for the education in Engineering. The rest of them think the system is really interesting.

These results underline the high quality of the system we developed, and encourage the use of this system in other subjects in Engineering Education.

V. Conclusions and Future Work

On-line education is nowadays supported by using e-learning platforms, which allow faculty to improve the process of teaching/learning. Some specific techniques are needed to analyze the students' needs and progress in order to make relevant improvements to a web-based course. Within the area of LA, our research focuses on using data mining techniques in the field of evaluation. In particular, this proposes an educational adaptive system, *AdaS*, that dynamically adapts the course evaluation resources to the students' knowledge level and progress. This system has been used for the evaluation of activities belonging to the NetServicesOS subject, but it would be easily transferable to other environments.

By means of this tool, the learning process can be automatically adapted to the students' knowledge level and skills (in terms of experience) in the system. Therefore, lecturers can dynamically follow the students' progress and grade their achievements for each proposed competences of a subject, in the case of Spain, in the framework of EHEA. Students are also able to rate the suitability of an evaluation resource, so

TABLE I. STUDENTS' SURVEY (5—THE BEST; 1—THE WORST).

Questions	1	2	3	4	5
1. Did you have any previous experience with these types of systems?	—	—	30%	30%	40%
2. What is your general satisfaction with the system?	—	—	—	40%	60%
3. What is your satisfaction with the user interface of the system?	—	—	—	20%	80%
4. Do you think this system is useful for their purposes?	—	—	—	10%	90%
5. Do you think this system is ease of use for their purposes?	—	—	—	60%	40%
6. Do you think your interaction with this system is suitable?	—	—	10%	50%	40%
7. Do you think these types of system are interesting for Engineering Education?	—	—	—	20%	80%

that lecturers receive feedback in order to improve the system or detect weaknesses of students. Moreover, we conducted a survey to test the quality of our developments in terms of its ease of use and usefulness. The main conclusions we obtained from the survey is that *AdaS* is easy to use and useful, which encourage its use in other subjects in Engineering Education.

As a future work, we plan to improve the functionality of the system by using alternative data mining techniques for the adaptation of activities to the students' needs, this way improving the adaptation of the evaluation resources to achieve a more intelligent curricula. Some of them can be sequential pattern mining, Markov models, and probabilistic latent variable models. On the other hand, our proposed approach will be integrated with our institutional educational platform in order to exhaustively be compared to other tutoring systems. Finally, different frameworks or contexts from EHEA, as the proposed ones by the ASEE Educational Research Methods (ERM) Division [32], could be explored within the *AdaS* environment in order to analyze if the results obtained are similar and/or it is need of making some changes.

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Once Again Around the Double Triangle

A Multi-Rater Assessment of Capstone Design Skills

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***Abstract*— The Senior Capstone Design Course serves for many engineering students as an opportunity to develop crucial skills in professionalism and design that are necessary for succeeding in industry post-graduation. This study delves into the effectiveness of a senior Mechanical Engineering Capstone Design Course for the development of professional and technical skills including: project management, design, engineering methods, communication, and teamwork. A triangulated assessment was performed to evaluate the development of student skills using a survey administered during the middle and end of the Senior Capstone Design Course. This survey was administered to the students, team Faculty Advisors and team Industry Mentors. After analysis, it was found that teams made a significant gain pre to post in engineering methods, project management, and design skills. Communication skills remained at an acceptable level while teamwork skills dropped significantly in the second semester due to difficulties resolving interpersonal conflicts.**

Keywords—Capstone design, industry partnerships, skill development, assessment

I. BACKGROUND AND RESEARCH QUESTIONS

The determination of skill development in Capstone Design courses typically occurs as students are close to graduation. For many schools, the Capstone experience is the only project-based design course in the curriculum and provides a unique opportunity to develop and assess important skills related to professionalism and engineering design. [1] The team based, project based nature of many Capstone courses constellates a variety of skills sets necessary for delivering a functional design ranging the gambit from hands on fabrication skills to the nuances of interpersonal conflict. [2] The research question for this study is whether a Capstone design experience is successful in building key professional and technical engineering skills that do not always receive developmental attention in the early portion of an engineering curriculum. What makes this research unique is the way that these skills are assessed.

Historically, skill development in Senior Capstone Design is often measured via student self-reported data. While this data is easier to obtain and has been found valid, criticisms have been leveled at self-reported student data as a standalone evaluation of student skills. These criticisms target the biases inherent in the limited experiences of a 22 year old student evaluating their own professional development. [3] One alternative to reduce bias is to implement triangulated assessment methods where three parties measure the same set of skills. [4-5] While this method provides additional perspectives, it is still difficult to determine technical and professional skill development from assessment conducted during a single assessment period. [6] Previous work by the authors looking at student rated skill development uncovered a need for a triangulation method to calibrate the ratings of the students' self-assessment against industry professionals and faculty advisors. [7] Similar efforts have been conducted at Stanford with data collected from multiple sources to evaluate a course on team based design with corporate partners and at UC-Berkeley where team design journals, faculty evaluations, and ratings from external judges are used to predict the success of design teams. [8-9] The present study offers an improved and innovative model—a multi-rater, triangulated assessment to investigate gains in skills between mid-term and the end of the Capstone year.

The Senior Capstone Design (SCD) course investigated in this study is a mechanical engineering, two-semester, industry sponsored course at the University of Colorado Boulder where students work in teams on a year-long, client-based design project. The course is presented as a model where the SCD experience is framed as a *transitional space*, connecting the chasm between a student's engineering education and a career as a practicing engineer. Instead of seeing Senior Capstone Design as a culmination of undergraduate engineering, we see it as a forward-looking event—*beyond Capstone*—launching students into the industry career that 80% of our nascent mechanical engineers pursue.

The key test-bed and housing structure for this Capstone transitional space is a state-of-the-art design center. Approximate 24 projects (~130 students/year) are fashioned in facilities with over 10,000 square feet of design space including student module work bays, material testing instrumentation, composites fabrication space, a student machine shop, and a student computer lab. Center curriculum for the SCD course is focused around an industry-education partnership between a university academic department and sponsoring partners from industry and government. Capstone teams operating out of the center meet weekly with two assigned mentors, one of which is university faculty and the other an industry representative from the sponsoring company. The projects culminate in an end-of-year design competition and expo.

II. METHOD

Data were collected for this study across a four-year period. Triangulated assessments were developed targeting specific course objectives and conducted for the course at mid-year and end-of-the-year with ratings carried out by Faculty Advisors, Industry Mentors, and team members themselves. Rating categories used 2-4 ratings per category with ratings made on Likert-type scales. Each rating was supported by qualitative responses to an open-ended question related to the rated skill. An example question from the teamwork category is, *"Was the team able to resolve interpersonal conflicts in a satisfactory way?"* The unit of analysis for this study is the team, with each team rated on the following five skills sets:

- **Engineering Methods**: The necessary technical background to complete a *long term, industry-sponsored* project and be able to apply a knowledge *of relevant manufacturing skills and computer software,*
- **Design**: The ability to demonstrate an understanding of the *iterative design* process and *contextual considerations* of design,
- **Communication**: The production of high quality communications including *oral presentations* and *written reports,*
- **Teamwork**: The adeptness to building *group cohesion* and *resolution of conflict,*
- **Project Management**: Demonstration of professional skills including proficiency at *project management*, planning, organizing, goal accomplishment and general *professional conduct* becoming of an engineer.

Mid and post-test mean scores were calculated and subjected to an independent samples t-test to determine statistical differences in triangulated skills between the two assessment times. Ratings from all raters were combined for this analysis.

III. PRELIMINARY RESULTS AND DISCUSSION

Results from the statistical analysis are presented in Table 1. Across raters, teams made significant gains mid to post in Design skills, Engineering Methods, and Project Management skills while Communication skills, team, written and oral, maintained an acceptable rating level (> 4.0/5). The strongest gains were in the area of *Engineering Methods: Fabrication methods* and *Project Management: Accomplished project goals*. Qualitative feedback supports these ratings with one student commenting, "I liked manufacturing all the parts for our project the most. I really enjoyed learning how to make parts using the mill and lathe." Regarding project management skills, one Faculty Advisor rated the best part of the course as, "seeing the team mature into a strong working unit and delivering the goods." Similarly, one Industry Mentor reported, "This group showed a strong bond of teamwork from the start and were motivated throughout the year to achieve the design objective. I met with the team every week and enjoyed seeing their progress, how each member was contributing to the project, and discussing ideas together. The best part of this experience for me was working with a great team and believing that they would do well, which they did."

An area for growth is in *Teamwork skills: Interpersonal conflict resolution*, where student ratings significantly dropped during the second semester related to their ability to resolve team conflict. One student commented on the post-survey that, "A lot of the team members were not very confrontational so a lot of the problems near the end were let go. They should have been dealt with." Similarly, a Faculty Advisor commented, "Team basically worked around a member by the end because of complete lack of their interest in project."

Another area of concern is in the area of Project *Management skills: Execute project schedule* and specifically, teams that did not achieve an average rating above 4.0/5 at the post-test. Along these lines, one industry mentor commented, "It would have been nice to have enough time left to run another set of tests to confirm the issues that they found on the initial tests."

A third area to consider for future development is the relevant technical background for the project (*Engineering Methods: Relevant Preparation)*. One Industry Mentor requested, "Curriculum needs to include more GD&T, CAD skills, and following a project from requirements definition through integration and test." Similarly, a Faculty Advisor reported, "I harangued the students about their writing because so many issues I have with my colleagues boil down to communication and quite often we communicate via e-mail. Please help them with this." Students reflected their concerns in a more straightforward fashion, "Help us find who we should talk to for our difficult, technical questions."

Implications of these results include the need to maintain curriculum that produced the strongest gains, including a continued emphasis on hands-on fabrication skills in the machine shop and a goals driven focus that seeks to produce a quality design for a paying client in time for the end-of-the-year design expo. Results also imply the need for curriculum modifications including the need to integrate additional conflict management training and coaching throughout the year. Industry partners have recommended and facilitated training opportunities with conflict management consulting firms and these are planned for future iterations of the course.

Also, additional project management training is under development to help students stay on their design schedule including adding workshops specifically for team members in the project manager role. Students' technical backgrounds are being addressed through efforts to add additional design curriculum to the sophomore and junior years. It is expected that earlier design experiences will catalyze and develop skills necessary for project-based design in advance of the senior year.

This study qualifies as a work in progress because data analysis is still preliminary. Future work will focus on disaggregating ratings by raters to determine the difference in industry, faculty and student perspectives. Further data collection will allow for a larger Faculty Advisor and Industry Mentor sample size to complete significance testing within raters rather than aggregated across all raters only. Additional work also needs to be accomplished on the assessment tool as the rating system was developed for assessment purposes. For obtaining research quality, the assessment tool should be more fully tested for reliability and validity, including a test for interrater reliability between raters.

TABLE 1: RESULTS FROM MULTI RATER, TRIANGULATED ASSESMENT

Objective	Rating Categories (All Raters)	n	Mid-year	n	End-year
Communication Skills	Oral presentations	303	4.24	307	4.33
	Team communications	260	3.95	231	4.01
	Written reports	263	4.22	328	4.21
Design Skills	Met project constraints	264	4.42	265	4.57
	Understand design loop	262	4.34	264	4.43
Project Management	Accomplished project goals	263	3.75	264	4.01
	Meetings effectively run	262	3.94	230	4.15
	Execute project schedule	261	3.60	232	3.72
	Professionalism	304	4.34	328	4.32
Skill at Engineering Methods	Fabrication methods	260	4.15	263	4.44
	Design/analysis software	261	4.13	262	4.27
	Relevant preparation	304	3.83	330	3.90
Teamwork Skills	Satisfaction with team's progress	304	4.20	329	4.36
	Fulfilled assigned roles	261	4.48	232	4.42
	Interpersonal conflict resolution	242	4.53	220	4.38
					$p < .05$

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Teaching computer networks: a practical approach using virtualization tools

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***Abstract*—Virtualization tools, useful softwares that enables tests and evaluation of functionalities, have been used in computer network classes to provide an environment for practice experiments. Although some papers describe these tools and their technical benefits, they do not provide quantitative information about its effectiveness. This paper presents a proposal for systematic use of this category of tools in computer classes and a evaluation of the Netkit tool use in computer network classes. It will be shown how tutorial sections have been developed to these courses, the receptivity from the students through surveys and a statistical analysis of how much students grades can be improved by applying such tutorials. Finally, it will be possible to conclude that, in fact, the use of such tools is strongly advised.**

Keywords—Netkit, Computer Education, Computer Network, Effectiveness Evaluation

I. INTRODUCTION

Virtual computer networks are wide-spreading along researchers, administrators and teachers all around the world. These kinds of tools provide a solution for creating low-cost experiments that students can run in their personal computer, even if they have a modest configuration [1]. Particularly, in the context of distance learning, when the student does not have, essentially, access to an adequately equipped computer network laboratory, these tools are indeed valuable. Although some educational institutions are already using virtualization tools in their computer network classes [2], no consolidated practice about the use of these tools is available and, currently, no bibliography describes how much effective they are when applied in teaching and learning processes.

A particular set of these tools are based on a special version of Linux Kernel, the UML (User Mode Linux). UML is used by Linux developers to allow kernel and file-system debugging in user space mode. So, if a critical modification needs to be performed, the computer itself will not crash [3]. Some examples of virtualization tools based on UML Kernel are *Netkit*[3], *VNUML*[1] and *GINI*[5]. They are relatively easy to use for create experiments [1] and they also need only a few computer resources [1].

From the educational perspective, from academic to industry expectations, the professional formed by industry needs to be prepared to handle a large number of issues [3]. In computer network domain, this means that the recently graduated professional will need to perform configuration of servers, security hardening of networks, routers configurations, among other tasks. Certification exams, like CCNA (*Cisco Certified Network Associate*) from Cisco Company, show what a starter, recently graduated computer network professional, needs to know [9].

Unlike other computer science disciplines, such as programming languages and algorithms, databases, operating systems, that usually require little computer resources and a few software tools, a deep study of practical computer networks requires access to a laboratory with specialized hardware, like switches and routers, beyond some computers. Simulators like *Cisco Packet Tracer* [10] enable some level of experimentation. However, such simulators have a strong limitation. Students are unable to install free and wide spread software used by network administrators, like Bind DNS Server [11], Apache Web Server [12] or MRTG management tool [13].

In this paper we discuss the use of *Netkit* tool in computer network practical courses. Also, we discuss how educational modules were developed using IMA-CID (*Integrated Modeling Approach - Conceptual, Instructional and Didactic*) [14]. From the conceptual model developed using IMA-CID, tutorials were developed to cover the course program, together with theoretical lessons, which could be streamed over Internet in distance learning courses or taught in traditional classroom courses. Finally, we presents an effectiveness evaluation conducted at ICMC / USP (Institute of Mathematics and Computers Sciences, University of São Paulo), from both quantitative and qualitative perspectives of the course, discussing how *Netkit* improved the student's apprenticeship.

The next sections of this paper are organized as follows: The Section II presents some related works that explores simulators and virtualization in computer sciences courses. The Section III presents IMA-CID and how computer network topics were modeled. The Section IV describes how *Netkit* topics were translated into tutorials and how they were used in the classes. A learning effectiveness evaluation of the course using *Netkit* will be present at Section V. Finally, Section VI summarizes our conclusions and future work.

II. Related Works

Gadelha et al. (2010), present the OS Simulator, which consists of a simulator file system to support the teaching and learning of operating systems. The authors' work describes the tool and analyzes the students positive attitude feedback obtained through questionnaires. No information is provided regarding the effectiveness of learning when using the tool [4].

Fuertes and Vergara (2007) present the VNUML, a virtualization tool similar to *Netkit* for virtualization of computer networks, VNUML has very similar features and based on UML as well. The authors show a comparison of performance among the VNUML, Netkit and other similar tools. However, tools for teaching computer networks are not the focus of this paper. This work lends to the choice of *Netkit* as a environment for development of tutorials teaching networks. Thus, in comparison with other tools for network virtualization, *Netkit* tool has better memory utilization, good processing performance and presents itself as a friendly configuration environment [1].

RCOS.Java simulator [7] is an open source operating system presented by Jones and Newman (1996). The paper shows the authors' motivation to create the tool, although it was not evaluated in a course to detect the apprenticeship level at the time of its publication. This work has contributed significantly to the educational foundations explored in the tutorials developed for teaching computer networks.

Bogo et al. (2009) discuss the use of Netkit to teaching routing algorithms. However their study is quite simple, showing the possibility of exploiting the tool for teaching a full course. The present study extends Bogo et al. study, making tutorials and also evaluating the level of student learning through practical experimentation [2].

Dobrilovic et al. (2012), present a study evaluating the use of VNLab tool. VNLab is a permanently virtual network hosted at Technical Faculty "Mihajlo Pupin", University of Novi Sad, Serbia. The students are able to connect to the virtual laboratory using a remote access tool and make experimentations. The paper describes hardware requirements and a list of network exercises, and a usability evaluation showing how much of the curriculum is covered by the tool. There is a major difference between both proposals. VNLab provides a stable, managed environment for experimentation, but the paper does not cover how a large concurrency is handled. Netkit experiments can be run at students own computers, giving them total privileges to study, modify, and even crash the whole network [15].

These studies show the relevance of using computational tools, in particular simulators, to support the teaching and learning process. Fuertes article, in particular, compares various tools that could have been chosen to achieve the same goal. However, Netkit little memory consumption was a relevant factor in its choice, according to some idealized scenarios. It is important to point out that there are several simulators of computer networks. However, none is used with the aim of improving the quality of teaching and learning level of the students, especially the way it is presented in this article.

Also, it is important to note that the authors of this paper are not the creators of the *Netkit* tool; the authors created the tutorials and applied a formal evaluation of the effectiveness of using this teaching method and tools, corroborating results demonstrated in other areas of knowledge to teaching and learning computer networking process. Some studies are referred, although they were applied to other areas of knowledge, helped in the development of tutorials and evaluations performed in this paper.

III. IMA-CID: An Integrated Approach for Modeling Educational Content

Educational modules are concise units of study, composed by theoretical and practical content, like books, papers, websites, multimedia resources, program code, software documentation and for the matter of this paper, virtual laboratory files. These content are integrated in term of learning materials, and require an infrastructure to be correctly created and delivered to students.

For systematically developing educational modules, Barbosa et al. (2004) define some supporting mechanisms for their development. A Standard Process for Educational Modules and an integrated modeling approach for educational content (IMA-CID – Integrated Modeling Approach: Conceptual, Instructional and Didactic) were established [14].

This process works with three models. The first one, the conceptual, is a description of the domain being researched. An instruction model can be used to design additional information, like examples, presentations, multimedia content and other resources that can facilitate the learning process. Finally, the didactic model gives a sequence of the elements generated or used in prior models. IMA-CID considers aspects like audience, goals, length and resources available.

IV. Netkit as a Tool to Support the Teaching and Learning of Computer Networks

4.1. Netkit: An Overview

Netkit is an emulator that enables the creation of experiments in virtual computer networks, including the hardware devices required for their support, as well as the creation of virtual links interconnecting them. Netkit started to be developed as an open source, in 1999, in Rome Tre University, Italy, later receiving support from the scientific community [2]. The virtual machines provided by *Netkit* are initialized with real software that, once running, provides

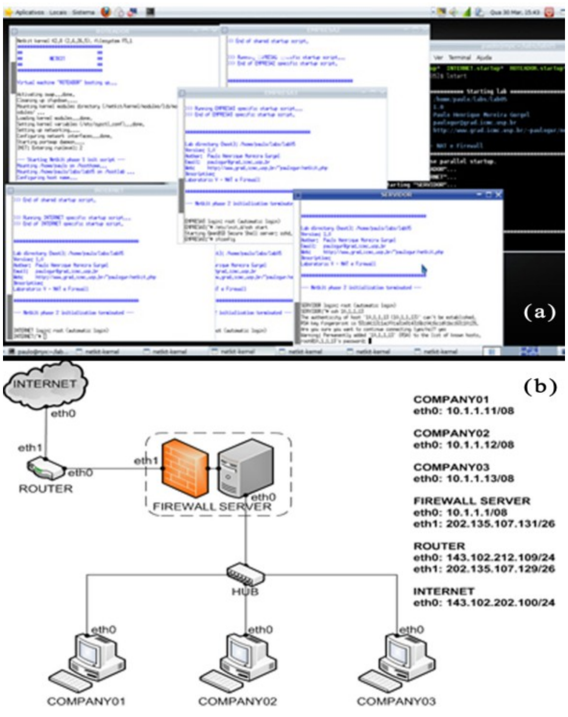

Fig. 1. (a) virtual laboratory in execution; (b) network topology emulated

practical experience to students, even if they has only one computer in their home. Fig. 1a shows an example of virtual laboratory in execution, as Fig. 1b shows the network topology implemented by this laboratory.

The choice of free software to run such experiments is relevant, because it enables institutions with low financial resources and students themselves on using the tool without worrying about the costs arising from a marketed product. In short, a virtual machine is started by Netkit as a full computer running a Debian GNU / Linux in single user mode. To transform this virtual machine on a specific device it is necessary only to run the appropriate software [3]. The basic system files accompanying the *Netkit* bring several tools preinstalled configuration for different network topologies, administration, management and security.

4.2. The use of Netkit at ICMC / USP

To carry out the practical activities in disciplines SSC-0142 (Computer Networks) and SSC-0152 (Administration and Network Management) courses at ICMC / USP, 11 virtual laboratory activities were developed. A virtual laboratory activity, simply called *lab* (acronym for *Basic Learning Laboratory,* in Portuguese), consists of a tutorial for implementing the activity and a set of files necessary for activation of the scenario studied in the laboratory by virtual Netkit. The tutorial, formulated in simple and accessible language, has the following sections:

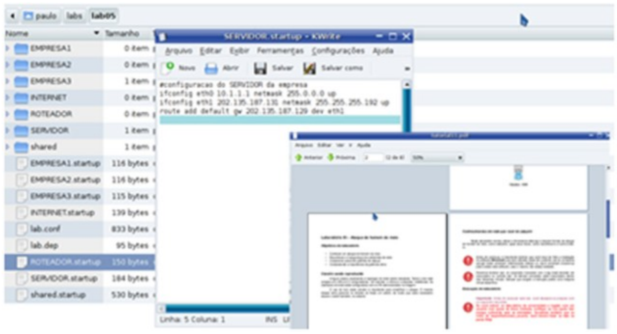

Fig. 2. Laboratory file structure and content

1) A presentation with the experiment goals;

2) A scenario explanation explorer by the virtual laboratory;

3) A brief explanation of the concepts of networks and / or network administration being studied in the tutorial;

4) A sequence of instructions for carrying out the practice;

5) Alternative proposals for experiments that can be performed on the stage;

6) Theoretical and practical exercises related to the subject being studied;

7) An explanation of Linux-related content and Netkit for student support.

SSC-0152 course is mostly practical. Firstly, a theoretical part is presented at the beginning of each class. Later, tutorials are implemented by students. The teacher and an assistent follow the experimentation and solve any doubts. Figure 2 shows the file structure of one of the labs, its content and a tutorial.

4.3. Laboratories applied

The tutorials, in Portuguese and English language, are available at http://www.paulogurgel.com.br/netkit.php. All the tutorials can have instructions that intentionally do not succeed. The idea is not only display successful situations to the students, but also failures and common configuration mistakes. Meanwhile, in all the tutorials, the student must perform capture of network packets used for communication and further study using the graphical tool Wireshark, where they can view the contents of the packet headers and the formation of the major network protocols being studied [17]. The following is a list of topics covered by tutorials:

1) Broadcast network: The first lab shows a rather simple scenario, with one hub, where the students need to configure addresses and test communication.

2) Peer network: This lab demonstrates the difference between broadcast networks and point to point through the use of a software switch.

3) Static Routing: In this lab, the student has contact with the Linux command *route* and learns how to manually configure routes and gateway.

4) Dynamic Routing: This tutorial presents a network with 5 *Quagga* routers. Students have contact with RIP (Routing Internet Protocol) for dynamic routing.

5) Firewall and Network Address Translation (NAT): This tutorial leads the student by setting a complete firewall, internet sharing and TCP port forwarding to internal network computers.

6) Domain Name System (DNS) with Bind9: This tutorial explains the process of configuring the DNS service and reverse DNS server provided by Bind9, the most widely used software for DNS [18].

7) Servers: This tutorial describes how to assemble an infrastructure of Linux servers with software Apache 2.0, MySQL 5.1, PHP 1.3 and ProFTP 5.3.

8) SysLog and Simple Network Management Protocol (SNMP): This tutorial shows the service configuration logging and SNMP agents for network management.

9) Multi Router Traffic Grapher2 (MRTG): The MRTG tutorial demonstrates the installation and configuration of a tool that allows monitoring of traffic and other information issued by SNMP.

10) The man in the middle attack: This tutorial presents a attack known as "man in the middle attack" using "Address Resolution Protocol (ARP) spoofing" technique.

V. APPRENTICESHIP EVALUATION

To evaluate the learning effectiveness of using *Netkit* and practical tutorials developed, two evaluations were performed. There were considered both a quantitative and a qualitative approach. For the quantitative approach, a particular issue was to find similar evaluation in bibliography, even on another computer science discipline, once qualitative evaluations are usually preferred. For this reason, techniques of statistic performance evaluation such as applied in information systems and softwares were done [16].

5.1. Quantitative approach

For a qualitative evaluation, a comparison between two classes of discipline SSC-0152 (Network Administration and Management) held at ICMC / USP, with equivalent prerequisites and the same professor were performed. The first class, called class A, with the participation of 40 students, was taught in the first semester of 2010 and took classes using only the physical structure of the network laboratory of the university, without the use of Netkit. The second class, called class B, had 27 students, was conducted in the first half of 2011, the Netkit being used to carry out the lessons. The classes of both disciplines occurred in the same laboratory.

Considering the course syllabus, at its conclusion, students should have early knowledge about management and network management, configuration of servers and routers, security aspects and network management. Each of these topics could be studied in depth in a specific course. Table 1 illustrates the possible levels of depth of the topics covered during the course and how these topics were evaluated. The column 4 contains a weight adjustment factor, used to calculate the knowledge levels. For level 1, the weight should be zero since the subject was not assessed. The purpose of this weight is readjusting the effect of a simple question about a topic that could be explored extensively.

For evaluation purposes, four discrete levels of acquired skill, denominated knowledge levels, were stipulated. Each student had they skills evaluated in every course topic, though exams and assignments. The weighted grade, considering the depth level, allows the discrete classification of a student skill. The knowledge level, the necessary grade and a description of what skills are expected from the student are presented in **Table 2**.

TABLE 1. DEPTH LEVEL

Level	Name	Description	Weight
1	Superficial	The topic was briefly mentioned, presenting what is, and what it is indicating bibliography for further self-study. The knowledge was not charged under evaluation.	0,00
2	Theoretical	The matter was presented to the student theoretically, during the course or course prerequisite. Theoretical knowledge is evaluated.	0,70
3	Practical	The subject was required to perform practical activity oriented. Theoretical knowledge is evaluated.	0,85
4	Full	The subject was charged in individual or collective practical work and written assessment.	1,00

TABLE 2. KNOWLEDGE LEVEL

Level	Name	Description	Grade
1	Unknown	Students at this level of knowledge cannot describe the usefulness of certain tool, protocol, or network service.	From 0.0 To 2.49
2	Acknowledged	The student understands the purpose of the tool, service or protocol in theory, but would not know how to apply this knowledge in practice	From 2.5 To 5,49
3	Maintainable	The student not only knows the purpose, as it is able to make small and medium adjustments and adaptations, as well as utilize the tools and network services.	From 5.5 To 7.49
4	Critical	The student is not only able to make adjustments and adaptations, as it is able to deploy new tools and features, carry out projects and evaluate the performance of the system and deployed solutions.	From 7.5 To 10

Table 3 presents the results obtained by comparing the level of depth to the knowledge level of the A and B classes. Asterisk (*) indicates topics not assessed from students. In the table is also presented the standard deviation (SD) as additional information. As can be inferred, the class B has a depth level (DL) greater than, or equal to the depth of the topics covered in class against class A. In fact, Netkit provided a more depth coverage of topics and intensification of practical activities. Although a deeper subject study could, intuitively, increase the subject difficulty degree, Netkit use showed a overall average improvement of 1.4 points and a reduction of 0.7 points on the standard deviation, demonstrating greater homogeneity in learning.

It is also possible to check that *Class A* weighted averages are penalized by the low level coverage during the course. Comparing the average absolute items "Tools" and "DNS", *Class A* has better overall average. The better results in these subjects are explained by the simple assessment of the class tests compared with *Class B*. For all other topics, even without the correction factor, the overall average was improved.

Problems caused by inadequate environment, perhaps exacerbated by the higher quantity of students, may have negatively influenced the performance of the class A. To ensure this evaluation accuracy, tests were applied at start of each class term to verify different levels of foreknowledge. Due to similar preparation, no significant averages or standard deviation differences were detected.

TABLE 3. COMPARATIVE RESULTS – DEEPNESS X KNOWLEDGE

Subject	Class A					Class B				
	DL	*AV*	*WA*	*KL*	*SD*	*DL*	*AV*	*WA*	*KL*	*SD*
Addressing	4	6,2	6,2	3	4,7	4	7,7	7,7	4	1,3
Routing	4	4,8	4,8	2	5,1	4	7,5	7,5	3	0,9
HTTP	2	7,3	5,1	2	2,7	3	7,7	6,6	3	0,7
FTP	2	7,3	5,1	2	2,7	3	8,5	7,2	4	0,4
SSH	1	*	*	*	*	2	9,2	6,5	3	0,3
Firewall	1	*	*	*	*	4	6,7	6,7	3	0,4
NAT	3	6,1	5,1	2	4,2	4	7,0	7,0	3	0,7
DNS	2	7,3	5,1	2	2,7	4	6,7	6,7	3	1,3
SysLog	1	*	*	*	*	3	8,5	7,2	3	0,5
SNMP	2	5,9	4,1	2	3,6	4	7,5	7,5	4	1,2
Tools	2	7,2	5,1	2	2,8	3	6,7	5,7	3	1,4
Concepts	3	6,1	5,2	2	3,7	4	8,3	8,2	4	1,3
Security	1	*	*	*	*	3	8,0	6,8	3	0,7
Ldap	1	*	*	*	*	1	*	*	*	*
Email	1	*	*	*	*	1	*	*	*	*
Samba	1	*	*	*	*	1	*	*	*	*
Overall	2	6,3	4,4	2	1,5	4	7,7	7,1	3	0,8

TABLE 4. SURVEY GRADES

Question		Average
Q1	What is your level of prior knowledge on the subject?	1,400
Q2	How would you rate the clearness of the tutorial?	4,025
Q3	What degree of difficulty in understanding the proposed scenario?	3,175
Q4	What is your level of satisfaction with the proposed practice?	4,250
Q5	How do you evaluate the presentation prior to the tutorial?	4,150
Q6	How much do you believe on your evolution on the subject?	3,650

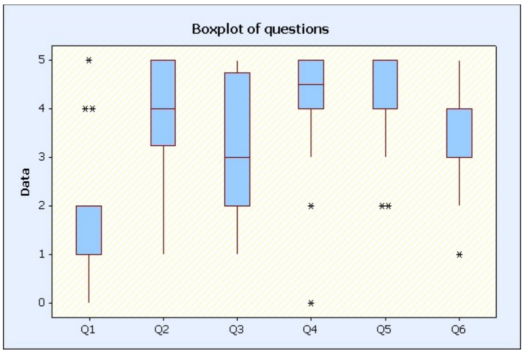

Fig. 3. Grades Distribution

5.2. Qualitative approach

Apart from quantitative research, qualitative research was applied through a survey conducted with students in two practical activities at Class B. These surveys, anonymously answered, were passed to get direct feedback from students' expectations.

The students were asked to give a grade for each question, from 0 to 5, with 5 as the highest rank. The questions and the average grade of each question based on student's replies are described in **Table 4**. Both activities are being accounted in the presented data. **Fig. 3** shows a boxplot chart of answers distribution.

Only three students stated that had prior knowledge about the subjects evaluated, and they evaluated with good grades their satisfaction with the practical activities. It is important to note that the majority were satisfied and believed in their own evolution.

VI. CONCLUSIONS AND FUTURE WORK

This paper discussed the use of Netkit, a tool that enables institutions and students without financial resources to execute computer network experiments, needing no more hardware than a single personal computer. It is also presented a evaluation of apprenticeship in computer networks through Netkit virtualization tool, and what strategies can be used to improve learning, proposing a working method that can be used in the classroom, or even in the students' homes in case of distance education courses disciplines.

The main contribution of this paper is to demonstrate the effectiveness of using the tool as a mean of teaching and learning process in the computer networks courses. Meanwhile, there was the development of study material available at website www.paulogurgel.com.br and they are the first study material using Netkit available in Portuguese, for the full course of networks.

Regarding the difficulties encountered, performing an effectiveness evaluation was challenging since no similar evaluation was found for the use of simulators / emulators in computing disciplines. It is possible to completely observe the benefits of network virtualization in education, and in particular the use of Netkit tool in expanding the depth of content taught and the effectiveness of practical learning facilitated by the tool.

Further comparative studies shall be done, to verify the results here presented and improve methods for evaluating the effectiveness of the methodology applied. From a technical point of view, it is necessary to do a continuous review of tutorials, seeking to detect spots where comprehension difficulties are perceived and adding new labs to address topics other than those listed in Table 3.

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Peer-Led Team Learning: Adjunct to Lectures in an Electrical Engineering Course for Non-Majors

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Abstract— Peer-Led Team Learning (PLTL) is a recognized model for teaching and learning in which select students in a course return in later semesters to serve as peer leaders who facilitate small learning groups. At our institution (a small, private, research-intensive university), this technique is adopted in Workshops; our peer leaders meet weekly with small groups of students to guide them through sets of exercises designed by the instructor(s) of the course. Peer leaders receive instruction and support in pedagogy and group dynamics in a course jointly taught by a learning specialist from the Center for Excellence in Teaching and Learning (CETL) and the instructor of the course. Workshops have been adopted in many courses, ranging from Chemistry, Biology, Earth Sciences, Physics, and Optics, to Economics and Business. This paper describes the use of Workshops for several years in an Electrical and Computer Engineering (ECE) course intended for non-ECE majors.

We discuss the processes and pitfalls for initiating the use of Workshops in this and other courses, present an example of Workshop problems and questions currently in use, and discuss the value of the Workshops to students, peer leaders, and faculty as told to us in surveys, course journals, and reflective sessions held after the course.

Keywords—Peer-Led Team-Learning, collaborative learning, circuits, non-majors.

I. Introduction

Students majoring in mechanical engineering and optics are typically required to complete at least one course on circuits, often without an explanation of the importance of this course. At some institutions like our own, they are then told that they can satisfy this requirement by taking an electrical circuits course designed for those who are not electrical and computer engineering (ECE) majors. Therefore, a significant fraction of students enter the course not knowing why it is required or what good it can possibly do them. Even worse, many already know they hate circuits (they have seen them in high school and in physics, after all, and seldom fully understood them there), and they wish they could be taking a course more relevant to their real interests. Too often, the response to this dilemma is an overreliance on the instructor's capacity to be profoundly inspirational and personally engaging as s/he works through the necessarily esoteric mathematics on the board in front of the class.

We began with the premise that there must be a better way to engage and motivate students in this service course. We had several requirements in mind: (1) we wanted to employ an approach that introduces students to the discussion format typical to research groups, (2) we wanted to engage the students for longer periods than a short lecture class can accommodate, (3) we sought to use methods proven in other contexts, and (4) we wished to provide immediate and active feedback and direction so the students use their time most efficiently. From the start the goal was not just to improve grades, as this is more an "enrichment" course than a "core" course for the major. As will be seen, we did find a positive correlation between grades and participation in the intervention.

II. Workshops

Our small, private, research-intensive university was one of the original development sites for the Workshop, or Peer-Led Team Learning, a recognized model for teaching and learning[1-6]. The initial implementation here was in organic chemistry[7]; subsequently, it has been adapted at our institution to many other courses, ranging from biology, earth sciences, optics, and physics to business and nursing.

Workshops at our university meet once a week outside of regular lecture hours for two-hour sessions. All students in the course are members of a Workshop; these groups of five to twelve students meet with their Workshop Leaders, who distribute the problem(s) of the day and guide the students in their analysis and discussion of each problem and the issues it raises. (An example problem is given in Appendix A of this paper.) Often the problems are worked on in subgroups and then presented to the larger group. Other times, one student serves as a scribe at the board while the rest of the group offers suggestions on how to proceed. The key is to engage as many students as possible in generating solutions and discussions. Another goal for the Workshop is efficiency; unlike lectures, during which students typically take notes to facilitate their study of that day's concepts at some later point, the Workshop is designed to promote on-the-spot learning of the material, with guidance from an experienced learner. The Workshop Leaders are paid a small stipend for this part of their activities, and they receive course credit toward graduation for the leader training course.

Workshop Leaders are undergraduate students who have done well in the course and return in later semesters to serve as

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peer leaders to facilitate small learning groups. These peer leaders direct small groups of students through sets of exercises designed by the instructor(s) of the course[8,9]. Workshop Leaders receive instruction in pedagogy and group activities in a separate course, originally designed by the second author[10]. This course is jointly taught by a learning specialist from the Center for Excellence in Teaching and Learning (CETL) and the instructor of the parent course.

Formatted as a two-credit course, the leader training program is designed to prepare Workshop Leaders for their role as facilitators. Each of the 90 minute weekly class periods is equally divided between a discussion of teaching and learning strategies and a review of the material for the upcoming Workshop sessions[8]. The pedagogical portion of the session covers a variety of issues over the semester, e.g., techniques for facilitating group discussions[11], question-asking strategies[6], and student development theory[12,13]. It also provides a venue for leaders to talk through any problems encountered during their recent sessions with their own students. In the content review portion of each class session, the instructor of the parent course rehearses the pertinent material with the leaders for their upcoming Workshop sessions and also points out the higher level ideas and concepts to be illustrated. (See the "Notes given to the Leaders" in Appendix B for an example of the details Leaders are provided about Workshop problems.) The leaders write journal entries each week about their experiences and also carry out a project to investigate a related topic of interest to them; they have created projects like "Increasing Involvement of Women in Engineering" or "How do Students at this University Perceive Engineering: Results of a Survey." The last few meetings of the semester are devoted to poster presentations by the leaders, a simulation of the usual entry-level presentation at scientific conferences.

In the Workshop sessions themselves, it is important that the material and techniques or reasoning processes provided to the students are reflected in whatever assessment tools are used in the course, whether they are exams, papers, or portfolios. If the material from the Workshops is seen as separate from the course, or disconnected from assessment, then it will not be taken seriously, and students understandably will not believe they should participate.

The design of the Workshop program is intended to mimic the organization of a university research group, in which an experienced director works with less experienced people to guide them in finding interesting questions to ask, figuring out how to collect information and evidence to address those questions, and formulating appropriate answers. An important point is that those activities are usually not carried out in isolation, but as part of a group, and that the answers are not known in advance but must be worked out. The Workshop program applies the same model to learning a subject (for the students) and learning about teaching (for the leaders).

Over many years and many courses in diverse areas, we have found that Workshop groups of six to eight students with one Leader generally work best. This is small enough to allow personal interaction with the Leader, but has possibilities for multiple subgroups (pairs or trios) to be formed to work on problems. This target Workshop size then determines how many Leaders are needed for a particular course. The course described here has ranged in size from 100 students (we arranged for 12 Workshop sessions by having some of the eight Leaders conduct two sessions per week) down to about 50 students (we had 6 Leaders that semester.)

III. ASSESSMENT

To examine the effect of this model on student performance, the second author and others[14] have compared course sections across time, i.e., examining student performance data in semesters prior to the implementation of Workshops and after the inclusion of this model. Other studies have included two sections of the course, both with a large number of students, taught by the same instructor, covering the same material, and with Workshops implemented in one section and not in the other. The same assessment tools and opinion questionnaires are used in both sections, and the grades and survey answers are compared. Studies on Workshops performed in this way typically have demonstrated the positive impact of Workshops on student performance[3,10,15,16]. Our opportunities for a comparison study were precluded for this particular course, as when the Workshop model was first taken up the instructor had not taught the course many times and the content was still changing. The instructor was able to offer only one section, the students could not have accommodated separate courses within their schedules, and the number of students in each section would have been too small to allow definitive conclusions to be drawn.

Instead, we began offering Workshops to all the students in this course. In the initial two years attendance was optional, and in subsequent years we began counting Workshop attendance as a part, usually 10%, of the course grade. We allow each student to miss two Workshop sessions with no penalty, then begin removing points, essentially 1% per Workshop missed. In addition to usual assessment practices (homework problems, laboratory participation, and examinations), we also administer surveys to the students to collect their reactions to the course, including Workshops.

We consciously strive to make the problems used in the Workshop sessions illustrate concepts and techniques that will be included in the assessments and have found that designing Workshop sessions to prepare for laboratory sessions are especially appreciated and useful. In addition, the Workshop Leaders point out both real-life examples and situations in later classes that rely on the concepts and techniques being covered.

IV. OUTCOMES

The reaction of students to the Workshops is understandably mixed. There are students who, rightly or wrongly, believe they learn well on their own, or have had a fairly strong background in electrical circuits in high school; they at least initially may be harder to engage in this format. Others may have formed informal study groups on their own, or have other coping mechanisms in place. These students usually know a good thing when they see it, and make use of the Workshops to reinforce their learning; they also know the adage that you never learn something as well as when you teach it. They often become informal "assistant leaders" and help others in the Workshop who are having problems understanding the material, knowing that they may need help on the next section of material. They do everything that is expected of them and do it well, and often become Workshop Leaders themselves in subsequent semesters.

There is another group of students who probably would pass the course but may not grasp the material well enough to apply the ideas and techniques to new situations. This is one of the groups we are most trying to reach through Workshops. By having them work with the concepts and materials of the course at a deeper level than usual homework problems, we believe we help the material come alive for them.

These groups above typically make up a large fraction of the students enrolled in this course. They are in their third or fourth year of a demanding and rigorous program, and most students without the mathematical or engineering background to succeed in the course typically have already decided to leave engineering.

Then there is the group of students (usually a very small number) who will struggle with the material or will believe throughout the course that they are "doing OK" when, in reality, they are failing. Through Workshops, we hope to help these students resolve any conceptual difficulties so they can succeed in the course.

An important observation is that most students vote with their feet and go to Workshops regularly, as can be seen in Figure 1, in contrast to the thin and sporadic attendance typical of standard recitations when not required.

More information about the impact of Workshops on students can be found in our student surveys. These surveys are anonymous, so we cannot correlate comments made by students with their performance; instead, we review these comments individually.

In general, we receive encouraging comments:

Workshop was AWESOME!! The best experience in a workshop ever!

Workshops and labs are well integrated.

Workshops were excellent in supporting material.

In response to the question "What are the major strengths of this [overall] course?" students often reply with comments that refer to Workshops:

Workshops. Fair tests and grading.

Workshops

Workshops are good.

Workshops were the one good thing about this class.

Workshop!!! In class demonstrations.

Workshop. Labs were decent.

Labs and workshops were very helpful w/understanding of material.

In response to another question "What are the major weaknesses of this course?" we sometimes hear about the length of the Workshop sessions:

Workshops do not need to be 2 hours long.

We collected data for five years and were able to correlate final course grade with Workshop attendance, and found a positive, although small, correlation (see Figure 1). Over these years, we sometimes did not give credit for Workshop attendance and some years we did, so the portion of the grade for attendance has been removed and the grade re-scaled for the graph.

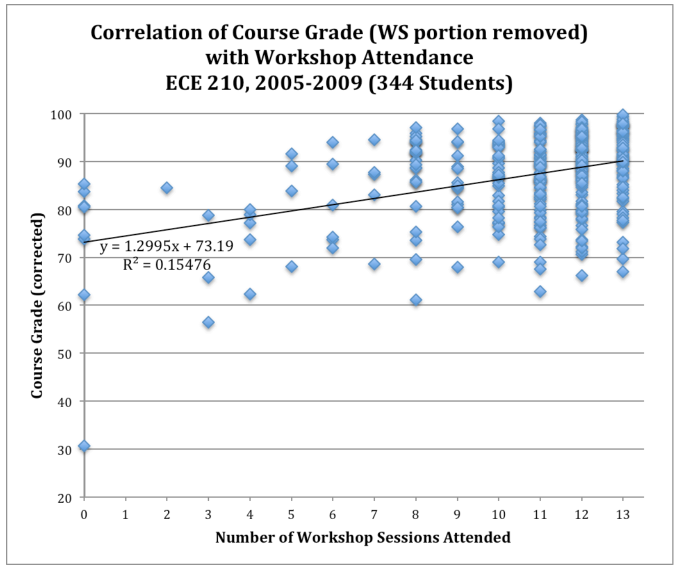

Figure 1 – Correlation of Course Grade (Workshop contribution removed) with the number of Workshop sessions attended for 344 students between 2005 and 2009. As can be appreciated from the low value of R^2=0.15476, the correlation is not very strong. As noted in the text, most students both attend a substantial number of Workshop sessions and ultimately do well in the course, so large changes or very high correlations were not expected. The Workshops provide an alternative learning environment that some students find very useful.

V. DIFFICULTIES ENCOUNTERED

Like any change to the status quo, there can be difficulties with implementation of Workshops. One we found is that it requires the instructor to begin preparing for the course during the previous semester. Workshop Leaders must be recruited and selected, preferably about the time students register for classes for the next semester, which at our institution happens about halfway through the current semester. While Chemistry and other departments often have an excess of applicants for Workshop Leader positions, leading to competitive hiring practices and extensive interviewing, within Engineering there tends to be a smaller applicant pool, resulting in less selectivity in hiring and larger than optimum Workshop groups. This may be due to the fact that upper-class engineering majors tend to be very busy with internships, design projects, etc.

Another difficulty is that instructors must develop their own set of Workshop problems for each course, and they often need to be modified and updated from year to year. This is best done by the instructor, with input from the Workshop Leaders, so that the class work remains in synch, uses the same terminology as the Workshop problems, and includes the topics in Workshops in lectures and assessments. The time for this development is, of course, largest in the first year of adoption.

VI. (UN)INTENDED CONSEQUENCES

We anticipated that some students would benefit from Workshops and the additional teaching style and structured time with the material, that Workshop Leaders would benefit somewhat from the review of the material in a course they had already taken, and that the leadership and teaching opportunities would be fruitful. One thing we did not anticipate is that virtually every leader who has subsequently gone on an interview, either for a job or a professional school admission, has reported back that the interviewers were both intrigued and impressed by the Workshop program, and that most of their interview time was often spent describing and reflecting on their Workshop Leader experience. Having been a Workshop Leader is now recognized as a useful experience.

VII. CONCLUSIONS

The high attendance in Workshops, the modest increase in student performance that correlates with Workshop attendance, and the expressions of satisfaction by students, student leaders, and instructors is sufficient to motivate those who have adopted this model to continue its implementation.

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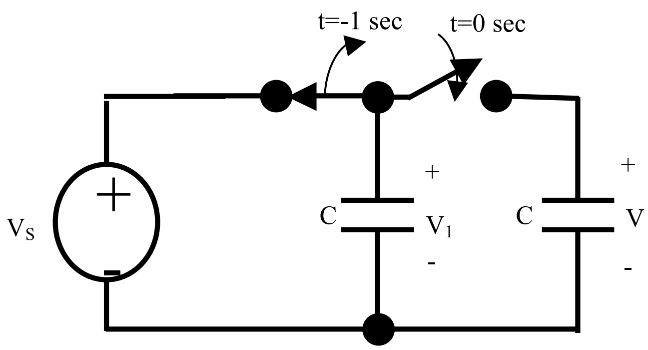
VIII. Appendix A: Example Workshop Problem (given to students)

Consider the circuit shown below, which contains two identical capacitors:



The capacitor on the right is initially discharged (V_2=0), and the one on the left is charged to a voltage V_S. The switch on the left is opened at t=-1 sec, and the switch on the right closes at t=0 sec.

A.

What energy is stored in the capacitor on the left between t=-1 and t=0 sec?

B.

What is the voltage on the two capacitors a long time after the switch on the right closes (say at t=10 sec.)? (HINT: Consider conservation of charge q.)

C.

What energy is stored in the two capacitors at t=10 sec (individually and the total)?

D.

Compare the energy in parts A and C. What happened to the extra energy?

E.

Let's figure it out. First, allow there to be a resistor in the "top" wire connecting the two capacitors:

Will the presence of the resistor change any of the Initial and Final Conditions you found above?

F.

What is the time constant of the circuit for the time regime AFTER the second switch has closed?

G.

Derive an expression for the voltage across the resistor for the time regime AFTER the second switch has closed.

H.

Write an expression for the POWER, p(t), dissipated in the resistor for the same time regime.

I.

Integrate the POWER from t=0 to ∞ to find the total ENERGY dissipated in the resistor. How does it compare to the values you found in Part D? Does it depend on the value of the resistor?

Appendix B: Notes given to Leaders in Review Session

Some students have asked for a more complete explanation of the "charged capacitors" problem. Here are points to consider: When charged, the left capacitor has a charge q of $q=CV_s$, and a long time after the switches are thrown that same charge is evenly distributed across the two capacitors (by symmetry if nothing else, why would one of two identical capacitors have more charge on it than another? Also, they have the same voltage across them, so they must have the same charge on each.) So, $q=q_1+q_2$ and $q_1=q_2$, so $q_1=q/2$, and $V_1(\infty)=V_2(\infty)=V_s/2$. The total energy stored in the left capacitor at t=0 was $W(0)=(CV_s^2)/2$, and the total stored at t=∞ is

$$W_1(\infty)+W_2(\infty)=\frac{1}{2}CV_1^2+\frac{1}{2}CV_2^2=C\left(\frac{V_S}{2}\right)^2=\frac{1}{2}\left(\frac{1}{2}CV_S^2\right)$$

or one half the original energy.

To see where the "extra" energy went, allow there to be a resistance R to the wire in the top of the circuit. Now we have two capacitors in series and a resistor in between, so the effective capacitance C_{eq} is $C_{eq}=\frac{CC}{C+C}=\frac{C}{2}$, and the time constant for the circuit will be $\tau=RC_{eq}=\frac{1}{2}RC$. We can now find the power dissipated in the resistor, P_R, and integrate over all time from t=0 to t=∞ to find the total energy dissipated, W_{dis}.

$$P_R(t)=I^2(t)R$$

$$I(t)=\left[I(0)-I(\infty)\right]e^{-\frac{t}{\tau}}+I(\infty)=\left[\frac{V_S}{R}-0\right]e^{-\frac{t}{\tau}}+0$$

$$P_R(t)=\frac{V_S^2}{R^2}e^{-2\frac{t}{\tau}}R=\frac{V_S^2}{R}e^{-2\frac{t}{\tau}}$$

Integrate over all time to get

$$W_{dis}=\int_0^\infty \frac{V_S^2}{R}e^{-2\frac{t}{\tau}}dt=\frac{V_S^2}{R}\left(\frac{1}{-2\frac{1}{\tau}}\right)e^{-2\frac{t}{\tau}}\Bigg|_0^\infty=\frac{V_S^2\tau}{2R}=\frac{V_S^2RC}{2R(2)}=\frac{1}{2}\left(\frac{1}{2}CV^2\right)$$

NOTE: The amount of energy dissipated is INDEPENDENT of R, so half the initial energy is dissipated in the wire, no matter what the resistance is!

The question sometimes arises "What if we made this out of superconductors, which we all know have truly zero resistance? How would that circuit dissipate the extra energy?" The answer is that superconductors have their limits as well, one of which is a "critical current density" specific to the particular material serving as the superconductor. When the critical current density is exceeded the superconductor "goes normal" and becomes a normal conductor again. If we built this circuit of superconductors and put the whole thing in a liquid helium bath and then tried to do the experiment, we would find that the instant the second switch closed the (infinite) current would exceed the critical current density and the wire would become normal. The necessary amount of energy would be dissipated, then the current density would drop to zero and the wires would return to being superconductors again. The only thing one would notice is that a little extra helium would boil off due to the resistive heating, and everything would return to its regular condition.

We can even figure out how much helium would boil: Assume V_1=50V and C=1μF, for starters. The energy dissipated is then going to be 625 μJ, which, given that the heat of vaporization of helium is 0.0845 kJ/mol, means that only 7.4 μmol, or 166μliter, of helium will boil away due to the dissipated energy, probably not enough to notice.

Concept Maps: An Automated Support for Monitoring the Learning Process

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***Abstract*—It is vital for a constructivist teacher to monitor the apprenticeship of each student in order to facilitate the definition of the next steps in the development of a discipline. This is a very time consuming and it requires a theoretical framework to support the observations of the teacher. This monitoring would benefit from certain automated tools to expedite parts of the process. Different pedagogical approaches say that the use of concept maps can help students in the processes of signification of new contents or in the resignitication of those already learned. The epistemological position of Piaget states that the development of a student's logical-mathematical structures is related to the learning of concepts, forming in this way a conceptual system. In the construction of concept maps we create, ultimately, what Piaget calls "significant implications" that evolve according to the semantic nature of the conceptual relations that we create. We propose here an environment for the automatic identification of the significant implications, using a family of software agents guided by an ontology. The analysis of maps will be made based on Piagetian theory. A prototype is under development and will be used to support the analysis of maps produced.**

Keywords—concept map; ontology; intelligent agent; learning environment; constructivism.

I. Introduction

It is essential for a constructivist teacher to accompany the learning process of each student in order to be able to define the necessary steps to be taken in the further development of a discipline. This task, however, is very complex and arduous, it is very time consuming and requires a theoretical framework to support the observations of the teacher. Traditional techniques used in the monitoring of learning (portfolio, performance test reports, interviews etc.) give it the characteristics of a classical assessment. Constructivist researchers and educators have demonstrated dissatisfaction with the efficiency and reliability of these methods, because the problems related to learning processes are generally diffuse, complex and often intractable by conventional techniques [11].

Alternative techniques to accompany learning have recently started to appear. Among them, the Concept Maps [12, 13] occupy a prominent position. Computational tools to facilitate the use of concept maps have been developed by research groups in order to meet the needs of interventions in the processes of learning. The results demonstrate the ease and precision the maps represent in tracking the changes that occur in a student's cognitive structure during learning.

Here we present a proposal for a tool with the goal of providing computational support to a theoretical investigation. It is based on a Ph.D. thesis [1], which proposes a reading of concept maps incorporating Piaget's bias. We do not intend to discuss here all the theoretical aspects addressed in this thesis, but just focus on one of several that may redefine the importance of maps in the process of knowledge construction. This tool constitutes for us an important step in the development of technologies to assist the constructivist educators in their pedagogical tasks.

The tool discussed here will be one of a set of tools, some of which have already been developed [16,17,18]. They are a part of our project called Portal of Knowledge, which is based on Concept Maps under a constructivist approach. We want to emphasize the use of technological resources to support educational practices focused on meaningful learning. The scope of the Portal is to develop appropriate computational support for the construction of concept maps. This support will improve the efficiency, reliability and validity of the use of concept maps as a tool to accompany and evaluate students' progress, as well as to intervene in the processes of learning, based on cooperation and collaboration.

This article is organized as follows: Section 2 presents the conceptual maps and some ways to use them; Section 3 is a brief description of Piaget´s significant implications, the motivating concepts of this work; Section 4 combines these implications with concept maps; Section 5 displays the specifications for a prototype of the proposed tool; and finally, Section 6 offers some conclusions.

II. The Concept Maps

Concept maps are graphical representations of relationships between concepts. They have been used in many different fields of knowledge. In particular, they have attracted the interest of educators worldwide. Novak [6], the inventor of concept map, defines it as a tool for organizing and representing knowledge. The concept map, based on the meaningful learning theory of Ausubel [7] is a graphical representation of a set of concepts constructed in such a way that the relationships between them are evident. Concepts appear in boxes while the relations between concepts are specified by means of phrases that connect the concepts. Concepts are defined by nouns while linking phrases must have a verb or a verbal composition. Two or more concepts connected by linking phrases creating a semantic unit, we call a proposition. Each proposition defines a truth, a fact, detachable and understandable by itself. The propositions are a particular feature of the concept maps as compared to other similar structures, such as mental maps or flowcharts. According to Novak, a concept map is a hierarchical tree structure, where the more general, or inclusive concepts appear at the top and the more specific ones in the lower parts of the tree. New knowledge is anchored to the old by semantic affinity.

There are different pedagogical approaches [3] where the use of concept maps can help students in the processes of signification of new contents or even in the re-signification of concepts already learned. This happens, because the maps allow students to locate and establish relations of composition, similarity, differentiation, and/or equivalence between what they are learning and the concepts already present in their cognitive structure. Therefore, various researches are being conducted and new tools developed to enable the use of concept maps for different pedagogical practices [4, 5].

Concept maps put Piaget's vision of concept into a different paradigm from the one established by the cognitivist view of Ausubel and Novak. According to Piaget's Genetic Epistemology [8], the knowledge is acquired by mechanisms involving a process of assimilation: an external element is incorporated into a scheme of action or a concept of an individual. This process occurs when the individual starts an active coordination of his/her actions, while coordinating the observable characteristics of an object. The process of assimilation occurs when there is a mechanism of accommodation, which allows the individual to incorporate the particularities of the object. This process results in a transformation of the individual systems of signification. It updates the so-called "prior knowledge", a precondition for integrating - and not just "anchoring" - the new knowledge.

According to Dutra [1], we can follow the representation of the system of significations of a student in the dynamics of building a concept map. In this system we also recognize relating subsystems supporting each other for the construction of these significations.

It is essential to emphasize the central role of linking phrases in a concept map. When we compare concept map with Piaget´s knowledge structure [14], we can conceive of the linking phrases as the structuring functions, because they are responsible for the laws of composition of the system represented by the map [1]. Jonassen [15] stresses the effort to choose a phrase that represents a relationship between two concepts, both due to the large number of possibilities as well as the need of placing such a relationship in the context in which the two concepts are presented.

As learning processes are the result of student-student and student-teacher partnerships, we understand that concept maps can also serve as an important guide for students, alerting them to more and more possibilities to qualitatively enhance the cognitive concepts and relationships in the process of acquiring knowledge.

As we said in Section 1, our interest here is in a single aspect of Piaget's constructivism: the regulations in the conceptual systems arising from the logical operations between concepts. These issues are briefly discussed in the following section.

III. THE SIGNIFICANT IMPLICATIONS

We, as humans, construct knowledge through our senses at every moment of our existence. In fact, cognitive processes occur even independently from our will. Through our sensory system we identify a new object and, almost instinctively, want to define its properties. Upon these definitions, we can manipulate and apply the knowledge we acquired of the object and we can start to discover its interactions and relations with other objects of our interest.

A transitive implication sentence $A \rightarrow B \rightarrow C$, in Piaget approach, means that if at least one signification of C is contained in any of B's, therefore it is also contained in any of A´s. Piaget [9] classified these as levels, and the set of them, as significant implications. A signification is all that can be said of an object, such as a description of its properties, as well as all we can observe on it. Furthermore, one implication is also all we can think of objects (sorting them, establish some kind of relationship etc.). For Piaget, all significations imply activities of the individual. These significations allow us to identify the degree of knowledge of a individual on a given domain. The following is a brief description of the implications.

- **Local implication -** It is local when the knowledge does not go beyond the object's observable properties in a given context. One local implication only characterizes an object. See examples in Figure 2.
- **Systemic implication -** It exceeds the limits of the observable. A systemic implication reveals object properties that are inferred or derived from some action on it. This implication displays relations of cause and effect without, however, revealing why it occurs. These relationships occur in general by the establishment of a relation of the object under study with some other object. Examples in Figure 3.
- **Structural implication –** It extends the previous implications because it contains the reasons, and explanations. Piaget speaks of endogenous understanding of the reasons and in the discovery of the relationships needed to occur the effect [9]. Thus, more than knowledge of causes and consequences the structural implications establish conditions which are essential to certain statements, distinguishing them from those that are just sufficient. The sum of the actions of several objects relating to the occurrence of another action establishes the existence of the implications of this new level. Examples in Figure 4. The concept map of Figure 1 illustrates the evolutive difference in the levels of the significant implications.

IV. THE IMPLICATIONS AND THE MAPS

It is important to mention that for the construction of concept maps we assume, that when we are choosing a relationship between two concepts we are doing, ultimately, a significant implication as suggested in [1]. This equivalence led us to adapt the characterization of the levels of the significant implications for analyzing the systems represented in concept maps. Because of this, we chose sets of verbs that best represented the implications.

For building a concept map representing each of the levels presented in the previous section we will show, as an example, concept maps produced by a master's student in computer science. The first map is shown in Figure 2.

The maps are a conceptual representation of his dissertation. Their conceptual nature approaches them to the requirements analysis of a system. Minor modifications to the sequence of maps displayed here were necessary in order for each map to represent one significant implication.

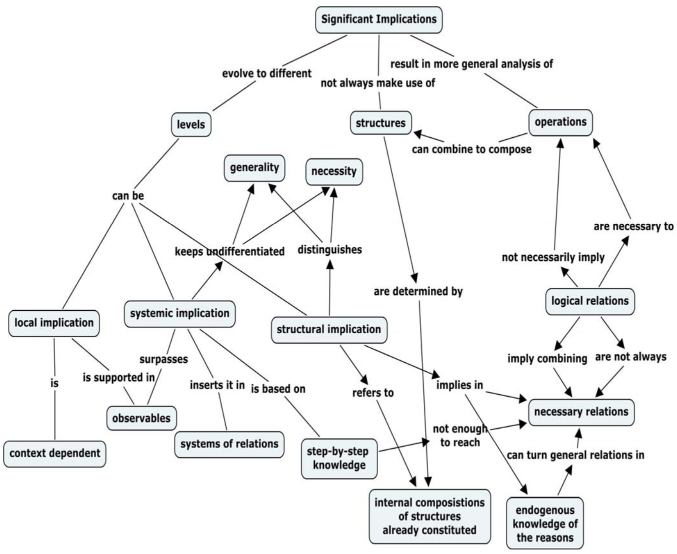

Figure 1 – The significant implications and their conceptual relations.

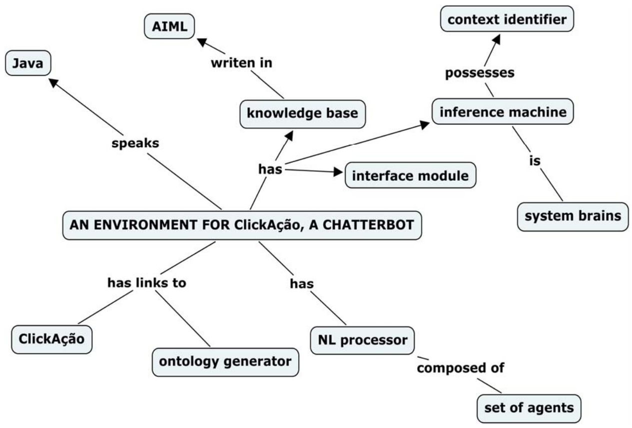

Figure 2 – Halysson´s map equivalent to local implications.´

We now extend the map to incorporate the knowledge of the next level of implications Figure 3 shows the result.

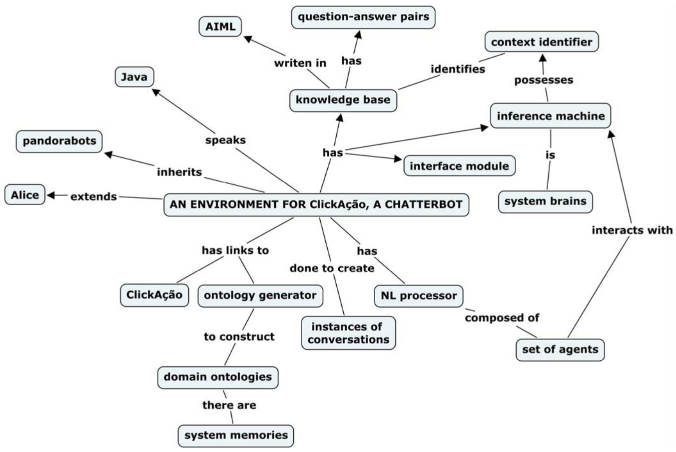

Figure 3 - Previous map with systemic implications.

Let's now add the third level of knowledge. The map would be:

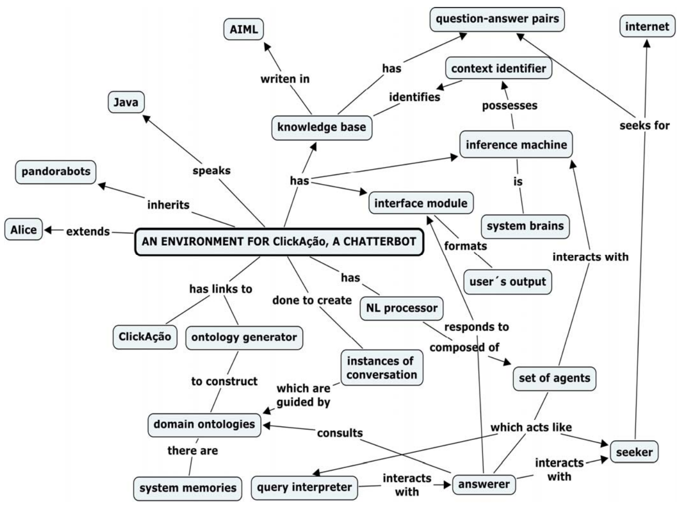

Figure 4 - Previous map with structural implications.

One can note how complex the map is, even when showing very simple relationships. Having a class of about 30 students, a teacher would have the task of identifying the cognitive profile of each student. He/she would have to identify on the maps the three levels of implications. This would be very cumbersome and time consuming. And, unfortunately, the teacher can still have many other activities such as:

- Organizing students per group of knowledge.
- Suggesting readings that are out of the ordinary for each group.
- Joining advanced groups with other less advanced.
- Establishing an average of knowledge of the class by comparing results at different times.
- Creating new maps.

In the following, we present a tool that can help both the teacher and the student.

V. THE TOOL

Based on the characteristics of the situations previously described, the architecture of the tool would consist of some databases, one knowledge base, and a software agent that uses these deposits. The agent is also responsible for interfacing with the users. An ontology of a domain chosen by the teacher guides the formation of concepts. The databases contain maps with their implications properly marked, and groups with their suggested readings. The knowledge base contains the significant implications with their features.

A. A preliminary requirements specification

We present here an initial specification only to guide the construction of the prototype. The prototype, in turn, will lead to a better specification. Our central problem in this activity consists of identifying patterns in existing concept maps capable of providing the necessary conditions for matching the knowledge base with the elements of the maps. We also want to emphasize that the patterns presented here are strictly temporary and, therefore, subject to much future research.

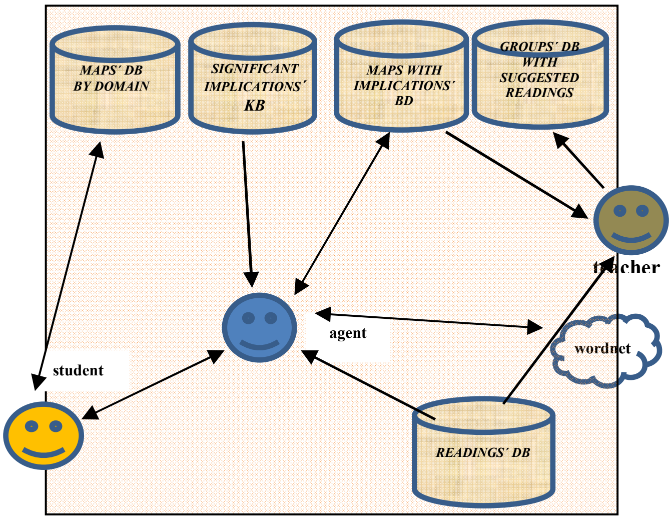

Figure 5- The preliminary architecture of the tool.

A concept map can be described as a well-known data structure called graph. A graph consists of vertices and edges labeled by strings. The vertices correspond to the concepts while edges denote the relationship between a pair of concepts.

The main idea presented here is to develop a tool to navigate the graph edges. The navigation is performed by a software agent that is guided with the aid of two bases. One contains a domain ontology for identifying the nature of the vertices. Another base contains the knowledge about the significant implications for the identification of edges.

For the pattern matching edge-implication we will use two different ways. For local and systemic implications we will use only the verb contained in the sentence designating the edge. Local implications will be identified by the occurrence of the verbs "be" or any other indicating possession or composition, such as “have”, “compose" etc. Systemic implications will be identified by any transitive verb.

The structural implications, on the other hand, will be identified by any subset consisting of edges and vertices whose combination results in explaining a cause-effect relationship (Section 3). Here the structural implications will be identified by the occurrence of verbs which require a preposition. Once the implication is identified, the agent will paint it with a certain color: yellow for local, green for the systemic, and blue for the structural.

The tool will be available both for students and teachers. Students may access it at any time to see how good the quality of their maps is. For example, if just yellow, showing only local implications, that suggests the student proceed to the next level. Once saved and finally sent to the teacher, the map will be temporarily unavailable for the student. Figure 5 illustrates the architecture resulting from the specification. However, it is in its preliminary version where the relationships between its elements are not yet well constituted.

B. The Functioning of the Tool

In the following, we describe all the activities and steps involved in the functioning of the architecture proposed in this paper.

1) Students deposit their maps of the domain previously created by the teacher.
2) The software agent searches the maps in the corresponding base. For a map, each link is analyzed according to the following actions: a) Stopwords are eliminated, since they are negligible for the retrieval of information, b) the agent checks if the verb of the connecting sentence matches some of the verbs of the base of significant implications.
3) The concepts are identified in the ontology by a recognizer. This recognizer is a dictionary automatically populated with concepts of the ontology. Words which are not concepts of the ontology are stemmed.
4) The map is then colored by the agent and deposited in the map and implication database. Figure 6 shows the expected result of the action of the tool.

Whenever the state of the maps with implications database changes, a message is sent to the teacher. He/She accesses the readings database and gives to each map the corresponding reading. The readings with their respective working groups are then stored in a groups with readings database. Messages are sent to the groups.

C. The Prototype

We created a prototypical version of our future tool only partially to illustrate the functionality we desire. The prototype takes as input a set of propositions extracted from concept maps constructed by our students. Figure 6 shows part of the code of the prototype with results. In the future, these propositions will be obtained through software agents. The output shows the implications to which propositions belong. The prototype was developed in Java. The experiment was conducted in a master degree class in computer science researching the question "What´s an Environment for ClickAçao, a chatterbot?".

The results obtained are just the same as the ones shown in Figure 7. However, the tool is presently in its first version and not yet able to identify the whole set of the significant implications. The final tool will be one of the results of a master thesis in computer science.

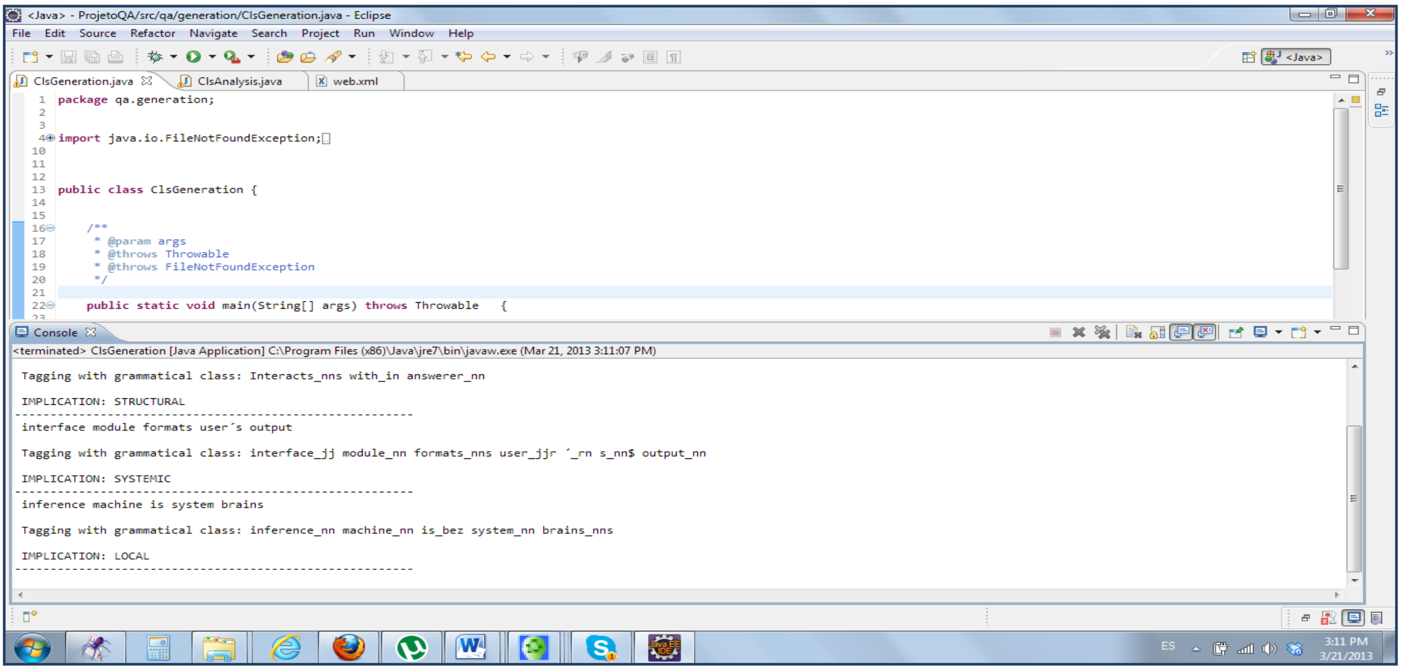

Figure 6 – The prototype partially implemented in Java.

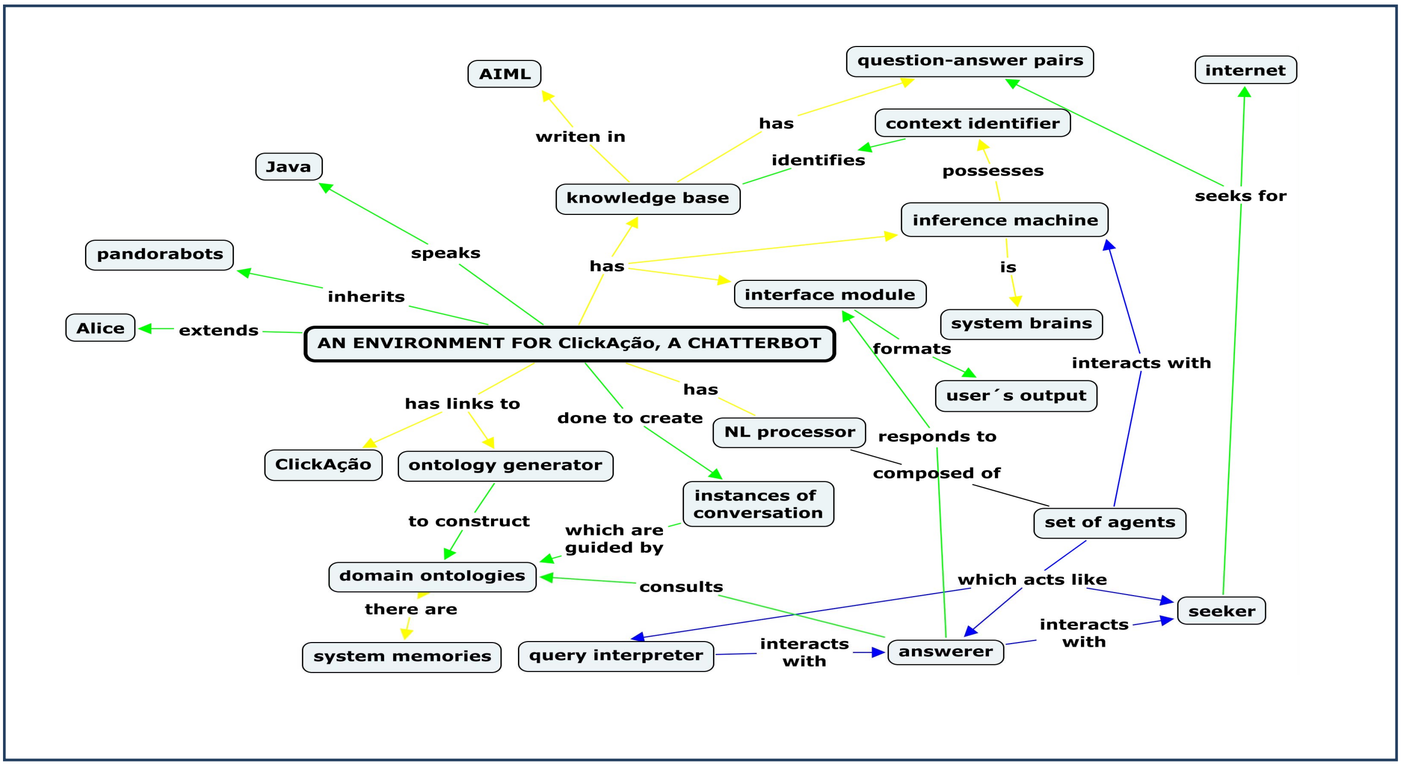

Figure 7 – Concept map colored by the tool.

I. PRELIMINARY CONCLUSIONS

The main idea is the use of concept maps as support to record students' understanding of a particular domain. The project proposes a form of automatic identification of the significant implications defined by Piaget in a map. This identification is made by using a family of software agents guided by an ontology of the relevant domain.

We are using concept maps for carrying several disciplines in computer science, where the analysis of maps based on Piagetian theory is being considered. Some related results are presented in this article. A prototype of the proposed environment is under development and will be used to support the analysis of the maps produced. This project is still in its first year, so the results are still preliminary. However, some experimental results have demonstrated its viability.

It is very well known that concept maps are good graphic representations for monitoring the learning process. Besides, they are a useful tool for knowledge construction. We dare to add that binding concept maps with piagetian implications creates a favorable context to learning. That becomes even more evident when the maps are automatically painted with the colors of the implications. This is valid not only for the teacher but also for the student. Like in a game, the implications establish the need of changing level, i.e., the need of going deeper into the domain. Immediately after seeing the map colored by the tool the teacher can see at which level the student is. Teaching becomes much easier than before, for the benefit of education.

So far, only a few computational tools have been developed to support constructivist teaching. We believe that the one presented here, which is based on Piaget´s learning theory, is an important step in facilitating the effective monitoring of the learning process.

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Enhancing Student Motivation In Targeted Undergraduate Education

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***Abstract*— Future aims of an undergraduate student are likely to evolve during the education timeline. While new knowledge and experiences emerge into students mind, the way of thinking and decision making matures, hence builds up student's mental and academic perspective. This whole progress embodies a natural motivation as a result of ongoing "change". However, a targeted undergraduate education may suffer from the deficiency of this natural motivation where the students are partially aware of the future awaiting them. Military academies are good examples of targeted education, since the students have substantial amount of knowledge about their career alternatives. It is up to the instructor to overcome the negative effects of this situation. The instructor, being acquainted with the practical aspects of the courses, can build solid connections between conceptual knowledge and real-world applications where possible. For instance, it is natural that Air Force Academy students are best motivated with flight and related activities. Hence, using flying platforms, flight dynamics and similar content in experimental studies and in-class demonstrations will play a vital role in motivating students for academic study. In this sense, a four rotor aerial experimentation platform is designed, built and utilized for courses and laboratories. Here learning objectives/outcomes of in-class demonstrations are emphasized rather than technical details which are given in previously published articles. The method is evaluated by student surveys and instructor observations.**

Keywords—undergraduate education; control education; flight control; UAVs

I. INTRODUCTION

Future aims of an undergraduate student are likely to evolve during the education timeline. While new knowledge and experiences emerge into students mind, the way of thinking and decision making matures, hence builds up student's mental and academic perspective. This whole progress embodies a natural motivation as a result of ongoing "change". However, a targeted undergraduate education may suffer from the deficiency of this natural motivation where the students are partially aware of the future awaiting them.

Military academies are good examples of targeted education, since the students have substantial amount of knowledge about their career alternatives. This situation has both negative and positive effects on students. If the student is in a good mental state and has clear future aims, academic motivation might well exceed expectations. Student becomes eager to learn and is often willing to participate in additional social and scientific activities, which is a clear sign of motivation. However, if the student has below average grades and unclear future aims, he begins to question the necessity of the academic education and its direct/indirect relations to his future career. The chronic questions, though not always expressed in an audible way, "why am I learning all this theory" or "where am I going to use these information" are quite common among students. These contagious questions wipe the positive attitude and remaining motivation. However, the scene is still well recoverable. The instructor, being acquainted with the practical aspects of the courses, can build solid connections between conceptual knowledge and real-world applications.

Turkish Air Force Academy (TurAFA) offers four year undergraduate education. There are five departments which are aeronautical, civil, electronics, computer engineering and management sciences. Flight training and related activities continue concurrently with the four year undergraduate education. Upon graduation, students acquire a bachelor degree in one of the five departments. This paper focuses on education enhancement in electronics engineering department courses. Basic motivation of cadets is concentrated around flight and pilotage right from the first day at TurAFA, hence every educational activity in the TurAFA must have a rich sense of applied flight practices wherever possible. Innovative and insightful approaches are essential for the motivation of cadets for a targeted undergraduate education. The instructor, who is acquainted with the practical aspects of the courses, builds solid connections between conceptual knowledge and real-world applications wherever possible. Laboratory courses and in-class demonstrations play a vital role at this point. Electronics engineering department curriculum includes control related courses that are considered suitable for practical applications [1], which are directly related to the Air Force mission. In this sense the four rotor experimentation setup which is used in such practical applications fosters the flight and pilotage ambition by highlighting dynamics, modeling, and control of a quadrotor UAV.

Four rotor mini unmanned air vehicles are popular among researchers, academicians, and hobbyists [2-6]. The reasons

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behind this popularity can be listed as reduced mechanical complexity compared to helicopters, ease of manufacturing and maintenance, as well as presenting a challenging control problem due to coupled and highly nonlinear dynamics [4]. Additionally, the widespread usage of quadrotor platforms led to a new benchmark system similar to acrobot, pendubot, and helicopter platforms. Comparison between control algorithms, tuned parameters, and mechanical structures might be made by means of metrics such as controller performance, robustness, and stability [5-7]. These key features answer the question of why a four rotor platform is chosen. Additionally, the platform is fixed on a universal joint for the safety issues while still maintaining the axial movement. The word "setup" is used throughout the paper to denote the educational platform..

Modern aircrafts are equipped with fly-by-wire systems where the aircraft is controlled by a flight computer rather than the direct operator manipulations. The flight computer receives data from sensors as well as pilot, calculates the best maneuver and activates control surfaces to achieve the required maneuver. This technology wrapped pilotage enables operation of sophisticated aircrafts, however it is not adequate for training of cadets. The real sensation of flight is achieved by a true understanding of the dynamics and how these dynamics are controlled. The setup is meant to help fulfill this requirement from an engineering point of view and prepare cadets for future practices. Engineering courses covering control related topics are adequate for this purpose. The setup is used to enhance learning in courses such as Automatic Control, Flight Control Systems, Control Systems Theory, and Control Systems Laboratory at the graduate level. This paper focuses on Automatic Control course.

The goal of the study is to present the motivation and learning enhancement in Automatic Control course with the aid of quadrotor setup. The learning objectives/outcomes of the in-class demonstrations are given in the second section. Third section addresses a summary of the procedure followed during in-class demonstrations. The success of the method is evaluated by student surveys and instructor observations in the fourth section. The conclusions are given in the fifth section.

II. The Learning Objectives/Outcomes Of In-class Demonstrations

In-class demonstrations are performed by the instructor within a single class hour (45 min) for maximum 15 students. If the number of students in a class is more than 15, two demonstration sessions are performed. Based on the subject and the learning objectives, the demonstrations are performed before or after the theoretical session. If it is aimed to put forward the question in advance, and arouse curiosity, demonstrations are performed right at the start of the class. Otherwise, they are performed after a theory or discussion to support learning by showing the practical aspect. In the latter case, the side benefits are eliciting an enjoyable discussion during the demonstration and helping students recover their concentration. The learning objectives/outcomes of the in-class demonstrations performed in Automatic Control course are summarized in Table **1**.

Table 1 The Learning Objectives/Outcomes of In-Class Demonstrations

Topic	**No**	**Objectives (It is aimed to learn …)**	**Before or after theory**	**Checklist of the desired outcomes (Can the students …)**
Feedback Control Basics	1	what feedback is.	before	define what is feedback?
				give examples of feedback?
	2	how feedback is applied to control systems.	after	give examples for open and closed loop control systems?
				design simple open and closed loop control systems?
Dynamic Modeling	3	what a dynamic model is.	before	see the physics behind the dynamic model?
				make an analogy between system behavior and its dynamic model?
	4	how parameters affect dynamic model.	after	identify the system parameters?
				see the effect of each system parameter?
Stability	5	what stability is. the symptoms of being stable or unstable.	before	comment on stability or instability of a system according to its behavior?
				see the necessity of stability analysis?
Time Domain Analysis	6	what a transient and a steady response is.	before	distinguish transient and steady state responses?
	7	what the causes of steady state error are.	after	comment on steady state errors of different systems?
Control System Design	8	how the requirements are defined for a controller.	before	state the basic controller requirements for different system behaviors?
	9	how controller parameters affect system performance.	after	make analysis on system responses for different controller parameters?
				predict controller parameters based on system behaviors ? (observational)
	10	what the differences between controllers are.	after	find an appropriate controller for given controller requirements?

III. The Procedure of In-class Demonstrations

The following paragraphs describe the procedure followed during in-class demonstrations.

A. Feedback Control Basics

Before the theory, a volunteer student is asked to help with the demonstration; and his eyes are covered. Then, he is asked to walk on a line without external support. After a few steps, he misses the line no matter how. It is emphasized that the eyes provide feedback to achieve walking precisely. Following this scene, the quadrotor setup is run; and it is emphasized that the inertial sensor mimics the eyes of the setup that provides feedback. Then, the inertial sensor is powered off; and it is shown that the setup can still be controlled; however, it is almost impossible to stabilize.

After the theory, the setup is run and the Simulink model of the controller are projected on the board. The closed and open loop control concept is shown on the model, and it is applied on the setup at the same time. A discussion about open and closed loop control systems in daily applications is elicited.

B. Dynamic Modeling

Before the theory, the setup is run, and the quadrotor coordinate system and dynamic equations are projected on the board. The symbols on the equations are briefly explained, and then the students are asked to brainstorm about the dynamic model while performing arbitrary maneuvers on the setup. Random questions are asked to students and they are couraged to make comments on the answers whether they are logical or not.

C. Stability

The stability demonstration aims to show what stability and instability are. Before the theory, the setup is run, and the quadrotor is held in a stabilized position. Then the controller coefficients are changed and it is seen that stability is lost and cannot be regained. After performing random maneuvers in unstable state, the controller coefficients are changed back to their optimized values and stability is regained. Following the scene, the students are asked to give examples of stability and instability from their daily lives. Additionally, a discussion is started about the practical applications of stable and unstable systems.

D. Time Domain Analysis

Before the theory, setup is run and arbitrary excitations on roll, pitch, and yaw axes are performed. The transient and the steady state responses for a unit step input are plotted and projected on the board. Maximum overshoot, rise time, settling time are emphasized on plots without giving formal definitions.

After the theory, the nonlinear causes of steady state error are demonstrated. The saturation and dead zones of actuators are simulated by artificially increasing and decreasing rotor speeds. The quantization error is simulated by decreasing the refresh rate of the inertial sensor. Following the demonstrations, the students are asked to give examples from daily life about systems suffering from steady state error and possible solutions to this problem.

E. Control System Design

Before the theory, the students are asked to think of maneuver envelopes and associated flight control systems of an airliner, a jet fighter, a UAV, and an air-to-air missile. Then, the setup is run and random maneuvers are performed with different controller coefficients. It is important to help students assign a coefficient profile to each air vehicle type. A simple table might be drawn on the board if necessary. Then a discussion is encouraged about flight controller characteristics of different types of flying machines.

The demonstrations of control system design aim to stress only the practical aspect and help students gain insights about the system behavior and the associated controller. This demonstration is last in the curriculum and the students should be monitored carefully not to go beyond the intended topics.

IV. Evaluation of the Method

A success criterion of in-class demonstrations is assessed by the survey results of spring 2012 in Figure 1. 68 students attended the survey anonymously. The average rating of each question is shown on top of the bar. Only 8 instances of “bad” ratings exist. However, “not good” ratings also address the issues that are awaiting improvement. The students are also asked whether having the setup fixed limited their interest or not. The majority of the students’ answers reveal that they are satisfied with the demonstrations and do not expect a flying setup in a room sized laboratory. However, it is thought that if the setup were located in a high ceiling laboratory where a quadrotor would safely fly, the students would well be expecting a flying setup. Consequently, a flying setup located in a furnished laboratory is considered a necessity for the future improvement of the in-class demonstrations.

In addition to survey analysis, instructor observations of years 2011 and 2012 are considered as a valuable metric. Since the number of students attending the demonstration sessions is below 15, the instructor can maintain eye contact and monitor individual involvements. It is up to the instructor to tune the level of the demonstration to the perception of the audience, and maximize learning as well as motivation. Students reveal their mental state by asking questions, making comments, joining discussions and all forms of body language. Based on two years’ observation of in-class demonstrations using the setup, it is fair to express that a notable enhancement of learning and motivation in “Automatic Control” course is achieved.

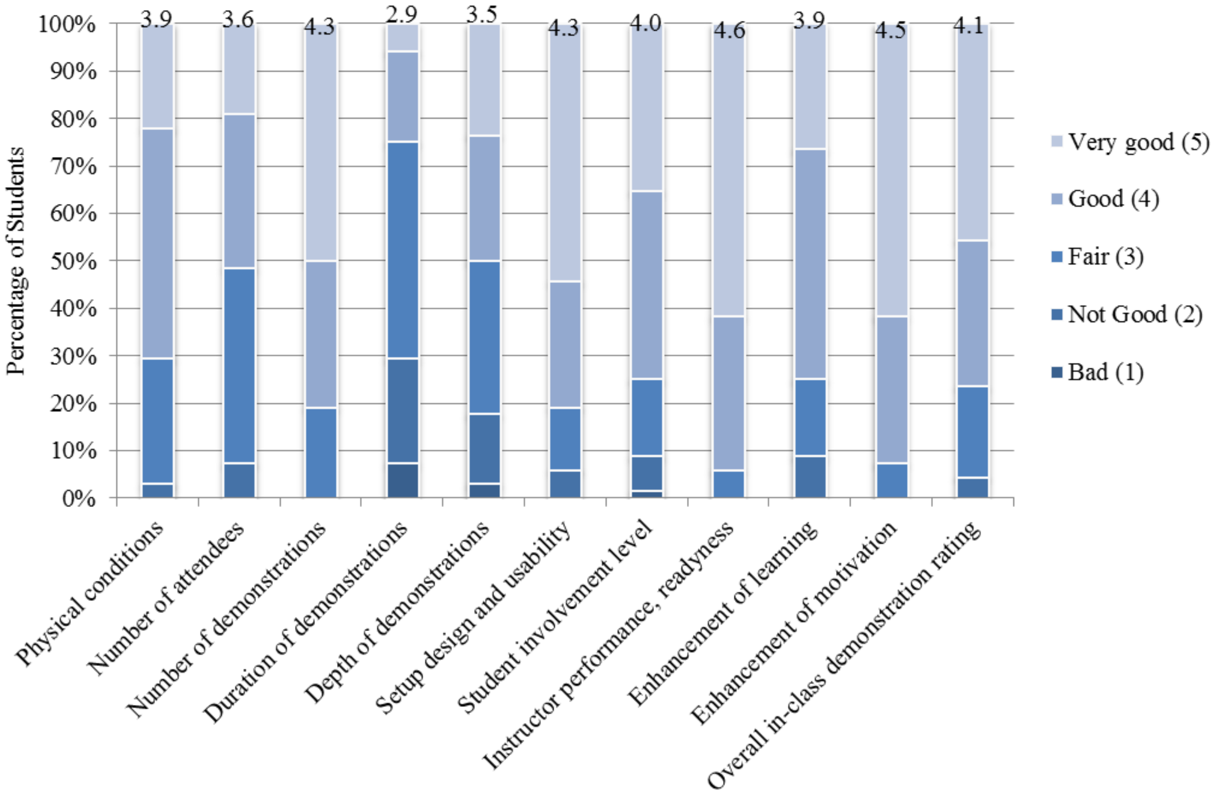

Figure 1 Student Feedback Analysis Graph

V. CONCLUSION

The presented quadrotor setup is a useful tool for control education. The setup meets the main objective which is an enhancement of motivation and learning in Automatic Control course. Additionally, the setup satisfies the academic requirements of undergraduate students, who are involved in pilotage or flight related activities. The success of the setup is deduced from the student survey analysis and instructor observations of years from 2011 to 2013.

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A Semi-Autonomous Embedded Systems Course

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***Abstract*— Educational research has shown that students learn with deeper understanding and retain that understanding for a greater duration when they learn in an environment of inquiry. In order to foster an environment of inquiry in an embedded systems course, we have redesigned the course to give students more and more autonomy with course material as the course progresses. In this paper, we describe the design and preliminary assessment of a semi-autonomous embedded systems course in the computer engineering program at Cal Poly, San Luis Obispo. Preliminary assessment data indicate that the course appears to provide an environment of inquiry for students, but further assessment is required to determine if the semi-autonomous nature of the course increased student understanding and retention of course material.**

Keywords—embedded systems; learner autonomy; scaffolding; self-directed learning

I. Introduction

Evidence shows that when students learn out of curiosity, they learn with deeper understanding and retain that understanding for greater duration [1,2]. Providing for students' needs of autonomy, relatedness and competence positively affects their intrinsic motivation, academic performance, and healthy psychological growth [3,4]. Opportunities for self-regulated learning may help learners attain a sense of competence [5]. High self-efficacy has a positive effect on motivation and learning performance [6]. Additionally, positive correlations exist between motivational components such as perceived competance, value and interest, and cognitive components such as engagement and self-regulation [7]. In order to foster an environment of inquiry and to support student autonomy, this paper describes the ongoing transformation of a microcontroller embedded systems course at California Polytechnic State Univeriesty, San Luis Obispo (Cal Poly) that is designed to support learner autonomy. We present a preliminary summative assessment of the course based on the Learning Climate Questionnaire (LCQ) [8] and the Motivated Strategies for Learning Questionnaire (MSLQ) [9]. The objective of this work-in-progress paper is to reach out to the engineering educational community for suggestions and feedback on how to improve both the embedded systems course and our assessment methodology.

II. Designing a Semi-Autonomous Embedded Systems Course

The embedded systems course (CPE 329) that is the topic of this paper is a required course for electrical engineering students and computer engineering students. Students typically take this 10-week course in the student's junior year. In this course, students work in pairs in what we call a "studio format", where students are in a lab for a total of six hours per week. This was a change from the previous format of three hours of lecture and three hours of lab per week.

While the disciplines of electrical engineering and computer engineering share significant overlap, we have found that the students in this course have wide and varying technical interests and enter our class with varying technical capabilities. We have developed a semi-autonomous pedagogy to accommodate students with these diverse backgrounds. Students with more experience in circuit design can tailor their course to incorporate more circuit design into their embedded systems, while students with a stronger background in programming can develop more software intensive projects. Students can progress at their own rate through much of the course material. This can keep the course challenging for those students who enter the course with embedded systems experience and, more importantly, relaxes the pace for students who require greater time to construct a solid foundation of embedded systems. To facilitate the semi-autonomous nature of CPE 329, there are four different mechanisms in place: 1. written tutorials, 2. instructional videos, 3. course projects, and 4. lab access.

Written Tutorials

The first mechanism is a set of tutorials. These tutorials are designed to be short, are typically two pages of written text and include a hands-on exercise that most students can complete in an hour. Tutorials cover topics such as C-programming, bit-twiddling, timers, interrupts, and common I/O interfaces. The tutorials are available at the start of the course and grouped into required or optional categories. The required tutorials are ordered at the start of the course to provide scaffolding for the first two course projects, which will be discussed later. As the course progresses, students choose tutorials from a selection, allowing them to customize the course to explore their strengths or develop technical competency in areas they are less comfortable.

Instructional Videos

The second mechanism that makes CPE 329 semi-autonomous is a series of instructional videos with associated self-assessments. Videos typically cover one interface of the microcontroller, or other related issue to embedded systems. Videos are designed to last about 10 minutes, can be watched

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at any time during the quarter, and are accessible anywhere via an internet connection. Suggested due dates for watching videos are included as the videos can serve as scaffolding for the course projects as well. Students can watch the videos in any order, thereby allowing students with more experience with microcontrollers to proceed to working on the course design projects sooner than their peers.

A majority of the videos cover required topics to fulfill the learning objectives of the course. However, there is also a set of videos that may be optionally viewed by students. Finally, some videos have been developed by students for their peers. Students receive credit for these videos through a "course improvement" assignment.

The self-assessments that accompany the instructional videos may be taken by students at any time and are administered online through our learning-management software (Moodle). There is at least one self-assessment per video. The self-assessments are typically 4-5 multiple choice or numeric questions. There are several goals of the self-assessments. The first goal is to highlight the most important aspects of the course. Another goal is to provide a low-pressure method for students to test their understanding of some of the basics of the course. Finally, the completion rates of the self-assessments provide the instructor feedback on the progress of the students in the course.

Course Projects

A third mechanism for facilitating autonomy is the use of course projects. In this course, there are four course projects, each of which have increasing amounts of autonomy. In the first project, students learn to write and compile C code and use software delays with general-purpose IO to display messages on an LCD display. Students design a function generator by using timers, interrupts and a digital-to-analog converter in the second project. These first two projects are highly scaffolded and cover the majority of the required learning objectives of the course. For the third project, students begin to have more autonomy while developing a sensor project. Students select a particular sensor from a list, or get one approved by the instructor. The goal of the project is to integrate the sensor with the microcontroller and test the sensor system for accuracy. Since both the sensor and its application are up to the student, there is considerable autonomy in the third project. For the final course project, students propose a microcontroller system of their choosing, allowing for significant autonomy.

Lab Access

Finally, at a lab-intensive school such as Cal Poly, it is sometimes difficult for students to access laboratories outside of class time. To mitigate this, we strive to provide lab access to students in the evenings and during weekends. For students with their own computers, the software development tools for the ATMega microcontroller used in the course are freely available. Low-cost lab measurement tools are promoted to the students, such as Salae's Logic 16 and Digilent's Analog Discovery tools. The cost of these tools is offset by providing all course resources in free electronic format. These tools, in conjunction with tutorials, videos and self-defined projects allow students to work remotely on their own schedule.

III. ASSESSMENT OF CPE 329

Assessing how autonomy contributes to learning is the primary concern we have for CPE 329. We have adapted the Learning Climate Questionnaire (LCQ) [8] to assess if the course is conducive to learning autonomy. The Motivated Strategies for Learning Questionnaire (MSLQ) [9] has also been distributed to students in CPE 329. We distributed the MSLQ survey to students before and after the course but the LCQ only at the end of the course. The new format has only existed for one quarter, for a total of N=42 students and the results collected are currently not statistically significant. However using the results of these surveys, we hope to draw a few broad generalizations to further inform out assessment strategy.

Fig. 1 shows the average results for the MSLQ pre and post surveys, broken down by different value components typically). We can see that Cal Poly students scored high on "task value" (measures perception of material interest, importance and utility), extrinsic motivation and their ability to control their academic performance. Likewise, students reported low metacognitive self-regulation, and do not seek help from others nor use many techniques for deep learning such as critical thinking, organization and rehearsal. For a student group with these characteristics, we believe that more autonomy is well suited but the challenge will be to influence deeper understanding of embedded systems issues.

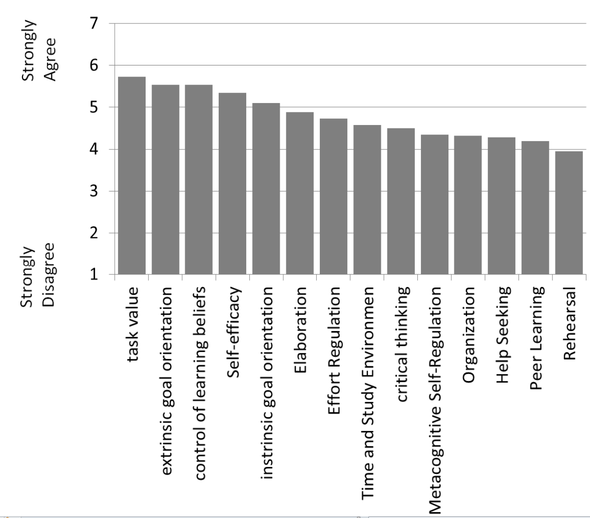

Figure 1. Average MSLQ results broken down by value component.

Fig. 2 shows results on the MSLQ with the largest difference between the pre-course survey and the post-course survey. For Fig.2, the number of responses to the pre-survey was 42 and the number of responses for the post survey was 34. Generally, students agree that the course material as taught in CPE 329 is both useful and interesting, meaning they have high motivation due to interest. This is encouraging as the context of the course material is being conveyed despite the semi-autonomous nature of the course. However, student motivation due to expectancy has fallen during the course of CPE 329. Possible reasons could be due to the semi-autonomous nature of the course, students feel disconnected from the assessment strategy of the course, possibly feel unsure if they are attaining the learning outcomes of the course, or in the worst case do not feel that the assessments fairly measure the course learning objectives.

Other questions with the largest differential between pre-course survey and post-course survey fall into two different categories. Survey questions relating to the understanding of written course materials fell by 1.25 ranks (on a Likert scale of 1 to 7). This is not particularly alarming as video is the primary method for delivering learning objectives in this course. However, since reading comprehension is an irreplaceable skill, this is something to be cognizant of for the future. Similarly, survey questions relating to note taking and summarization of course content also see a negative trend from pre to post course surveys.

The results of the LCQ were generally positive but uninteresting. Students found the learning environment comfortable and that their instructor would listen to them. Participation in the LCQ was very low (N=13) as the survey was given after the end of the class.

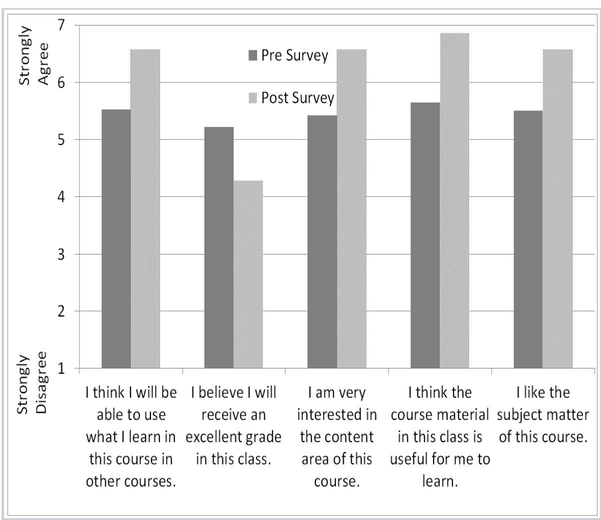

Figure 2. MSLQ questions with a high pre-to-post differential

Several confounding factors in our assessment strategy have been identified. First is that the data was gathered across different instructors. While lecturing in these courses is kept minimal, the instructor has a significant role in helping students in the classroom with the course material. Instructor personal interaction style could influence the data. The problems in schools questionnaire [10] could be used to help differentiate instructor differences.

Correlating learning outcomes with student motivation is difficult and due to the anonymity of the surveys we are unable to correlate final course grades with the different survey questions.

Outside of assessment, future work may include requiring students to complete some meta-cognitive exercises such as a reflective journal [11] and including exercises that will help students identify learning strategies that work well for them. Also including more assigned readings and group problem solving could address issues in reading comprehension as well as help seeking.

IV. NEXT STEPS & DISCUSSION

It was our hope that our assessment strategy would show growth in student self-efficacy in CPE 329. Instead, preliminary results indicate that students' confidence in getting a good grade in the course eroded over the course of the class. While results indicate that task value may have increased, we attribute these gains more to the subject material and its application to course projects rather than due to the semi-autonomous nature of the course. We are searching for alternative assessment strategies to better determine the contribution of autonomy in learning objective attainment. Also, rather than using a summative assessment, perhaps a formative assessment approach would yield more interesting results.

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Can utilizing social media and visual programming increase retention of minorities in programming classes?

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***Abstract*— This paper discusses how Social Digital Literacy is being used in CS1 to teach critical and computational thinking by delivering content to students through the use of social media. Social Digital Literacy (SDL) is the way in which people use social media to enhance their social network, effectively increase their knowledge base, while communicating clearly and professionally through the use of social media. The increased popularity of social media amongst college students makes it an opportune time to consider a new form of literacy based on how technology is used by students, the devices that students interact with on a daily bases and the mainstream acceptance of social media in daily life. In order to retain students in computing classes, students are taught in an efficacious manner how to capitalize on the technology that they use on a daily basis. By increasing their SDL proficiency to become a more informed student, a well versed employee and consciously aware of what they post to social media. The expectation is that the approach being used can be implemented in any introductory programming course.**

Keywords—social media; visual programming; engineering education; diversity

I. INTRODUCTION

At the community college level it can be a challenge to retain women and underrepresented minorities in programming classes, mainly due to misconceptions of what programmers do, what a programmer looks like, and the misconception amongst Triton students that high level math is required before a programming class can be taken. This paper discusses how Social Digital Literacy is being used at Triton College to teach critical and computational thinking by delivering content to students through the use of social media and visual programming. Social Digital Literacy (SDL) is the way in which people use social media to enhance their social network, effectively increase their knowledge base, while communicating clearly and professionally through the use of social media

The increased popularity of social media amongst college students makes it a opportune time to consider a new form of literacy based on how technology is used by students, the devices that students interact with on a daily bases and the mainstream acceptance of social media in daily life. SDL addresses this by creatively teaching students how to maximize technology through the use of social media.

We use technology which students are most familiar to introduce them to the principles of programming. Students are required to read, watch and comment on technology postings made to the class Facebook page. They are able to learn about engineering and computing jobs through social media, which they can access from their smartphones or any web enabled device. As for students who do not have a facebook account, or who prefer not to have a social media account as part of thier daily life. Are given the option of creating an alias facebook account that is connected to an email that they create just for the semester to link to facebook. These students who number less then three per class are able to learn SDL skills by having an alias facebook account. Thereby allowing for all students to participate in the facebook questions each week.

Programming fundamentals are taught in conjunction with visual programming using Scratch. Scratch enables students the ability to fully understand abstract concepts such as objects, making it possible for them to have a clearer understanding of computer programming [1]. This paper discusses how (1)SDL is being used for undergraduate college students to increase student engagement in introductory programming classes (CS1) and (2) how SDL is being used as a retention strategy for women and under-represented minorities.

Currently 94% of freshmen students entering Triton College have test into developmental math and do not have the desired level of math achievement for a traditional programming course. Triton College has chosen to eliminate the math pre-requisite for CS1 programming courses, which consists of CIS 191 Programming for Engineers, CIS 121 Introduction to Programming and CIS 163 Introduction to Java, thereby allowing students who would traditionally not be qualified to take a freshmen level programming course to be exposed to the world of engineering in the early stages of their academic journey within a community college classroom [4][2]. Research supports the utilization of social media and visual programming as successful learning tools for the 21st century student [1][3][4][5]. Literature also supports the need for faculty to be cognizant of the unique needs of women and underrepresented minorities in programming classes when teaching fundamental programming concepts to students [6]. While removing the math requirement is not a new concept its absence at the community college level is significant because it opens up the possibility for a new pool of qualified candidates for engineering and computing professions that would otherwise be overlooked.

II. SOCIAL MEDIA

The use of social media as a tool to teach students has been shown to enhance engagement and interest of students while increasing digital literacy [4][3]. Due to familiarity with Facebook and the nonjudgmental environment, students currently ask questions that require critical thought processes via this format more often then they do in class. Types of posts include articles and videos to watch such as the video from code.org entitled "What most schools don't teach," which features computing pioneers, women, and underrepresented minorities who advocate teaching kids to code. Students where asked to respond to the following question based on the content in the video [7].

Question: Why should kids learn to code?

Student Responses:

"I agree that computer programming can seem a bit intimidating but its a learned language if you give the kids opportunity to learn something new they have a feel for it and it can even drive them into the computer field like the video said everything is dependent of technology. Since taking this class I catch myself at work a little fascinated by how a program is constructed. What codes where required to build the software being used. " *Hispanic Female*

"Coding should be taught to children because coding involves problem-solving…The biggest justification for learning a valuable skill is not economic but moral. If our educational system doesn't act now, children will be short-changed, if they don't have a deeper understanding of technology they will effectively be intellectually crippled. They will grow up as passive consumers of closed devices and services …" *African-American Female*

Exposing students to how different programmers are in respect to age, gender, and race conveys to students positive impressions of programming as a career. Removing 'unspoken' barriers that would otherwise hold students back from entertaining a career or major in engineering. An example of what programmers look like was shown to students via a video by Google in Education focusing on women in technology [8].

Question: What excites these women about Technology?

Student Responses:

"I liked this video because it shows that girls can be creative and make a difference in the technology world too. Most people think of guys when they think of technology and this video proves that stereotype wrong. I also liked this video because it shows me that there are girls working on the technology I will be using in my career". *Caucasion Female*

"The ladies in the video are excited about what they do because they love the interaction they get to do with other people and touching other fields because mostly every field requires a computer. They want to contribute to the technology business as much as they can and show it is not just a male dominate world anymore. Just like men get a kick out of the things they create also the women in the video love the new ideas and creations they make." *Hispanic Male*

The concept of SDL is explained to students prior to completing a Facebook question. With a brief in class discussion on the topic posted on Facebook. All students are given up to twenty minutes of class time, once a week, to complete the facebook question. Completing Facebook as a class allows for videos to be watched as a group, clarification of the question, if needed, to be explained and access to a web enabled computer for question completion. Giving students the resources needed in class has proven to be successful for students who do not own smartphones or have internet access at home. Allowing all students the opportunity to develop SDL skills.

Using social media in class requires students to think critically about the particular question before responding; while educating students about the diverse nature of computing. Such as the Facebook post of a Technology, Entertainment, Design (TED) talk video that focused on how technology is being used to find jobs in England[9].

Question: After viewing the TED talk do you think jobs and workers are being impacted by technology? Why?

Student Responses:

"It would appear that there is a tremendous untapped market for immediate hands on workers whom themselves are out of traditional work (myself included). Providing such a system would have immediate beneficial effects on workers and companies; companies get the bodies they need to get the job done and workers get to earn some money in the little free time they have to spare. One could argue that with such a system in place some people would have the option of working only when they needed to thus relieving the strain of life with having to work but also having other obligations that one simply cannot ignore such as higher education and child care.." *African-American Male*

Students are learning how coding is fundamentally connected to programming and are taught in CS1 courses how the two become one, instead of experiencing them as seperate entities as it was taught in the 20th century[10]. Students are empowered by the intricacies and diversity of programming.

Scratch enables students to understand abstract concepts in programming such as objects, variables and looping through the use of programming blocks. Scratch was designed for grade school children but can be used at the CS1 level to teach programming concepts [1][5]. At the beginning of the semester Scratch is introduced to help students understand the fundamentals of programming. This exposure has proven effective for students who have limited math skills and minimal computational thought process. By effectively letting the student see an abstract object, such as a variable that is used for taking score or the use of random numbers working immediately. "*Scratch helps users stay engaged in testing, debugging, and improving their projects*"[1]. By using Scratch in conjunction with traditional teaching strategies and social media, students are more enthusiastic and eager to create a Java or C++ program. A Hispanic Female student pointed out that she saw the similarities between arithmetic operators and variables used in C++ to that used in visual programming blocks in Scratch

III. Retention Strategies

Research has shown that "understanding digital communication tools and putting them to work effectively- achieving digital literacy- is essential for success in the 21st Century"[4]. The use of social media as a tool for student retention and engagement in college classrooms is in its infancy, yet students have fully embraced every aspect of social media, and are comfortable using it for educational purposes[3].

Emphasizing digital literacy through social media and visual programming has increased the retention of students in CS1 courses at Triton College. Approximately 30% of Students who have taken CS1 went on to register for advanced Programming courses. Compared to 2% the previous year. There were a total of 38 students enrolled in two CS1 courses for Spring 2013 semester; 32 students remained enrolled beyond week 6 of the semester, 26 males and 6 females of that 11 Hispanic males, 3 Hispanic females, 3 African-American males, and 0 African-American females.

CS1 taught with social media, visual programming and traditional methods retained 84% of students in the course after the official drop date compared to only 55% of students after the official drop date for Fall 2012 semester. At the end of the semester students share via an online survey upon course completion what they learned form the course; how they feel about the use of Facebook in the class and any recommendations they have to improve the course. 89% of the students said that they liked using Facebook in the course. 90% said they learned how to use social media for educational purposes and 10% disliked using Facebook for educational use.

The primary question posed in this paper - Can utilizing social media and visual programming increase retention of minorities in programming classes? Yes, it has been successfully implemented at Triton College with students enrolling in advance programming courses after completion of CS1, with the belief that CS1 nurtured a sustainable interest with students who want to major in Computer Science or Engineering. The expectation is that the approach being used can be implemented in any introductory programming course to attract, retain, and graduate a more diverse group of qualified engineering and computing professionals for the 21st century workforce. Therefore the question that Academia should consider would be how to incorporate social media into the curriculum and not if social media is relevant to education.

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Health Monitoring Laboratories by Interfacing Physiological Sensors to Mobile Android Devices

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***Abstract*— The recent sensing capabilities of mobile devices along with their interactivity and popularity in the student community can be used to create a unique learning environment in engineering education. Android Java-DSP (AJDSP) is a mobile educational application that interfaces with sensors and enables simulation and visualization of signal processing concepts. In this paper, we present the work done towards building non-invasive physiological signal monitoring tools in AJDSP through hardware interfaces to both external sensors and on-board device sensors. Examples of laboratory exercises that can be introduced in classes are presented. The proposed software tools can be used to provide intuitive understanding in wireless sensing and feature extraction to demonstrate the application of DSP to health monitoring systems. The effectiveness of the software modules in enhancing student understanding is demonstrated with the help of preliminary assessments.**

Keywords—Android, DSP, Mobile Health Monitoring, Wireless Sensors, Physiological Signals

I. Introduction

Over the last decade computer based tools have created a great impact in engineering education. This has led to the development of several tools used in digital signal processing (DSP) courses that enable students to apply concepts in a variety of contexts. One such important tool is Java-DSP [1,2], a web-based visual programming environment consisting of various functions built to perform DSP simulations. Recently, mobile devices are being used to progressively engage students through their ability to provide enhanced visual representations of content with interactive user interfaces. This, in turn, brings a need to develop mobile applications (apps) that can augment a course curriculum in STEM education. Instead of using these devices as an alternative platform for content delivery, exploiting their interactivity can create a personalized learning environment that continues to move outside the classroom [3]. Wireless and mobile technologies can provide learning in multiple contexts [4] by connecting students with their peers and teachers, and introducing instant feedback in the learning process. Studies suggest that students feel more confident, develop critical reasoning and are able to retain their learning for longer when working in such an environment [5].

Current Android devices comprise sufficient memory, processing power and a rich set of on-board peripherals such as accelerometers, digital magnetometers, gyroscopes, GPS receivers, microphones, and cameras [6]. Together, these sensors enable the development of a diverse set of applications, many of which can be used for research in mobile healthcare (m-Health). For instance, parameters such as pulse rate, blood pressure, oxygen saturation, and skin conductance, shown to vary based on physical activity and stress can be measured using mobile devices and sensors.

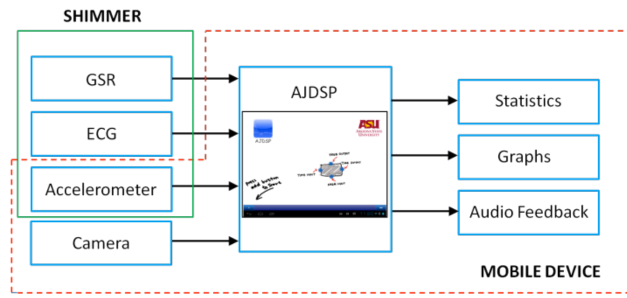

Fig. 1. Overview of the proposed mobile health monitoring system using android mobile devices.

In this paper, we explore the trend of mobile sensing and adapt it towards improving digital signal processing (DSP) instruction by building interfaces to external and on-board sensors (Fig. 1), thereby providing a new scientific paradigm for teaching. Some of the popular Android apps available for learning DSP principles include MATLAB Mobile [7], WolframAlpha [8], and Octave [9]. Several of these apps typically have a command-line interface and require Internet connectivity to interface with the cloud. In addition, MATLAB Mobile and WolframAlpha also require an active license. Although these and other applications available in the market today are compelling, most do not provide a way to design and configure simulations and visualize results. To address these drawbacks, we have developed iOS and Android graphical programming apps (iJDSP and AJDSP) that can be used to complement instruction in graduate and undergraduate DSP courses [10-13]. The iJDSP app is available for free download on the iTunes App Store [14]. The AJDSP app will be available for download on the Google Play store by late summer 2013, and it can be run on all Android smartphones and tablets [15]. The apps support several DSP functions pertaining to topics such as filter design, convolution, multirate signal processing and the FFT. They also comprise an easy-to-use interactive design, numerous visualization tools, and a provision to create simulations of DSP systems.

The primary focus of this paper is to present AJDSP interfaces to wearable wireless sensors, developed by

Shimmer Research Inc. The new sensing features are used to link concepts in DSP and wireless networks to applications in health monitoring. The proposed interfaces will enable students from the STEM program to perform laboratories that associate basic parameters estimated from bio-signals with bio-physical conditions. As part of this work, we have developed software modules in AJDSP to: (a) acquire data from on-board and SHIMMER sensors; (b) extract relevant features from the sensor measurements; and (c) compute and visualize bio-signal parameters. In addition, data acquired from these sensors can be processed using other AJDSP functions. Laboratory exercises and tutorials to be deployed in an undergraduate level DSP course (EEE 407) and a graduate level biosensors (EEE 598) course at Arizona State University (ASU) are being developed. The AJDSP app with its unique combination of sophisticated DSP functionalities, the proposed sensing features, and interactive workspace for performing block-based simulations make it a novel and valuable educational tool.

This rest of this paper is organized in the following manner. Section II provides a brief background on mobile apps for education and healthcare, and the SHIMMER sensor platform. Section III gives an overview of the AJDSP app. Section IV describes the proposed interfaces and the various physiological signals that can be monitored using AJDSP. In addition, it presents an overview of the learning opportunity using such interfaces. Section V presents a few sample laboratory exercises. Section VI discusses the assessment results, and concluding remarks are presented in Section VII.

II. MOBILE APPLICATIONS AND SENSORS

In this section, a brief overview of existing apps used in education and health monitoring are presented. Furthermore, a background on the SHIMMER sensor platform that is interfaced with the AJDSP app is also provided.

A. *Apps in Education and Healthcare*

A plethora of apps exist in the market today, many of which are geared towards assisting teachers and students in various tasks related to coursework. Some examples are Blackboard Mobile [16], Class Dojo [17], Calculus Tools [18], and Cram [19].

In addition, there exist several apps providing health related information based on measurements acquired using on-board device sensors. At times these can also connect to remote databases containing patient health records. A few examples are: (a) Endomondo which monitors users engaged in activities such as running, walking, and cycling [20]; (b) Instant Heart Rate Pro is an app that measures heart rate and allows sharing information via internet; (c) The Stress Check app measures stress levels of a person using their heart rate [21]; (d) Blood Pressure Journal that measures blood pressure, heart rate, custom medication doses, weight, and body mass index (BMI) [22]; and (e) FitBit, which automatically and wirelessly records data such as steps, distances, and calories burned, obtained from a FitBit tracker. It enables daily monitoring of food, activity, weight, water, and sleep [23]. However, these apps do not have the facility to allow users to perform tasks and analyses using DSP tools, and therefore have no scope to be used for DSP education and research.

B. *SHIMMER Sensor Platform*

Sensing Health with Intelligence, Modularity, Mobility and Experimental Reusability (SHIMMER) is a small wireless low-power sensor platform that can record and transmit physiological and kinematic data in real-time. This sensing platform has been adopted to increase the applications of sensor technology in healthcare, using open standards to achieve this goal. The platform focuses on integrating hardware and software components to allow for rapid prototyping of research in biomedical applications [24]. The SHIMMER baseboard forms the core component of this platform and comprises a microcontroller, a Texas Instruments™ MSP430 MCU, the advantage of which is that it consumes low power when inactive and is effective in medical sensing applications. The baseboard also consists of a Bluetooth or 802.15.4 low power radio transceiver, an accelerometer for activity monitoring, data storage using a micro SD card, and connection capabilities to different kinds of daughterboards (biosensors). The daughterboards extend the abilities of this platform by providing various kinematic, ambient and physiological sensing functionalities:

1) *Kinematic sensing:* Accelerometers, gyroscopes and magnetometers are included and utilized for inertial measurement applications.
2) *Physiological sensing:* Incorporates Galvanic Skin Response (GSR), Electrocardiogram (ECG), and Electromyography (EMG) sensors.
3) *Ambient sensing:* Comprises of temperature and light sensors.

In the recent past, several m-Health applications have used the SHIMMER sensor platform to reliably obtain sensing measurements in real-time for signal monitoring and diagnosis. BioMOBIUS is an example where SHIMMER is used as part of a medical research platform [24]. Accelerometers have been used to study energy expenditure estimation in patients with Rheumatoid Arthritis [25]. ECG sensors have enabled a wavelet-based real-time delineation and compressed sensing-based compression of ECG signals [26,27]. Motion analysis of patients with Parkinson's disease, stroke, and epilepsy, using a wearable wireless sensor platform called Mercury has been developed in [28]. A combination of physiological sensors has been used to perform activity aware stress detection [29].

In the proposed interface, we employ the SHIMMER platform for real-time sensing, as it includes libraries for app development on Android devices. Moreover, the compact size, extensive sensing capabilities, wearability and light weight nature, make the SHIMMER ideal for creating mobile and nonintrusive physiological signal monitoring systems. The purpose of building this platform has primarily been for use in various biomedical and activity aware applications; however, it has not been used for demonstrative purposes in an undergraduate DSP course.

Fig. 2. SHIMMER interface to stream data in real-time. As an example, the accelerometer is chosen as shown in the options menu.

III. AJDSP OVERVIEW

In this section, we provide a brief background on the AJDSP app and its functionalities.

AJDSP is a standalone mobile graphical programming app designed to be used to aid in signal processing education. The app comprises of a block-based interface consisting of inputs and outputs that allow presentation of DSP concepts in an easily understandable manner. Using AJDSP, students can establish and run DSP algorithms with various configurations on their Android devices and can also perform undergraduate signal processing laboratories.

Signal processing functions, including signal generation, signal processing and signal display units are incorporated into the application. AJDSP has capabilities to generate deterministic and random signals, as well as MIDI and DTMF waveforms. Along with a rich suite of time and frequency domain signal processing functions, algorithms such as the fast Fourier transform, filter design and *z*-domain operations have been implemented. Furthermore, interactive demonstrations to teach concepts of continous-time and discrete-time convolution and relationships between the *z*-domain and the frequency-domain using the pole-zero placement method are provided.

IV. DEVELOPMENT OF AJDSP HEALTH MONITORING LABS

In this section, we describe the proposed sensing interfaces for AJDSP and highlight the concepts about which intuition can be provided by introducing health monitoring laboratories in DSP courses.

The proposed sensor interfaces allow access to both external SHIMMER sensors and on-board mobile device sensors. Data can be streamed in real-time from the SHIMMER-based electrocardiogram (ECG) sensor, galvanic skin response (GSR) sensor, and the accelerometer using the *Shimmer Signal Generator* block. It establishes a Bluetooth connection between the SHIMMER baseboard and the

Fig. 3. FFT processing of SHIMMER sensor data.

Android device and data is acquired by configuring the required sensor to be turned on. Fig. 2 shows streaming data from a 3-axis accelerometer and Fig. 3 shows the FFT of the data. Changes in readings indicate movement of the sensor along each of the 3 axes. A brief description of the various sensor signals and the corresponding features that can be extracted using AJDSP is presented below. In addition, concepts that are intended to be taught using the proposed interfaces of AJDSP for in-class demonstrations and purposes of performing laboratory exercises are mentioned.

A. *Accelerometer*

The accelerometer can be used to measure instantaneous acceleration due to forces acting on the sensor. Analysis of accelerometer data requires extraction of features such as mean, standard deviation, and energy for each axis, and correlations between axes. Students can be provided with an insight on how physiological responses tend to be affected by physical activity. Examples inlude, displaying readings and waveforms of sensor measurements obtained while a person is at rest, in comparison to while a person is walking. Therefore, a need to incorporate accelerometer measurements in context-aware applications such as stress detection can be demonstrated. Furthermore, the appropriate placement and positioning of sensors for different appplications can be presented. For example, it can be shown that placing the accelerometer on the hip helps in classifying physical activity [30].

B. *Electrocardiogram (ECG)*

The ECG sensor detects small changes in electrical activity of the skin at every heart beat. The measurement is used to analyze the functionality of the heart based on the regularity of the heartbeats. An important processing step in ECG signal analysis is the extraction of the QRS-complex and detection of the R-wave peaks [31]. A few other features that can be extracted include the mean and standard deviation of heart rate and R-R interval, root mean square (RMS) value of the differences between successive R-R intervals, and percentage of heat beat intervals with a successive R-R difference in interval greater than 50ms (pNN50) [32].

Using these functions, demonstrations on the different configurations of electrode placement used to acquire the ECG measurements can be provided. Typical characteristics of ECG waveforms (Fig. 4) like the QRS-complex, P-wave and T-wave segments and their corresponding range of time intervals for normal and abnormal recordings can be understood. ECG signal artifacts such as low frequency baseline wandering and high frequency power line interferences that occur during signal acquisition can be observed.

Fig. 4. The ECG Signal Generator function block.

Concepts of signal denoising operations and the challenges faced can be highlighted. In addition, the time-domain and the frequency-domain visualization of extracted feature vectors such as, R-R interval and heart rate variability (HRV) can be associated with corresponding health conditions.

C. *Galvanic Skin Response (GSR)*

The GSR sensor measures the electrical resistance of skin based on the amount of moisture content present in it. This conductance varies based on skin and muscle tissue responses to stimuli. It is used to detect stress, fear or anxiety, all of which make sweat glands more active and cause a decrease in the skin resistance. Two signal characteristics that can be visualized from the GSR signal are: (a) Skin Conductance Level (SCL) – a slowly varying signal; and (b) Skin Conductance Response (SCR) – a fast varying signal. Important features extracted from this signal are the amplitude and latency of SCR and the mean and standard deviation of SCL. The distribution of the SCL peak and the SCR peak rate can be shown to carry information regarding the stress level of a person [29]. Using these features, classification of skin conductance into Tonic conductance and Phasic conductance can be demonstrated. The former is observed as a sharp transition in the signal values due to a stimulus and the latter is observed 1-2 seconds after the stimulus. Tonic conductance can further be shown to increase with stress levels or demanding mental activities. In addition to this, concepts of a startle response, which is the physiological response of the body due to a sudden stimulus, can be presented. The total number of startle responses in a windowed segment of GSR, the sum of the response magnitude and the sum of the response duration can be shown to characterize the startle response.

D. *Photoplethysmogram (PPG):*

In addition to acquiring physiological signals from SHIMMER sensors, the on-board device camera can be used to extract a Photoplethysmogram (PPG). The PPG signal is obtained by recording a video with the finger tip placed on the camera lens.

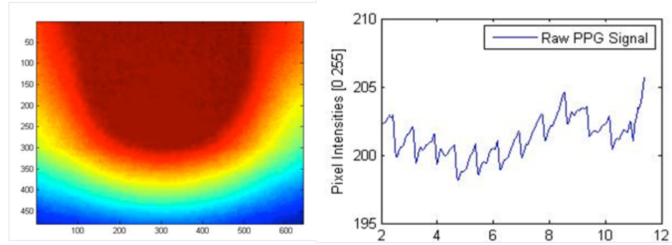

Fig. 5. The pixel intensities present in a single video frame (left) and the extracted PPG signal (right).

It provides a volumetric measurement of organs, such as the heart and the lungs. The PPG typically measures changes in light absorption by the skin. It can be used to monitor heart-rate and cardiac cycle, respiration, and hypovolemia and hypervolemia. The algorithm used to extract the PPG signal from the video was derived from [33] and an example signal is shown in Fig. 5.

V. SAMPLE LABORATORY EXERCISES

In this section, a few sample laboratory exercises designed for undergraduate students belonging to the STEM program is described.

A. *Undertanding QRS detection and Denoising of ECG*

Most physiological signals are non-stationary (frequency varies with time) and need to be observed in real-time to provide students a better perspective of its content. However, acquiring ECG signals from each student individually to work on an exercise can be cumbersome. Therefore, a few sample ECG recordings are provided internally within the *ECG Signal Generator* block. Fig. 4 shows the ECG signal generator interface with a normal sinus rhythm loaded into the block. It also shows the buttons provided to enable frame-by-frame processing of the non-stationary signal. The objective of this exercise is to provide hands-on experiences with AJDSP and a basic understanding of ECG signal characteristics, parameter estimation, and filtering.

The first part of the exercise provides an overview of various signal characteristics in relation to the corresponding health conditions diagnosed from the patient data. Students are asked to use the *ECG Signal Generator* block to load the sample synthetic waveform obtained from Physionet's ECGSYN toolkit [34]. They observe the P-wave, the QRS-complex and the T-wave of this artificially synthesized normal ECG and understand concepts of atrioventricular (AV) ratio, and the required ordering of the wave segments for a normal heart. The sampling rate of this signal and number of samples comprising the R-R time interval are provided to enable students to estimate the heart rate.

Next, real ECG recordings, normal sinus rhythm, arterial fibrillation (AFB) and ventricular tachycardia (VT), and the corresponding waveforms are observed for these abnormalities. Furthermore, signals obtained using a lead VI configuration with and without baseline wandering (noise) are also provided and visualized [35].

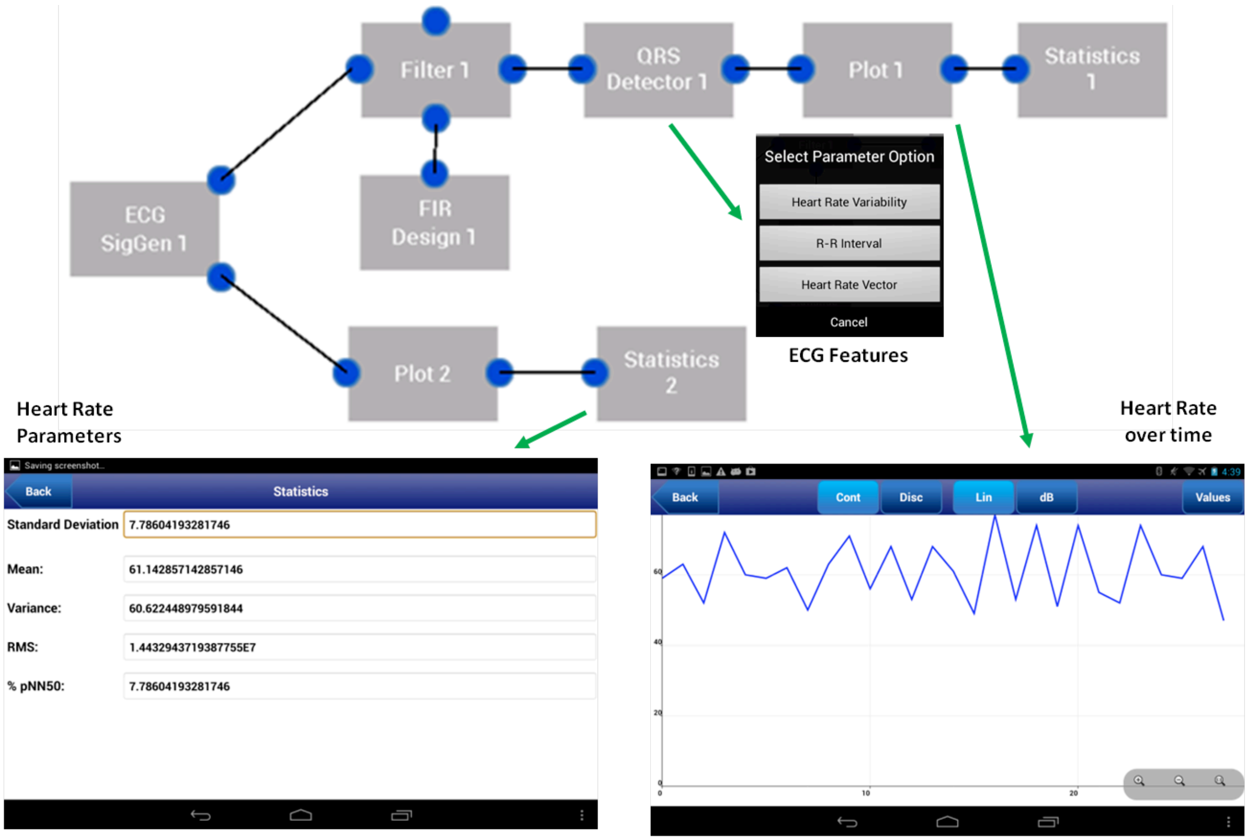

Fig. 6. Sample laboratory simulation exercise using ECG signals.

In the second part of the exercise, the baseline wandering artifact is removed by designing filters using the *FIR Design* block. The R-wave peaks are detected and relevant features are extracted using the *QRS Detector* block. The algorithm to detect these R-R peaks and extract features is based on multiresolution wavelet transform as described in [36]. The simulation diagram and expected outputs for this part of the exercise are shown in Fig. 6. Students can also visualize the frequency spectra of both the noisy and the de-noised ECG signals using the *FFT* block. Heart rate variability (HRV) analysis is conducted and feature vectors such as difference in successive R-R interval, mean and standard deviation of heart rate and R-R interval are calculated in the time-domain using the *Statistics* block.

B. Accelerometer Data Acquisition for a Step Counter Application

The objective of this exercise is to demonstrate a wireless DSP sensor system, to understand remote data acquisition, and to learn simple concepts about accelerometers and their role in context aware applications.

In the first part of this exercise students are asked to use the *Accelerometer* block and select the option to connect to Shimmer sensors. The sensors are either held in their hand or strapped around their waist/ankle. They then establish a Bluetooth connection between the mobile device and the sensor through the app user interface. Data is streamed from the accelerometer and the signal from each of the 3 axes is observed. The change in the axis experiencing the gravitational-force and the corresponding signal transitions based on different orientations of the sensor and activity of the subject is noted. In the second part of the exercise, students stream data from the accelerometer built-in-to the mobile device. They are asked to simultaneously stream data and calibrate the step counter by performing a predetermined activity, such as walking for five steps. Once calibrated, they then perform one of three activities: standing, walking and running. On stopping the data streaming, the total number of steps taken and the duration of each of the listed activities are displayed. By observing the frames of the signal, students learn that each step corresponds to a peak in the accelerometer magnitude and sharp signal transitions mark a change in activity.

C. PPG Extraction and Bio-parameter Estimation using a Camera

The objective of this exercise is to demonstrate a non-invasive health monitoring system by using the camera to extract a physiological signal.

In the first part of this exercise students record a video of their finger tip using the *Health Meter* block. A preview of the video is observed during the recording to understand the optical principle behind the PPG signal. A pulsating light ring within the preview can be visualized with care to understand the physiological property of the signal obtained as every pulsing ring corresponds to a heartbeat [33]. After about 15 seconds, the recording stops and a meter displays the estimated heart rate. The extracted PPG waveform can be observed along with parameters such as oxygen saturation and respiratory rate. In the second part of the exercise students learn about extracting the frequency band that corresponds to the respiratory information in the PPG signal using the *Wavelet Transform* and *Inverse Wavelet Transform* blocks. The different bands can be observed by selecting the low frequency detail coefficients to be preserved during reconstruction of the transformed signal. Concepts on the relationship between scale, wavelet width and frequency can be understood using the wavelet blocks. The significance of approximation and detail coefficients and their relationship to signal energy can also be understood. In addition, a brief idea on the different family of wavelets that exist and choosing the right one in relevance to the application is provided.

Performing laboratories using these sensors provides an overview of the procedure of collecting sensor measurements from the different sensors, and the abilities of mobile devices to act as computational signal analysis platforms. Additionally, the AJDSP block functionality of processing signals in a frame-by-frame manner gives a better intuition of the processing operation that takes place, and a way to closely observe important signal characteristics. The interface between sensors and mobile apps can be used to present students with the diverse applications of DSP.

VI. ASSESSMENTS AND OUTREACH

Preliminary assessments were conducted for AJDSP in general DSP and how students receive it in class. Two workshops were held, one comprising graduate students and the other, undergraduate students. A detailed evaluation methodology was designed to test various aspects of the AJDSP app such as educational value, robustness, and improvement in conceptual understanding.

The goal for the graduate student workshop was to assess the robustness and the accuracy of the software while the undergraduate student workshop was conducted to assess the ability of the application to foster understanding of signal processing concepts. The concepts tested in the workshop with the help of exercises consisted of filter design, FFT, *z*-transforms and convolution. A total of thirty-three students participated in the assessment workshops. Fig. 7 shows the results obtained. Most students were satisfied with the robustness and speed of the AJDSP app. Based on this exercise, an overall improvement in understanding was observed to be about 11 percent (Fig. 8). From these results, we can substantiate that mobile learning introduced into the curriculum improves conceptual learning. Detailed assessments on using the proposed functions for m-health applications will be provided at the conference.

As part of outreach, the AJDSP app was displayed at the Engineering Open House event conducted at ASU. The event was designed to showcase engineering and technology, in a creative and interactive fashion to students from K through 8th Grade.

VII. CONCLUSIONS

The ability to experience how sensors measurements are acquired and signals are processed will help students relate textbook knowledge to applications and creatively conceptualize their understanding. By depicting the challenges faced in the healthcare domain, students can be guided to innovate in these areas. In particular, the role of DSP in tackling problems in such real-world contexts can be presented along with its diverse applications. Furthermore, the AJDSP app helps to serve as a platform to visualize physiological signals such as PPG, ECG and GSR. In addition, function blocks to extract features and compute parameters such as heart rate, oxygen saturation and step count were developed. These functions were used to create laboratory exercises, samples of which were provided. Preliminary assessments show promise in improving students' understanding of DSP concepts when using the AJDSP app as part of the curriculum. Detailed assessments will be conducted and the results will be presented at the conference.

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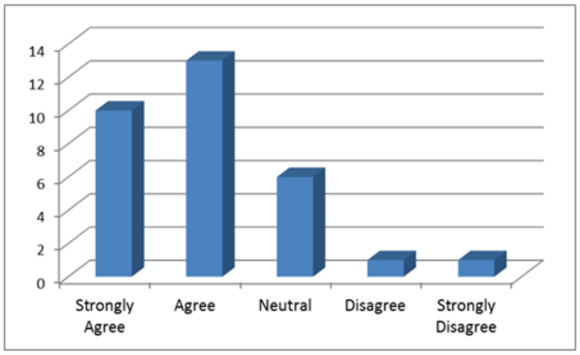
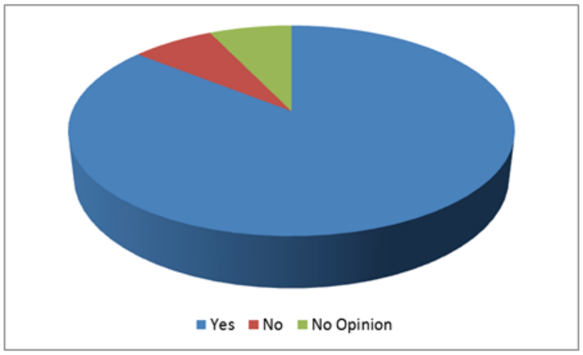


(a) Response of students when asked if the AJDSP app is stable.



(b) Response from students if they found the speed of the app satisfactory.

Fig. 7. Preliminary assessments obtained from graduate students on the AJDSP app robustness and speed.

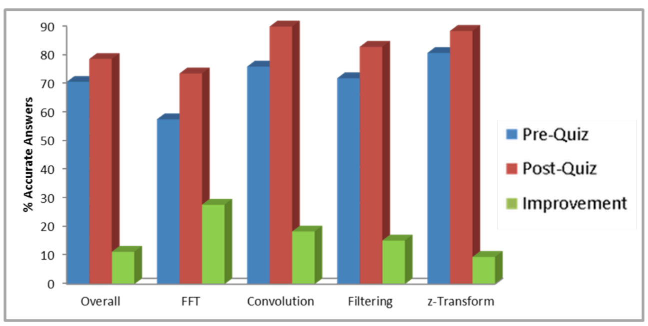


Fig. 8. Improvement shown in student understanding of different DSP concepts.

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Update 2013 on the iCollaborate MSE Project

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***Abstract*—The primary goals of the iCollaborate Materials Science and Engineering (MSE) project are to improve student learning outcomes, engagement, and completion rates in introductory materials engineering courses. This extensive research project is multidimensional and includes several interrelated components, all of which are founded upon best practices from STEM education research. There are several individual elements within the project that operate simultaneously or sequentially and unite to form a novel teaching and learning system. The first element of the project was the transformation of the structure in our basic MSE course from primarily deductive practice to an Information Communication Technology (ICT) enabled, student centered, inductive teaching and learning environment. Collaborative learning, active/inquiry learning, concept learning, peer learning, problem/case-based learning, low stakes quizzing, mini-lectures with just-in-time reading, collaborative research writing, and constructive alignment are all important components of our multi-dimensional approach. Also completed as part of this research program were: detailed explorations to understand the students' pre-course knowledge and misperceptions, an investigation of student preparation and how that preparation influenced pre-course concept knowledge and overall course outcomes, and an analysis of Felder's Index of Learning Styles (ILS) assessment by student and course section. The detailed analysis of pre-course knowledge and misperceptions showed a surprising lack of pre-conceptual knowledge and revealed several important student misperceptions.**

This paper focuses on components of the iCollaborate project that were researched, analyzed, or developed during the Fall 2011 through Winter 2013 timeframe. First, a summary of the pre-course assessment findings is given in this paper. Second, an overview of the suite of MSE iPod applications and newly developed web applications for iCollaborate is presented. Finally, an overview of the supporting web site for the project, which is currently under development, is described. The paper concludes with a description of the remaining objectives for the iCollaborate project and future research directions.

Keywords—inductive practice; Information Communication Technology (ICT); distributed cognition; collaborative learning; iLearning

I. Introduction

The primary goals of the iCollaborate MSE project are to improve specific, targeted student learning outcomes, student engagement opportunities, and completion rates in introductory materials science and engineering courses. The iCollaborate project combines best practices from STEM education research and targeted, outcome based ICT support in novel ways to create a student centered teaching and learning system. The other project elements include: detailed research to understand students' pre-course knowledge and misperceptions, an investigation of student preparation and how that preparation influences pre-course concept knowledge and overall course outcomes, an analysis of ILS assessments by student and course section, inductive teaching practices which include collaborative learning, active learning modules, concept/peer learning opportunities, collaborative writing of research papers, low stakes quizzing, the development of targeted iPod applications that promote enhanced student understanding in MSE, and the development of a web site with web apps. Individual elements within the project operate simultaneously or sequentially. The justification of the STEM education research base for this project has been described in detail elsewhere [1]-[2]. Educational theory based on cognitive and social constructivism support the effectiveness of our project elements [3]-[4]. There is an additional research base that supports connections between ICT enhanced collaborative learning, distributed cognition, and enhanced student outcomes [5]. "Between 1924 and 1997, over 168 studies were conducted comparing the relative efficacy of cooperative learning. These studies indicate that cooperative learning promotes higher individual achievement than do competitive approaches … "[6].

II. Analysis of Pre-course Information

As part of the iCollaborate MSE project, the students completed a pre-course evaluation instrument consisting of 26 questions, in three broad conceptual areas (chemistry, basic physics/science knowledge, and hands-on/project learning) and Felder's ILS assessment. An outside evaluator and assessment specialist (Dr. Phil Buly) completed the analysis of all pre-course information. For this element of the research, we placed the students into four categories: engineering technology (ET) majors, industrial technology (IT) majors, science majors, and non-science or technology majors. For the pre-course evaluation materials, we examined overall GPA, GPA in the Chemistry pre-requisite, GPA in the Mathematics pre-requisite, and the ILS data for each student

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for each question. A one-way ANOVA test with $p<0.05$ was used to evaluate statistically significant differences, except where IT and ET students only were compared. In those cases, a T-test with $p<0.05$ was used. The overall sample size was 180 students.

When we aggregated the pre-course assessment, we found that overall the students answered only about half (54%) of our very basic questions correctly. This result was alarming in that we had always assumed the students had a basic level of knowledge about materials. We were surprised to learn that the students could not always name an example of a metal, ceramic, or polymer, or the three basic bond types, and that their fundamental understanding of the term "elastic constant" was fundmentally flawed. The students performed the worst on the basic chemistry questions (44% correct), while they only did only somewhat better on the questions reflecting on hands-on learning (55% correct). As disappointing as the overall results were, chemistry pre-requisite GPA did, for certain questions, predict understanding. For the question covering metallic bonding, GPA in the introductory chemistry class resulted in different outcomes, with 2.0 GPA students scoring the lowest (34% correct), as compared to 3.0 and 4.0 GPA students (48%, 44% correct). Interestingly, Intuitive (INT) learners scored higher (50%) than Sensing (SEN) students (39%). A science (SCI) student, with a high GPA in chemistry, who is an INT learner, had the overall best outcome. And, an ET student, with a low GPA in chemistry, who is a SEN learner, needs the most support during conceptual change activities. Chemistry GPA also correlated to the ability of the students to name a ceramic material. Seventy-four percent of Chemistry GPA 4.0 students were able to name one ceramic material, while only 51% of the GPA 2.0 students answered correctly. Overall GPA also was significant for this question, with students in the top quartile answering correctly 75% of the time, while the students in the lowest quartile answered correctly only 54% of the time. Overall GPA also was linked to the ability of students to correctly identify a polymer, but in a more complex manner.

For the pre-course assessment, major type did predict the overall outcomes, even though all the students have completed the same course pre-requisites in Chemistry, Mathematics, and Physics. The SCI students scored the best, with 60% correct overall and IT students scored slightly higher than ET students (55% versus 53%). And, VIS students outscored VER students 55% versus 48.5%. Finally, INT learners scored 56.7% versus 52.7% for SEN students. Obviously, we are not claming learning style correlates to outcome. But, these results certainly do reinforce what has been found in STEM education research about students, student learning, and the complexities of instructional design. We do know that students come to our classrooms with different levels of preparation and that scores in pre-requisite courses do matter, but are not always perfect indicators that key information has been retained. Students enter our courses with a wide range of learning styles, and some pre-requisite information is retained or learned differently based on student learning style and many, many other factors.

III. iPod and Web Applications

MSE content based apps were developed with the Apple iOS SDK for our research project: iCollaborate Vocabulary (Vocab), iCollaborate Basic Knowledge building (BasicK), iCollaborate Concept Questions (ConQuest), skill tune-up (Tune-Up), a graphical Materials Properties application with list features (MatProps), a unit conversion tool specific to only those units encountered in a basic MSE course (MSEConvert), and a tool to calculate the Elastic Constant of two component, unidirectional fiber composites (MSEComposites). The MSEKnowledge Tools app has been built, but we are still developing the content for the topic-by-topic study guides. In order to facilitate our dissemination plan, web app versions for the iCollaborate website are under development for key MSE apps. The web apps are designed to run from any PC or Apple computer and mobile devices that support browsers. Thus far, the Materials Properties web app and the MSE Vocabulary web app have been built and are undergoing testing.

Screen captures of the MSE Vocabulary apps are shown in Figs. 1 and 2. Fig. 1 shows the conceptual topic titles that are common to the apps for the iPods, while Fig. 2 compares the Vocabulary mobile and web app interfaces. The topics are those specific to introductory materials engineering courses, but are generic in nature and are not tied to any one particular text. Similarly, vocabulary terms are common to materials science and engineering topics, but are not focused on any particular text and, in general, go well beyond the content of any one text and basic content. In these mobile apps, the students flip the card to see if they have the correct answer. If their answer is incorrect, another screen shows up with a more detailed explanation, a web link, and an audio explanation. In these apps, the students can work in either practice mode or test mode since these apps are designed to facilitate collaborative knowledge building. The concept question app (MSEConQuest) was built with the same type of help for the user, but in a multiple choice format so that we could display known misperceptions as multiple choice answers or have the students select different material choices, also based upon discovered, common student misperceptions. In this application, the students select an answer, and the correct answer displays as green (other answers display as red). Currently, students rate this MSEConquest app as the most helpful in building their own knowledge.

However, other apps have helped improve student outcomes in totally different ways. For example, even though there are commercially available unit conversion tool apps, we found that they contained too many different types of units, and none had the exact suite of tools needed for basic MSE courses. Thus, we built a unit conversion program that was limited to only those unit conversations commonly encountered in basic materials engineering courses. The units conversion areas are: mass, force, stress, density, temperature, length, area, volume, SI Prefixes, fracture toughness, specific heat, and thermal conductivity. The MSEConvert app allows students with poor mathematics skills to check their own work and rarely do we see simple unit conversion errors now on design problems as the term progresses. Similarly, the

MatProp app (see Figs. 3 and 4) helps students develop a sense of the range of material property values for different classifications of materials. MatProp shows conceptually contained lists of material properties because students can select from different basic material decks that are predefined by the instructor. The app helps the students compare a material property of up to six different materials or, later in the course, they can create scatter plots of two different material properties for six different materials. The bar graph view is more useful at the beginning of the term, but the scatter plot is more useful as the students begin their design work. As a result, the students infrequently select inappropriate materials for various applications by the end of the term. We also built an elastic constant, density, and volume fraction of fiber calculator app for a unidirectional composite composed of a matrix and unidirectional fibers. We have found this app useful to help the students understand the implication of fiber to matrix ratio and, the students do not neglect the influence of the matrix material on overall composite materials properties now in their research papers. On the other hand, we found it was unnecessary to keep building our Basic Knowledge app because robust support for both basic Mathematics and basic Chemistry are widely available. Additionally, robust periodic chart apps are also commercially available. Thus, we chose to invest development time into novel application of those existing periodic tables and made the support apps in both Chemistry and Mathematics available on the iPods.

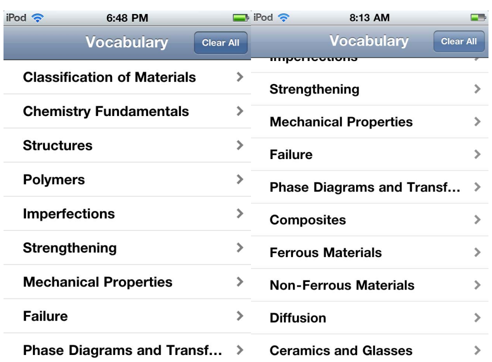

Figure 1. Topics Areas for MSE iOS Apps.

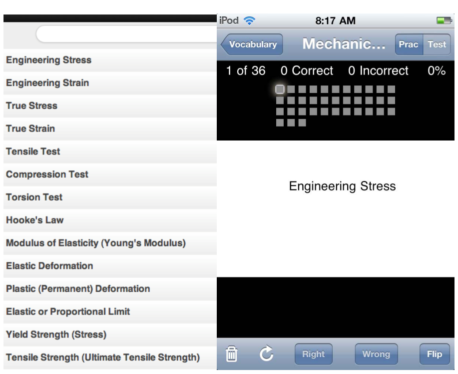

Figure 2. Card Interface for Web App Versus Mobile App.

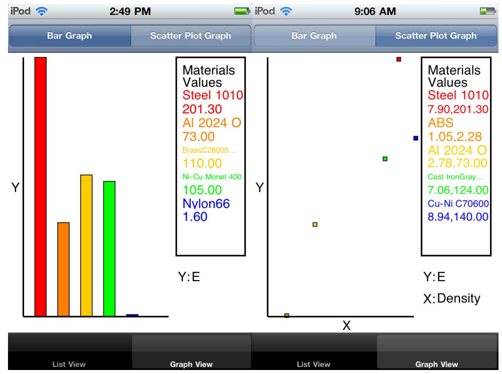

Figure 3. Mobile iOS Interface for Materials Properties App.

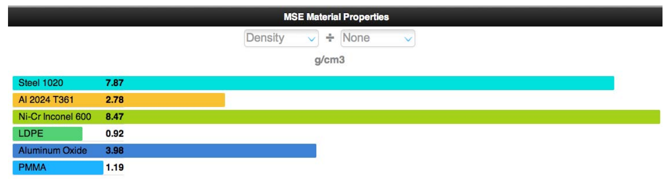

Figure 4. Web App Interface for Materials Properties App.

IV. FUTURE TASKS

The final assessment task is to examine standard test scores by individual question by individual student by individual section. And, we then need to aggregate those results. The few remaining anomalies need to be removed from the apps and the web apps completed. And, we must find a way to move the apps to the Apple Store for free distribution rather than keeping them on development devices. The content for the Knowledge app will be added next summer. The concept map web site to accompany the project needs additional content. An additional future project would be to revise our app code to understand how the students use the iPods in their own learning.

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The effectiveness of brief, spaced practice on student difficulties with basic and essential engineering skills

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***Abstract*—Through extensive testing and interviews of sophomore, junior, and senior engineering students in a Materials Science Engineering course at The Ohio State University, we found that these students struggle with many skills necessary for their coursework. Often these "essential skills" were prerequisite to the course and little to no instruction time was spent on them. Online training was developed to attempt to improve these skills. Students participated in the training several times over the term, with each assignment taking 10-20 minutes and consisting of 10 questions. Students were allowed unlimited attempts on each assignment and were required to achieve mastery (80% or better) for full credit. Training covered a wide range of topics: interpreting log plots and log scales, using metric prefixes for various conversions, estimating typical values of common material properties, employing dimensional analysis, and operating equations when given variables in mixed units. Unlike the success achieved by the log plots training, most of the topics saw little and insufficient improvement as a result of training, despite the basic nature of the skills. Future improvements to the training will focus on determining which factors will help to convince students of the importance of mastering these prerequisite skills.**

Keywords—engineering, computer training, online homework, mastery learning, student understanding, essential skills

I. Introduction and Theoretical Background

Many engineering students at The Ohio State University are required to take an introductory course in Materials Science Engineering. Students are expected to leave the course with mastery of certain categories of knowledge which are utilized frequently during coursework, some of which are considered prerequisite to the course. An example of this knowledge is the ability to read and interpret log plots, training on which has been successful across multiple terms [1]. Through interviews with instructors and exploratory pilot testing, we found that students have significant difficulties with a number of other basic skills essential to a functional understanding of materials science engineering and engineering in general.

The "essential skills" studied here consist both of prerequisite skills to the course—e.g., metric prefixes and conversions, dimensional analysis, and operating equations when given variables with mixed units—as well as skills the instructor expects to impart to the students—e.g., order of magnitude estimates and patterns of common material properties.

One critical aspect of the essential skills is that they are necessary for solving the types of problems posed in exams—even the simpler ones. Therefore, it is expected that students are near 100% accuracy with these skills. Even if students are 80% accurate with these essential skills, this lack of mastery is a critical bottleneck for successful performance. Here we demonstrate that a worrisome 20-50% of students performed poorly in many of these categories. Despite this, instructional time was typically not dedicated to the prerequisite skills. In this study, we developed a series of computer-based training tasks, assigned as homework, to attempt to address these issues. The training employs the method of mastery learning, in which time on task is allowed to vary to allow each student to obtain a required level of mastery.

The two most influential versions of mastery learning are Bloom's Learning For Mastery [2] and Keller's Personalized System of Instruction [3]. Though these strategies vary in many ways, Block and Burns describe their similarities in [4]: (1) they prespecify a set of course objectives that students will be expected to master at some high level, (2) they break the course into a number of smaller learning units so as to teach only a few of the course's objectives at one time, (3) they teach each unit for mastery--all students are first exposed to a unit's material in a standard fashion; then they are tested for their mastery of the unit's objectives, and those whose test performance is below mastery are provided with additional instruction, (4) they evaluate each student's mastery over the course as a whole, on the basis of what the student has and has not achieved rather than on how well he has achieved relative to his classmates.

In a meta-analysis of courses utilizing mastery criterion for learning, Kulik showed in [5] that mastery learning is effective in improving student performance on exams at all levels of learning. This improvement is greater for students with weaker content knowledge, making mastery learning a useful remediation tool.

Another successful, and more recent, approach to learning is to use computer training as part of coursework. This has been successful in many forms: Multimedia learning modules

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viewed before lecture improved performance on immediate and delayed post-tests when compared to reading static text and figures alone [6]; deficiencies in math are largely remediated by the adaptive ALEKS tutor program [7]; and integration of physics simulations, such as circuit building, into lab have been successful in improving content knowledge as well as proficiency at actual lab tasks [8]; to name a few.

The prerequisite nature of many of the knowledge gaps we observed in Materials Science Engineering students suggests that computer-based training graded for mastery may be able to provide successful remediation of these difficulties.

This paper aims to investigate and describe student difficulties with engineering essential skills. A more complete understanding of the knowledge state of the current student population is invaluable to future steps in correcting these difficulties. Also presented are the results of mastery-based training, which can be used as a model or starting place for future corrective measures.

II. Methods

Exploratory data taken during Autumn quarter 2011 showed poor performance at the essential skills described in this paper. During Autumn semester 2012, computer-based training was given to N = 271 students in an introductory Materials Science Engineering course at The Ohio State University. Most of the students in this class are sophomore and junior engineering majors. For 6 weeks during the term, beginning in week 6, students completed the "Essential Skills Quizzes", each worth approximately the same amount of credit as one homework assignment. There were 6 quizzes, each remaining open to the students for one week. Students all followed the same training pattern; they were allowed unlimited attempts on each quiz and were required to achieve mastery--80% or better--to obtain full credit. Content in the six Essential Skills Quizzes was divided approximately evenly between interpreting log scales and the "essential skills" mentioned above. Time spent on each week's quiz varied due to the mastery grading criterion, but averaged around 15 minutes per quiz. The "essential skills" comprised the entirety of Essential Skills Quizzes 2 and 4, and half of Essential Skills Quiz 6. The remainder of the six Essential Skills Quizzes covered log scales; these results are not considered here.

In addition to the Essential Skills Quizzes, students were again awarded approximately one homework's worth of points to attend a "FLEX homework" session, where the students completed the essential skills assessment, which took about 30 minutes; cumulative time spent during the term on essential skills training and assessment averaged around 70 minutes per student. In order to better assess the impact of both the essential skills quizzes and instruction, the population was randomly split into two conditions: 127 pre-Essential Skills Quiz (week 4) participants and 144 post-Essential Skills Quiz (week 13) participants. Twenty students per condition were selected for interview data; these students were video recorded while taking the essential skills assessment and were asked to think out loud and respond to prompts from the proctor. An overview of the experimental design can be seen in Fig. 1.

Condition	Week 4	Weeks 6-12	Week 13
Pretest	**FLEX Homework** Essential Skills Assessment (≈30 minutes)	**Computer Training** Essential Skills Quizzes (≈40 minutes total)	None
Posttest	None	**Computer Training** Essential Skills Quizzes (≈40 minutes total)	**FLEX Homework** Essential Skills Assessment (≈30 minutes)

Fig. 1. Experimental conditions used in this study. Students in both conditions took the same assessment but at different times; all students completed the Essential Skills Quizzes concurrently.

Training with the Essential Skills Quizzes was administered on Carmen, a course management website used by The Ohio State University and developed by Desire2Learn. Each quiz draws randomly from a categorized question bank, so that the content each student sees is the same for a given quiz, but the specific questions may not be. This also means that consecutive attempts at a single quiz by a single student will not yield the same 10 questions, but rather a new set of 10 on the same topics. This pseudo-randomization was included to attempt to reduce the number of students simply copying down solutions from earlier attempts or from other students.

Training was consistent with the four common traits of mastery learning described by Block as follows: (1) the "essential skills" to be learned and their importance to the students were specified to the students prior to training, (2) he topics covered by the Essential Skills Quizzes were divided into 6 separate quizzes, with one quiz given per week, (3) each Essential Skills Quizzes was mastery graded and all students were given quizzes over the same content. Upon completing an attempt, Carmen provided the correct answers to all questions on the quiz, allowing the students the opportunity to learn from their errors, (4) As the entire course was not taught in mastery learning style--just the Essential Skills Quizzes--student mastery over the course as a whole could not be evaluated. However, students were awarded more points for mastering more of the quizzes. In this sense, students were rewarded by their mastery alone, not by the time it took to achieve.

Thus, the computer-based Essential Skills Quizzes fit within the standard framework of mastery learning, as described above.

III. Results

All comparisons were between-student. Correctness between pretest and posttest was compared using a Chi-squared test and numerical values were compared using appropriate t tests. Effect sizes are reported using Cohen's d such that a positive d means improvement, not merely an increase in proportion. Results are presented by category:

A. Metric Conversions

Engineering students are expected to be proficient in converting between metric units (micrograms to kilograms, centimeters to nanometers, megapascals to gigapascals, etc.). Pretest students averaged only 74.8% correct on simple metric conversion problems--surprisingly far from ceiling, given the simplicity of the skill and its constant use in the engineering

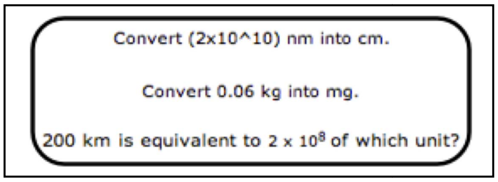

Fig. 2. Metric conversion training questions came in three types: scientific notation questions (top); decimal form questions (middle); and "find the unit" questions (bottom), which were given with multiple choice options.

courses the student had already taken. Training on metric conversions comprised 6 of the 10 questions in Essential Skills Quiz #2 plus 2 of the 10 questions in Essential Skills Quiz #6, and involved three problem types (Fig. 2).

Despite the fact that students had to achieve mastery during the Essential Skills Quizzes, we found that training on metric conversions resulted in no significant change in student performance. One of the three metric conversion questions on the essential skills assessment asked students to make a volumetric conversion from cubic centimeters to cubic meters. There was no significant difference in scores from pretest (73%) to posttest (71%). The most common error was to treat the problem as a length conversion (centimeters to meters), ignoring the volumetric nature of the problem (Fig. 3). It should be noted, however, that volumetric problems were not included in the training, thus students failed to utilize any skills they may have acquired from this quiz.

The remaining two metric conversion questions involved only linear conversions and gave conflicting results. One question asked students to convert from micrograms to megagrams, working in scientific notation; this question significantly improved from 62% to 74% ($\chi^2(1)$^2 = 4.053, p = 0.044, d = 0.25). The other question asked students to convert from kilometers to centimeters in decimal form; this question showed a marginal decrease from 89% to 82% ($\chi^2(1)$^2 = 2.652, p = 0.103, d = -0.20).

Overall, student performance on metric conversions yielded rather limited and inconsistent results. Given the importance and relative simplicity of the task, student performance is unacceptable low. On average, students scored just 74.8% correct on the three metric conversion questions before training and 75.5% after (t = 0.193, p = 0.847).

B. Dimensional Analysis

Students in engineering are expected to understand units, meaning they need to be able to analyze the dimensional relationships between variables in an equation with minimal

Response	Pretest	Posttest
Correct	73.2%	70.8%
Treat as length conversion	11.8%	15.3%

Fig 3. Common answer patterns on an example metric conversion problem. Students were asked to convert from cubic meters to cubic centimeters. The most common error was to treat the problem as a length conversion, as though converting from meters to centimeters. Neither of these changes were statistically significant.

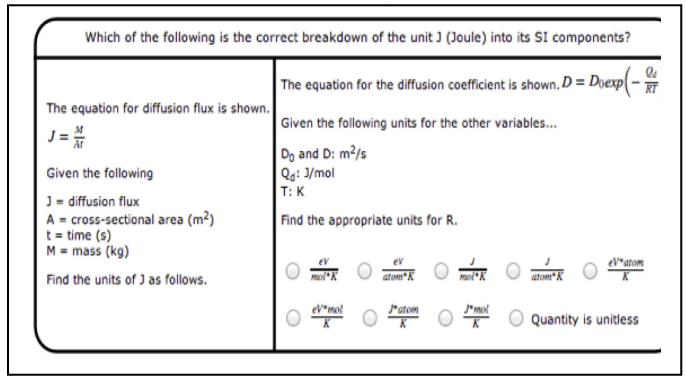

Fig 4. Dimensional analysis training questions came in three categories: unit breakdown questions (top); find the missing unit questions (left), where students were given an equation and units for all but one of the variables, then asked to solve for the units of the remaining variable; and specialized find the missing unit questions (right) dealing with the difference between the gas constant, R, and the Boltzmann constant, k. Each category consisted of both multiple choice questions and directed fill-in-the-blank questions where the student indicated the powers of respective units. An example of multiple choice responses is shown (right).

effort. For example, students should be able to determine the units of a given quantity in an equation based on the other variables involved (e.g., Fig. 4). Students would also be expected to know whether to use the gas constant or the Boltzmann constant—identical constants in different units—depending on the units of the other variables. Training on dimensional analysis involved three problem types and consisted of 7 of the 10 questions in Essential Skills Quiz #4, plus 3 of the 10 questions in Essential Skills Quiz #6.

In contrast to other essential skills categories, training on dimensional analysis resulted in significant gains in student performance for the category as a whole, improving average scores on the dimensional analysis portion of the assessment from 43% to 57% (t = 3.922, p = 0.0001, d = 0.48); it is worth noting that this is still far from ceiling, despite a relatively large effect size. Significant gains were also seen on many individual questions. One item on the assessment gave the students the equation for the theoretical density of a crystalline metallic solid as well as appropriate units for all but one of the variables. The students were then tasked with finding the units for the remaining variable. Significant improvement was shown after training (χ^2 (1)^2 = 6.781, p = 0.009, d = 0.32), with correctness increasing from 71% to 84%.

Another similar question involved determining the units of a variable in the exponent of the equation for the equilibrium number of vacancies in a material. Through interviews, it became apparent that some students were merely balancing the sides of the equation, ignorant to the fact that the exponent itself must be unitless. Part of the way through the pretest, this question was updated to the form shown in Fig. 5. This updated question showed significant improvement in terms of correctness ($\chi^2(1)$ = 7.500, p = 0.006, d = 0.49) from 33% to 56%, while the most common error--the belief that more information was needed to answer the question--decreased significantly ($\chi^2(1)$^2 = 4.545, p = 0.033, d = 0.38) from 42% to 25%. Most students claiming to need more information indicated that the rest of the equation was required.

A certain quantity changes in proportion to $e^{\frac{Q_V}{RT}}$, where
Q_V = energy required for vacancy (eV/mol)
T = temperature (K)

Find the appropriate units for the gas constant R.
If you cannot determine this without more information, what more information is required?

Response	Pretest	Posttest	
Correct	32.6%	56.4%	*
Need more info	41.9%	25.0%	*
Inverse Error	4.7%	7.1%	

Fig. 5. An example dimensional analysis question from the essential skills assessment and patterns of right and wrong answers. Asterisks indicate statistical significance at the $p < 0.05$ level. Student committing an inverse error submitted an answer that was the reciprocal of the correct answer.

Interestingly, students who believed that the problem could be solved with the given information showed an improvement in correctness from 56% to 72%, though this result fell just outside the range of significance ($\chi^2(1)$^2 = 3.670, p = 0.055, d = 0.43). The lack of statistical significance--despite a respectable effect size--is likely due to small pretest sample sizes, a deficiency owed to the change in pretest versions of the problem and the larger proportion of students believing more information was needed in the pretest condition.

C. Mixed Unit Equations

Engineers in the field use equations to calculate values from measurements, and the instruments providing these measurements don't always do so in consistent units. As such, it is essential that engineering students be able to operate equations--to find the value of the dependent variable--when presented with independent variables in mixed units.

The equation for the diffusion flux is shown.

$$J = \frac{M}{At}$$, where

A = cross-sectional area
M = mass (or number of atoms)
t = elapsed time.

Given M = 1.0 mols of a gas passing through an area of 1 cm^2 over a time of 40 ms, what is the diffusion flux in atoms/(m^2s)?

Response	Pretest	Posttest	
Correct	39.7%	46.2%	
Wrong Units	15.1%	6.3%	*
Forgot only mole to atoms conversion	10.3%	11.9%	
Off only by some power of 10	23.0%	20.3%	
Forgot mole to atoms AND off by some power of 10	19.0%	13.3%	

Fig 6. An example of a mixed unit equation train question is shown. All questions in this category had the same form, but many dealt with different equations.

The equation for the theoretical density of a crystalline metallic solid is $\rho = \frac{nA}{V_C N_A}$, where

n = number of atoms associated with each unit cell
A = atomic weight
V_C = the volume of the unit cell
N_A = Avogadro's number

Given n = 4 atoms/unit cell of aluminum (A = 27 g/mol) with V_C = 4.42*10^-23 cm^3/unit cell, find the theoretical density in kg/m^3

Fig. 7. An example mixed unit equations question from the assessment and patters of right and wrong answers. Asterisks indicate statistical significance at p< 0.05 level.

As a part of training, students were presented with an equation as well as values for the independent variables involved, which were purposefully given in mixed units (Fig. 6). Students were then asked to calculate the dependent variable in specified "target units." Training on mixed unit equation consisted of 3 of 10 questions in Essential Skills Quiz 4. Training was somewhat successful in improving average assessment scores on mixed unit equation questions from 36% to 48% (t = 2.765, p= 0.006, d=0.34), leaving posttest scores still below 50%.

While overall scores in the mixed unit equations category showed significant improvement in student performance, two of the three individual questions in the essential skills assessment failed to do so. Scores on the diffusion flux question, increased from 40% to 46%, but this improvement was not statistically significant ($\chi^2(1)$^2 = 1.144, p = 0.285, d = 0.13). The question statement and common errors--explicitly converting to incorrect target units, forgetting the mole to atoms conversion, and erring exactly by some power of 10--are shown in Fig. 7. For this item, the only error significantly affected by training was students giving an answer in different target units than specified in the problem statement.

A similar question involving a conversion from psi to gigapascals using Hooke's law also showed no significant change in student performance ($\chi^2(1)$^2 = 2.279, p = 0.131, d = 0.18) from pre (35%) to post (44%).

The simplest question provided students with a force in newtons and an area in square millimeters, then asked for a force in kilopascals; this was the only mixed unit equation question to show significant improvement ($\chi^2(1)$^2 = 8.992, p = 0.003, d = 0.37), with correctness increasing from 35% to 53%. It is worth emphasis that this was the simplest of the three questions of this type presented in the essential skills assessment, and 47% of students are still submitting incorrect answers after training.

D. Typical Values of Material Properties

Engineers are expected to know approximate values for various material properties and other physical constants. For example, an engineer should know that melting points and Young's moduli are usually higher for metals than polymers. They should also be able to provide a rough value for a specific material that is within a reasonable range. Training on typical values contained two problem types (Fig. 8) and consisted of 4 of the 10 questions in Essential Skills Quiz #2.

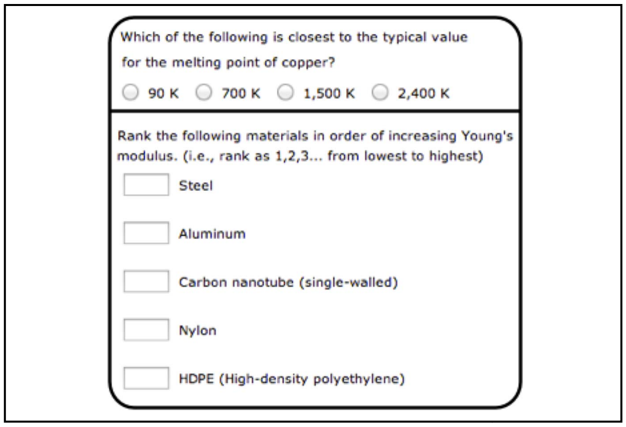

Fig 8. Typical values training questions had two categories: multiple choice (top); and ranking questions (bottom), which contained 2-5 materials to be appropriately ranked by some material property.

Training on estimates of typical values of material properties produced a range of results from significant gains to marginal losses. Cumulative student performance on questions in this category showed a nonsignificant change (t = 1.461, p = 0.145, d = 0.18) from pre (35%) to post (40%).

A series of three questions asked students to estimate the Young's modulus of three materials: copper, aluminum, and high-density polyethylene (HDPE). Since student responses to these questions spanned such a broad range, we analyze the results a number of ways. One metric was to use an "acceptable range" for the numerical answers, which was set by a course instructor (see Fig. 9). By this metric, student responses to the question on copper showed significant improvement ($\chi^2(1)$^2 = 5.377, p = 0.020, d = 0.30), with the percentage of students in the acceptable range increasing from 34% to 49%. Student estimates of the Young's modulus of aluminum showed no significant improvement ($\chi^2(1)$^2 = 0.805, p = 0.370, d = 0.11) from pre (40%) to post (45%). HDPE started and remained at 25% within the acceptable range, showing no change at all. Note that none of the posttest values are higher than 50%, despite the fact that training contained problems dealing with Young's modulus.

A second metric was to determine whether student responses were in any of four increasingly large "ballparks": within 20% of the correct answer, within 2x the correct answer, within 5x the correct answer, and within 10x the correct answer. This metric revealed a slightly more detailed picture which can be seen Fig. 10. While student performance on the copper question showed some improvement across the board, most of this came from significant increases in the larger ranges--students in the "within 10x" range increased from 48% to 75% ($\chi^2(1)$^2 = 18.531, p < 0.0001, d = 0.57). Conversely, students in the "within 20%" range did not significantly change ($\chi^2(1)$^2 = 1.988, p = 0.159, d = 0.18) from pre (9%) to post (15%). Student responses for aluminum displayed strange behavior; students in the "within 10x" range significantly increased ($\chi^2(1)$^2 = 10.349, p = 0.001, d = 0.41) from 55% to 74%, while those in the "within 20%" range actually saw a significant decrease ($\chi^2(1)$^2 = 5.395, p = 0.020, d = -0.30) from 21% to 10%. In essence, student responses settled into something resembling orbit around the correct answer. This approach yielded no significant change in student responses for the question about HDPE for all ranges.

The final metric attempts to focus more on the relative values of student responses, rather than the magnitude of the value itself. Through discussions with the course instructor, it was expected of the students that they at least give higher Young's modulus values for the metals than for the polymer. Students giving a higher value for HDPE than for aluminum decreased significantly ($\chi^2(1)$^2 = 9.280, p = 0.002, d = 0.40) from 55% to 36%; students giving a higher value for HDPE than for copper decreased significantly ($\chi^2(1)$^2 = 6.250, p = 0.012, d = 0.32) from 59% to 43%. The percentage of students incorrectly giving a higher Young's modulus for HDPE than for both aluminum and copper fell significantly ($\chi^2(1)$^2 =4.314, p = 0.038, d = 0.27) as well, from 49% to 36%. These values can be seen in Fig. 11. Despite statistical significance, it is again worth noting that posttest students still make at least one of these errors about 40% of the time.

Students were also asked to rate their confidence in their answers. Student confidence increased significantly for copper (t = 2.477, p = 0.014, d = 0.43) and HDPE (t = 2.410, p = 0.017, d = 0.43), but decreased non-significantly for aluminum (t = -1.159, p = 0.248, d = -0.20). Neither pretest nor posttest confidence rankings exceeded 2.2 out of 5 for any of

Material	Actual Value	Accepted Range
Copper	117 GPa	50 - 300 GPa
Aluminum	69 GPa	25 - 200 GPa
HDPE	800 MPa	500 MPa - 10 GPa

Fig 9. "Acceptable ranges" for the Young's modulus of materials used on the essential skills assessment, specified by the instructor.

Material & Range	Pretest	Posttest	
Copper (within 20%)	8.9%	14.8%	
Copper (within 2x)	27.7%	39.3%	
Copper (within 5x)	40.2%	68.1%	*
Copper (within 10x)	48.2%	74.8%	*
Aluminum (within 20%)	20.7%	10.2%	*
Aluminum (within 2x)	33.6%	31.4%	
Aluminum (within 5x)	43.1%	59.9%	*
Aluminum (within 10x)	55.2%	74.5%	*
HDPE (within 20%)	1.8%	0.7%	
HDPE (within 2x)	6.2%	5.9%	
HDPE (within 5x)	15.9%	17.0%	
HDPE (within 10x)	28.3%	25.9%	

Fig 10. Classification of student estimates of the Young's modulus of copper, aluminum, and high-density polyethylene (HDPE) in relation to the actual value. Asterisks indicate significant change at the p < 0.05 level, though not all of these changes were improvements.

Error	Pretest	Posttest	
HDPE > Aluminum	55.4%	36.0%	*
HDPE > Copper	59.3%	43.4%	*
HDPE > Both	49.1%	36.0%	*

Fig 11. Relative value error frequencies for typical value problems asking student to estimate Young's modulus of aluminum, copper and HDPE. As these are errors, a decrease in percentage corresponds to increasing correctness.

the three materials involved, and changes in student confidence did not match student improvement in terms of correctness.

Finally, posttest students were asked to give approximate melting points for metals, polymers, and ceramics—this question was not included in the pretest. Student responses were judged based on the correct relative order of melting points; 71% of students ordered the melting points correctly. This leaves almost 30% of posttest students unable to correctly rank typical melting points of three distinct material classes.

E. *Interview Data*

Twenty students each from pretest posttest conditions were subjected to "think-aloud" interviews as they completed the FLEX assessment. The most striking feature of these interviews was that many students not only admitted that they lacked certain knowledge and skills, but seemed content with that fact. Some excerpts from interviews are shown below:

- "Usually I look [the metric prefixes/conversions] up."
- "[Metric prefixes are] readily available on the internet and textbook."
- When asked if they felt it was important to memorize: "I feel like there's always a table for it."
- Some students described their lack of memorization of these topics as a conscious choice: "I've always been able to look them up. So, as of now, I haven't *decided* to memorize them." (Emphasis is author's)

The prevailing view for certain knowledge components seems to be something along the lines of "Why memorize it when I can always look it up?" Perhaps the whole experience is best described by one student in particular. When this student struggled on metric conversions, the proctor stated "I can answer any questions you have [about metric prefixes and conversions] once you're done." to which the student replied "Or I can just go on Wikipedia."

IV. Discussion

Computer-based, mastery-graded training on engineering "essential skills" has been effective for some knowledge, while failing to be effective other knowledge. 20-30% of students were unable to perform simple metric conversions, and neither instruction nor training was able to alter these numbers. Almost 30% of posttest students were unable to correctly rank the typical melting points of polymers, metals, and ceramics. More than 50% of students were unable to correctly operate

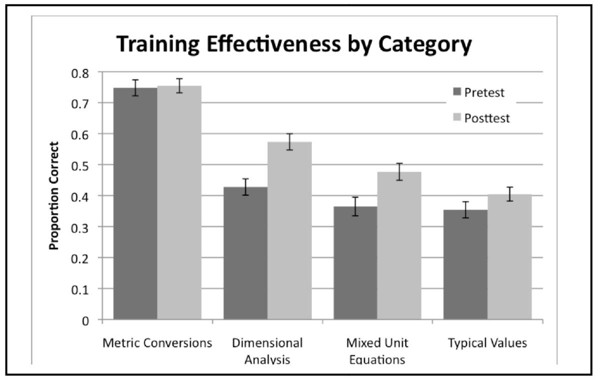

Fig 12. Training effectiveness as measured performance on the essential skills assessment, averaged by category. Only dimensional analysis and mixed unit equations showed statistically significant improvement at the $p<0.05$ level.

equations when given variables in mixed units; once again, instruction and training did little to alter these numbers. While some limited success was seen in student estimates of common material properties, 50% of posttest students were unable to estimate the Young's moduli of two metals within an instructor-specified acceptable range; a similar question involving a polymer saw 75% of students outside the acceptable range. Not only were the values incorrect, about 40% of students gave a higher Young's modulus for the polymer than for the metals.

An overview of student performance as a result of training in the four categories considered in this study can be seen in Fig. 12. Even where training was effective, as in dimensional analysis, posttest scores are still far from ceiling. The highest-performing question still saw 16% of posttest students unable to solve for the units of a given variable when given an equation and units for all other variables. As many as 25% of students leave the course not knowing that an exponential is unitless and, of the ones that do, still 25% cannot correctly solve for the units of the variable in question. Further more, 50% of student could not successfully convert a force in Newtons and an area in mm^2 to a stress in kilopascals.

Though training was more effective for some categories than for others, it was not as effective overall as necessary for such essential and fundamental skills, i.e. a posttest performance of greater than 90% correct. There are a number of possible explanations for these observations. These include:

- The training was too short (≈20 minutes for each topic).
- Posttest scores were already approaching ceiling (71% for the unit conversion).
- The students did not exert their full efforts in answering the post test questions.
- The students did not learn some of the categories because they believe that the knowledge and skills are not relevant to them.
- The students did not learn the some of the categories because they perceive the information as something not to be learned, but looked up online or in a text.

It is likely that some combination of these explanations are relevant, but as stated earlier, we have evidence from interviews that the last bullet is important for at least some of the topics. The interview data hint at an explanation for this lack of consistent success. “Or I can just go on Wikipedia.” Unlike training on log plots, the answers to which questions cannot be easily “googled,” many of the essential skills can be performed with the aide of computer tools and text references—unit conversions can be typed into the Google search bar, the metric prefixes are inside the front cover of the text, Wolfram Alpha will operate equations and perform conversions for you. Because these references are so readily available, many students do not see committing these essential skills to memory as a task worthy of their time. In the process of maximizing points earned per time spent, these tasks simply fall by the wayside. The relative success of dimensional analysis training is in line with this explanation; you can’t “google” dimensional analysis very easily, so knowledge in this category was better retained in training.

As far as students not exerting a full effort in the posttest, this is likely to play a factor, but from a number of years of experience with tests in this context, we have found that students *do* answer these questions with a reasonable amount of effort.

Note that one threat to the external validity of this study is that pre to post training gains on the test were in fact not due to the training but rather from the instruction in the course. That is, all effects reported here may be the result of a combination of training *and* course instruction, and it is not clear which (if not both) caused the gains. Therefore further research in this area would benefit from a more controlled design in order to isolate the effects of training and instruction. In any case, it is clear that, from an instructional point of view, significantly higher gains are desired.

V. INSTRUCTIONAL IMPLICATIONS AND NEXT STEPS

The results of this study offer invaluable insights into the knowledge state of undergraduate engineering students. Instructors should be aware of these fundamental deficiencies in their classrooms and should take measures to ensure students are made aware of their shortcomings as well. Simple mastery-based training has been shown to be effective with some skills; future training can use this study as a starting point or a model upon which to build. At the very least, some form of intervention—instructional or otherwise—seems necessary to prevent allowing students with such critical deficiencies to slip through the academic cracks.

The continued poor performance of students suggests that it may be useful to focus on determining with factors might help convince them of the importance of mastering these essential skills, thus motivating the students to achieve mastery. In this study, the essential skills were somewhat separate from the activities of the lecture and recitations. One way to mitigate this effect is to increase the direct involvement of the instructors, helping to create a dialogue with students as to why mastery of these skills is important.

Another possible approach to further improving mastery and fluency is to progressively limit the time allowed for the Essential Skills Quizzes, particularly those containing knowledge that can easily be looked up online. This will help compel students to internalize and automate the essential skills and related knowledge.

Finally, this study suggests that instructors should consider two practical categories of essential skills and knowledge. The first is the category of skills and knowledge that lend themselves well to short, spaced training. The second category is comprised of simple knowledge or skills that one can quickly access via other resources such as the internet. This study suggests that the latter category seems to be resistant to brief training, as students often recognize easier methods for success in place of committing the skills to memory. In this second case, the relevant instructional goal would be to improve students’ mastery in efficiently accessing this information.

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Student accuracy in reading logarithmic plots: the problem and how to fix it

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***Abstract*— Through extensive student testing and interviews, we found that the majority of university sophomore, junior, and senior engineering students in a standard introductory materials science engineering course have a variety of difficulties reading correct values from simple logarithmic graphs. For example, students often unknowingly interpreted the log scale as linear and were confused about the order of magnitude of a value in the negative exponent region. To address these issues, we used the results of our findings to develop and implement a set of online "essential skills" tasks to help students achieve a core level of mastery and fluency in reading log plots, a basic and critical skill for engineers. The online tasks were administered as for-credit homework assigned several times throughout the semester, and students spent 10-20 minutes on each assignment. Results of post-tests indicate that with this minimal practice, students were able to dramatically improve their accuracy in reading log plots compared to a control group with no log plot practice. Furthermore, testing one month after training demonstrated that student continued to retain the learned skill. Future development will focus on making these essentials skills task broadly available online and further improving effectiveness and usability.**

Keywords—logarithmic graphs; problem solving skills ; graph interpretation; online homework

I. INTRODUCTION

While complex problem solving skills are critical for engineers to learn and are thus the focus of considerable research and instructional efforts, it is also the case that more simple, elementary skills, are also necessary for solving problems. These simple yet "essential skills" may be fairly straightforward to learn through deliberate practice, but, often to the surprise or chagrin of the instructor, students typically do not have these skills or they are far from fluent in their use. In this study, we investigate the essential skill of reading logarithmic plots. We demonstrate and describe the significant difficulties that most junior and senior level students have with reading simple log plots, and we demonstrate a method to help students achieve and retain significant gains in mastery with a relatively small commitment of time.

II. PARTICIPANTS AND METHODS

The participants in this study were enrolled in an introductory materials science course for engineers, which is a required core course for many of the engineering major programs at Ohio State University, a large public research university. The students ranged from 2nd to 5th-year engineering students. About 10-15% of the students intended on becoming materials science engineering majors, and about 35% of the students were mechanical engineering majors, the most common major in the course.

Data was collected over a period of 5 quarters, for a total of approximately 600 participants. The data was collected in three ways. First, we administered free response and multiple choice tests. In addition to the standard homework, students were given a "flexible homework" assignment with credit for participation as part of the course grade. The flexible homework assignment consisted of participation in a one-hour session where students completed some combination of testing and interviewing. Throughout the quarter, students were randomly selected to participate in the flexible homework. Typically, about 95% of all enrolled students participated in the flexible homework. The tests items were in either multiple-choice, free-response, or a multiple-choice-with-explanation format. Students completed the material at their own pace at individual stations in a quiet room. Afterwards we would informally ask students to explain their answers and they were also asked whether they had any questions. We observed during these sessions that students made a good faith effort to answer the questions to the best of their ability.

Second, we conducted individual or group interviews with over 50 students. These interviews consisted of asking students to verbally answer questions and provide their reasoning on simple log plot questions. Several dozen interviews were videotaped, and the rest were recorded via interview notes. The interviews were used to gain more insight into student difficulties that were discovered in the written tests. Most interviews were conducted individually, but some were given in groups of 3 or 4.

Finally, the third method for collecting data was via the official online homework assignments administered as part of the course.

Tests and interviews were administered either before or after relevant instruction. Different conditions were constructed in order to obtain pre-post test data needed to assess the effectiveness of the instructional intervention.

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The difficulties reported here were found in both written tests and interviews. Thus incorrect answers to the questions should not be viewed as uninteresting artifacts of the particular questions, but rather indicative of authentic student difficulties with understanding and interpreting logarithmic plots.

III. STUDENT DIFFICULTIES WITH LOG PLOTS

Perhaps surprisingly, we could find no research documenting student difficulties with reading log plots, though there are studies documenting student difficulties with understanding logarithm functions [1], and logarithmic functions in the context of pH [2,3].

In the course of testing and interviews we identified a number of specific difficulties, described below. Note that for results reported in this section, testing was administered near the end of the course, and as such the reported student difficulties should be considered post traditional instruction.

A. *Determining Values when Minor Tick Marks are Absent*

When minor tick marks between orders of magnitude are absent on a graph, most students interpret the scale between the orders of magnitude as linear. To demonstrate this, we randomly assigned students into one of two conditions. In the first condition, 107 students were given a numerical value and asked to provide a mark were this value is represented on a line that has orders of ten (major tick marks) indicated on a logarithmic scale. In the second condition, a mark was provided on the scale, and 106 students were asked to determine the value. For example, as seen in Figures 1 and 2, students were either asked to determine the value of the position approximately half-way between 10^8 and 10^9, or they were given the value of 3.0×10^8 and asked to mark that value on the graph.

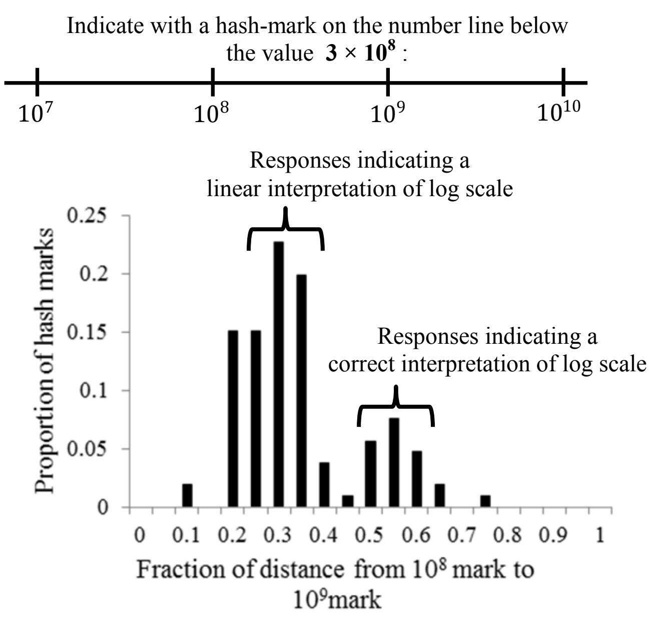


Fig.1 Provide-mark question with minor tick marks absent. Majority of student responses indicated a linear interpretation of log scale.

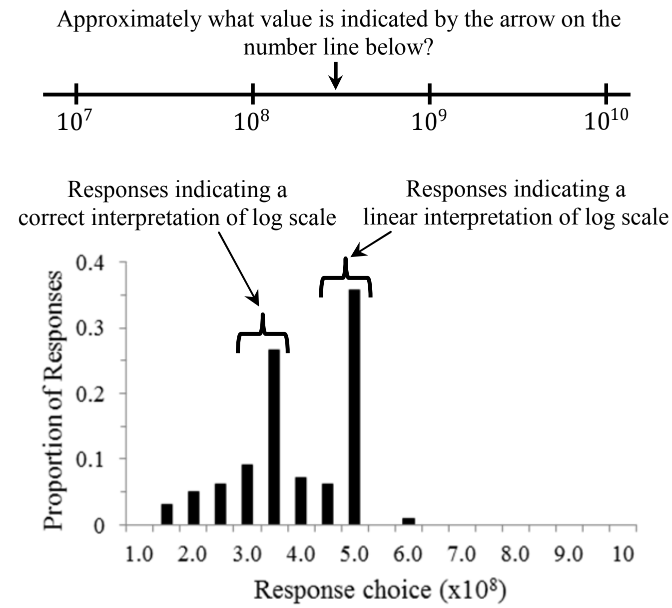


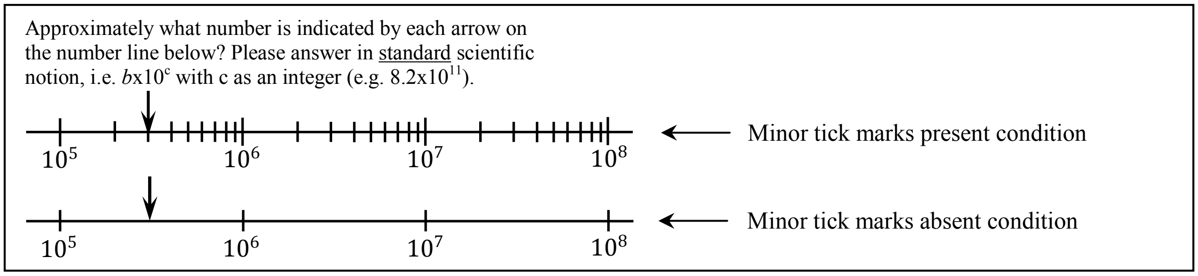
Fig 2. Determine-the-value question with minor tick marks absent. Almost half of student responses indicated a linear interpretation of log scale.

The results indicate that in both conditions, the majority of students interpreted the scale between the major tick marks as linear. For example, in the provide-mark condition in Figure 1, 57% of students indicated that 3.0×10^8 was one-third of the way between 10^8 and 10^9, clearly a linear interpretation. In the determine-value condition in Figure 2, 49% of students indicated that the arrow (placed at the 3.0×10^8 position, which is a little less than halfway between 10^8 and 10^9 on the graph), indicated a value between 4.0×10^8 and 5.0×10^8. This is also a clear indication of a linear interpretation, and post- interviews with students verified this interpretation for both conditions.

B. *Confusion of Values of Minor Tick Marks*

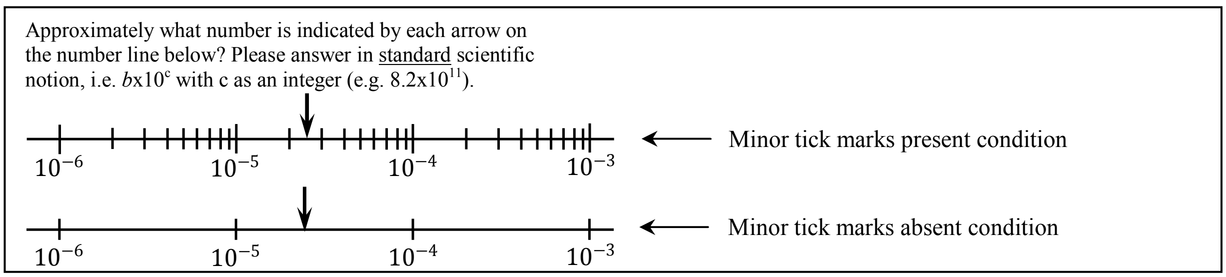
When minor tick marks are provided between the order of magnitude major tick marks, many students misinterpret the value to the hash marks, counting the first mark as "1" instead of "2" and so on. Also, to our surprise, even with minor tick marks present, some students still interpret the logarithmic scale as linear. To demonstrate this, we randomly assigned students to either a minor tick-mark present condition or a minor tick marks absent condition. As shown in Figure 3, students were provided with a graph with mark at the same position for both conditions, the only difference being that one graph had minor tick marks provided and the other did not.

The results indicate that student perform poorly in both conditions, but more students answer correctly when tick marks are provided (41%) compared to when they are not (21%) ($\chi(1)= 6.3$, $p = 0.01$) . The majority of the errors for the tick mark present condition are in misinterpreting the values of the tick marks (15%), and surprisingly interpreting the scale as linear, apparently ignoring the minor tick marks (20%). Note also, that a small number of students made an error on the order of magnitude, this error will appear more frequently in another context discussed in the next subsection. For the tick mark absent condition, the majority of errors resulted from



	Responses						
	1.5×10^5	2.0×10^5	3.0×10^5	5.0×10^5	3.0×10^6	5.0×10^6	Other
Minor tick marks provided (N = 74)	3%	15%	**41%**	20%	3%	4%	15%
No minor tick marks provided (N = 67)	4%	4%	**21%**	58%	0%	6%	10%
Comments		Tick mark error	**Correct**	Linear scale error	Order of mag error	Order of mag error + linear scale error	

Fig 3. Example of question with minor tick marks present or absent (with positive exponents), including a table of student responses from each question type.



	Responses							
	$1.4\text{-}1.6\times10^{-5}$	$2.0\text{-}2.5\times10^{-5}$	$4.0\text{-}6.0\times10^{-5}$	$1.0\text{-}2.5\times10^{-4}$	$4.0\text{-}5.0\times10^{-4}$	$6.0\text{-}6.5\times10^{-4}$	$7.0\text{-}8.5\times10^{-4}$	Other
Minor tick marks provided (N=73)	10%	**30%**	10%	14%	5%	4%	16%	11%
No minor tick marks provided (N=69)	3%	**13%**	35%	4%	19%	10%	3%	13%
Comments	Tick mark error	**Correct**	Linear scale error	Order of mag eror	Order of mag error + linear scale error	Order of mag error + reverse scale error		

Fig 4. Example of question with minor tick marks present or absent (with negative exponents), including a table of student responses from each question type.

interpreting the scale as linear, which is a replication of results from the experiment in the previous subsection.

C. Determining Values in the Negative Exponent Region

When logarithmic graphs represent regions of negative exponents, additional difficulties of determining the correct order of magnitude, and determining the correct direction of the scale are introduced, further decreasing student performance. This was demonstrated by assigning students to either a tick mark present or absent condition, similar to the previous experiment, only in this experiment, the graphs represent negative exponent regions. For example, students where shown graphs with a mark between 10^{-5} and 10^{-4} indicating the value of 2.3×10^{-5}, and student were asked to determine this value from the graph (see Figure 4).

The results shown in Figure 4 suggest that the performance on this task is even worse than the performance on positive exponent graphs with only 30% of students answering correctly in the tick mark present condition, and only 13% of students in the tick mark absent condition answering correctly. The low scores are a result of an additional error in the interpretation of the order of magnitude. Students were often confused, for example which side of the 10^{-4} major tick mark (i.e., to the right or left side) represents the order of magnitude of 10^{-4}. In addition, student often made what we labeled in Figure 4 as the "reverse scale error", meaning that students would "count down" (leftward) from the higher order of magnitude and use the fraction of distance as the value. For example in figure 4, students would note that the arrow is about 3/4 away from (to the left of) the 10^{-4} mark toward 10^{-5}, so they would reason that the value should be 7.5×10^{-4}. Post interviews with students verified our interpretations of the errors and correct responses.

D. Determining Values on 2-d Graphs

Up to this point, we have only discussed student interpretations of one dimensional logarithmic plots. However, in practice we are more interested in student performance on two dimensional logarithmic plots (i.e. log-log or log-linear plots), which are commonly found in materials science text books. For two dimensional plots, we found that student performance is still poor, and the mistakes they make are the same as those found in one dimensional plots. To demonstrate this, we provided 206 students with a log-log plot with a line on it, gave them the value on one axis and asked them to read off the value on the other axis. For example in figure 5, we present a stress vs. creep rate log-log graph, and ask the students to determine the creep rate for a given stress.

The results, shown in Figure 5, indicate that 41% of students answered within the accepted range, however, some of these responses may be false positives, since the accepted range includes one of the possible tick mark errors. The Figure also indicates that many students make the order of magnitude error and the minor tick mark error, though interestingly there was no evidence of the linear interpretation error, though this could be due to the specific values, which in this case do not lend themselves to a clear signal of a linear interpretation error because the values are not near the middle of the scale.

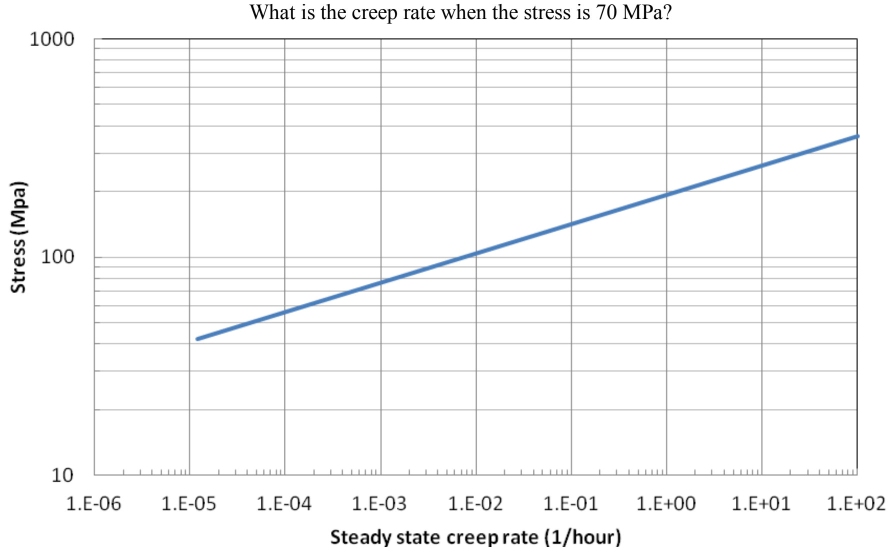
IV. ADDRESSING STUDENT DIFFICULTIES: ESSENTIAL SKILLS PRACTICE ASSIGNMENTS

The results of the last section not only clearly demonstrate that even junior and senior level engineering students have difficulty reading values off of simple logarithmic plots, but the details of the difficulties allow us to design practice tasks to help them improve on specific common errors and become proficient in the essential skill of reading logarithmic plots.

To this end, we designed a set of training tasks to improve student performance on reading logarithmic plots. The rationale is based on the general finding that experts have mastered a set of basic skills and knowledge to the extent that they are fluent or automatic in their use [4]. The central idea is that if necessary and frequently called processes are automated, this will place less demand on attention and other cognitive processes, allowing for efficient and effective problem solving (e.g., reference [5]). In this case, we are interested in improving fluency in reading logarithmic plots so that student may devote resources to solving more important engineering problems.

The strategy used in this proposal to improve mastery and fluency is based on numerous studies demonstrating that testing with feedback can be an effective method for learning [6,7]. In order to further improve the learning and retention, the practice will also be spaced on the order of weeks, following the evidence of the advantages of spaced practice (e.g., reference [8]).

The figure below presents a stress vs. steady state creep rate graph for a steel alloy at 925°C.
What is the creep rate when the stress is 70 MPa?



Responses (N=206)					
< 1.0×10^{-4}	1.0-3.5 $\times10^{-4}$	4.0-8.0 $\times10^{-4}$	1.0-1.5 $\times10^{-3}$	4.0-8.0 $\times10^{-3}$	Other
3%	15%	**41%**	12%	21%	7%
Order of mag error	Order of mag error + tick mark error	**Correct (potential tick mark error)**	Tick mark error	Order of mag error	

Fig 5. Example of 2-dimensional graph question, including table of student responses.

We employed practical logistical constraints on the training, namely that the training would be administered via an automated online system as for-credit homework, and the training, integrated over the course, would require only a relatively small time commitment by the student, on the order of one hour, since this is an additional task assigned in the course.

The training consisted of four assignments spaced throughout the semester, and each assignment took 15 minutes to complete on average. The assignments consisted of sets of ten questions drawn randomly from a pool of questions, taking care to ensure that each set receives a diversity of question types. To receive credit for the assignment, students were required to continue to complete sets until they correctly answered at least 80% of the questions in a set. If they did not reach this level on a given set, they were provided with the answers to the set they failed, then given another set of ten questions This follows a "mastery" model of training, namely that students must practice until they have reached some minimum level of proficiency.

The training consisted of a combination of questions that were aimed at improving the common student errors, including linear interpretation of a log plot, minor tick mark error, order of magnitude error and the reverse scale error. Log plots in one and two dimensions were given, as well as plots with positive or negative exponent regions. This included typical plots that one would find in the text book. These the training items were very similar to the questions presented in Figures 1-5, with variations in numbers, scales etc.

V. Assessment and Results

In order to assess the effectiveness of the essential skills practice tasks, we randomly assigned students to one of three conditions: 47 students to control (no practice), 44 to train and delayed test (practice for 4 weeks early in the quarter), and 53 to train and no-delay test (practice for 4 weeks late in the quarter). Afterwards, all conditions were given a 10 item log plot test, which consisted of a combination of one and two dimension graphs, graphs with positive and negative exponents, and graphs in which minor tick mark values are critical. The items were similar in content to the training questions given in the homework assignment. During the construction of the log plot test, we conducted think-aloud and post student interviews for each items and made adjustments to the items as necessary in order to improve the validity of each item. Two training conditions were used in order to compare student performance shortly after the training (~ few days) vs. 4 weeks after the training. That is, the second condition had a delay of 4 weeks between the last practice and the test, and the third condition had "no-delay" (i.e. only a few days) between the last practice and the test. Note that, to be fair to all students, log plot training was given to the control group after the log plot test and before the final course exam.

The results, shown in Figure 6, indicate that both the log plot training resulted in significant gains in student performance on log plot questions. Specifically, the averages for the train and delay and train and no-delay test were approximately 75% correct on a post test, compared to control, which had an average score of 39% correct ($t(142)=7.1$, $p<0.001$). This gain in score was relatively uniform across all

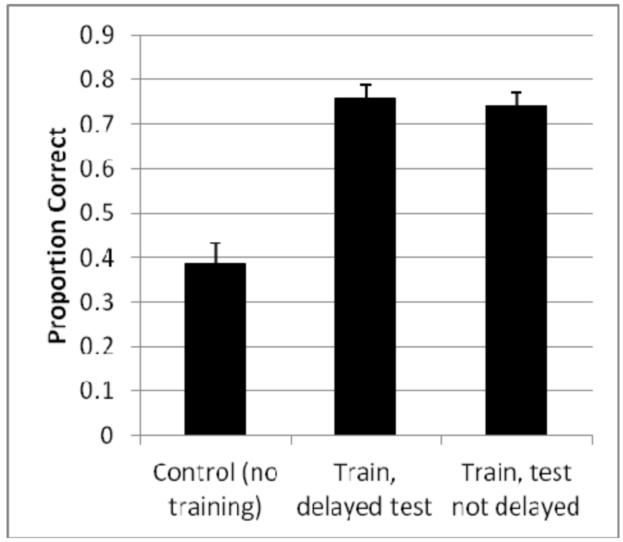


Fig 6. Average scores on log plot test for the control and two training conditions. Results indicate a significant gain (d=1.4) from training.

question types in the assessment, though the poorest performance remained in reading plots with negative exponents (about 70% after training).

In terms of effect size, either training resulted in a large increase in score of approximately d = 1.4 standard deviations. Furthermore, the final score for both the delay and no-delay testing training conditions was the same, thus there was no loss of performance even 4 weeks after the assignment, indicating that the students retained what they learned for at least one month after training.

VI. Conclusion

We found that sophomore, junior, and senior level engineering students had significant difficulties reading off values from simple log plots. Their poor performance (around 30-40% correct) resulted from a number of difficulties including interpreting log scales as linear, confusion on how to interpret negative exponent regions, and confusion of the values of minor tick marks.

Based on these findings we constructed brief practice assignments for the students, and found that with less than an hour of practice, spaced in several sessions over the semester, students could dramatically increase their performance, and they retained this knowledge even one month after training. However, it should be noted that the average post-training performance was still only at the 80% level, and since this is such a basic skill, we would like to continue with further improvement of the practice tasks in order to increase this to above 90% accuracy.

Nonetheless, since the skill of reading log plots is both a critical skill and a skill assumed to be mastered, it would appear that assigning students this automated online "essential skill" homework task is a useful and effective course of action requiring a relatively small amount of effort on the part of the student and the instructor.

ACKNOWLEDGMENT

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Inquiry-based Learning Environment Using Intelligent Tutoring System

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***Abstract*—The present study aims to discuss the development of a collaborative inquiry-based learning environment with the support of an intelligent tutoring system for general education. Following an inquiry-based learning approach, the learner-centered activities involve students making questions about a given theme based on a subject proposed by teachers. Here the collaborative nature of interaction is seen as a fertile space for learning since it enables the mobilization, interpretation and coordination of contributions to achieve a common goal. Students may require instruction and feedback to help them exploit the learning environment to its full potential. To provide the necessary assistance, an intelligent tutoring system is proposed. Intelligent tutoring systems are computer programs capable of providing immediate and customized instruction or feedback to students, without the need of human intervention. In our proposal, a text mining tool provides key concepts about the interaction of the student within the environment. This information can be used by a recommender system, which searches for related material in the Internet and in other specific learning repositories. The relevance of the learning environment proposed here lies on its capacity to give assistance through a recommender system, promoting a richer interactive learning.**

I. Introduction

Reports from PISA (Program for International Student Assessment) have been indicating the deficiency of students in many countries regarding language and digital literacy. Despite the fact that a lot of investments have been made in computer laboratories in schools and other educational settings, technology's full potential as a collaborative learning tool tends to be undermined by traditional teacher-centered approaches.

Current studies indicate the importance of promoting creative, reflective and autonomous use of technology and language, by proposing tasks that challenge students to adapt and transform knowledge towards their learning goals [1], [2], [3]. As Benson [4] claims, autonomy is the ability of individuals to control their own learning. The author adds that such capability is the result of a constant process of construction and redevelopment of knowledge based on the evaluation of previous decision-making in problem solving.

An active positioning of students towards their learning process derives from their own interests [5]. Therefore, critical thinking, autonomy and collaborative skills can be promoted by learning that emerges from students' questioning, which is supported by social interaction [6]. According to Kim et. al. [7], further research is needed in order to establish a relationship between intersubjectivity, collaborative interaction, media choice as an expression of meaning, critical thinking and problem-solving strategies.

Based on this educational scenario, this paper aims to present a collaborative inquiry-based learning environment with the support of a tutoring system for general education to improve students' language and digital literacy proficiency. This interactive virtual environment is intended to foster autonomy, critical thinking and collaborative skills.

II. The project

This section describes the main features of the environment and the theory used to support it. In Section II-A is described *inquiry-based learning*, the learning theory in which we support our environment. Section II-B describes *intelligent tutoring system*, which, alongside with *text mining* (Section II-C), produce the means for the environment to interact with the users (both teachers and students).

A. Inquiry-based learning environment

Inquiry-based learning is defined as a learning approach guided by the process of making questions by learners themselves [8]. The research presented here focuses on the expansion of the SMILE Project (Stanford Mobile Inquiry Based Learning Environment), whose goal is to allow students to create and share questions and answers related to a given subject [7]. In our project, students are requested to make questions about a given theme based on a triggering text proposed by teachers, as a way to lead them to develop their own investigations about a given topic.

After reading the triggering text, the students are asked to create their own questions. These questions are shared among students who are challenged to reflect about the topics proposed by interacting with their classmates. To help students create more elaborate questions, this web-based environment is integrated to a recommender system that suggests additional material according to the main concepts extracted from the triggering text. When a student posts a question, the system uses a text mining tool to extract relevant terms from the student's writings and the triggering text, as a way to identify keywords. Then, these keywords are sent to a web search engine that returns different contents such as texts, documents,

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images and videos. These contents are subsequently filtered and presented to the students as recommendations that may assist them in broadening or deepening their investigations.

B. Intelligent Tutoring System

The learning environment proposed uses an intelligent tutoring system in the form of a pedagogical agent, who assists students based on their performance on the quiz, indicating complimentary learning materials and correcting syntactic and semantic mistakes. Pedagogical agents are human-like virtual characters used in interactive learning systems that can search and interpret information to support learners' activities through a more natural interaction. The pedagogical agent can adapt its interventions to provide appropriate feedback, based on the analysis of the students' actions [9], [10], [11]. It can promote learning by modeling, scaffolding and guiding students' actions, facilitating students' use of multimedia content, motivating learners to participate in a virtual learning community. Gulz [12] emphasizes that pedagogical agents may increase students' motivation and improve their perception of ease and comfort in using a learning environment.

Research on pedagogical agents in educational applications has demonstrated that, by simulating social interaction, these animated characters may improve student's engagement and learning experience [13]. Here, we consider the pedagogical agent's role as a tutor [14] that helps students to notice and correct errors by suggesting complimentary study material. Thus, high order thinking processes are fostered through the interaction of the agent with the student in cognitive and social spaces [6], [15], [16]. Besides language literacy, this new learning environment promotes digital fluency skills since it requires a creative and active use of technology to produce and transform knowledge [1]. The system's main contribution to education lies on its capacity to provide relevant assistance through a pedagogical agent who can promote knowledge construction through a more interactive learning environment.

C. Text mining

Text mining is a research area that has as a main goal to retrieve relevant information from texts. Such information can be retrieved through the identification of patterns in non-structured data [17], thus separating text mining from data mining, which is mostly based on the search for patterns in structured data bases. The recommender system and pedagogical agent's actions rely on the use of a text mining tool to identify concepts the students use in their writings. In this project, a text mining tool called Sobek [18] is employed.

The mining process starts with a statistical approach that identifies the most frequent concepts. A concept may be one or several words, if the combining words represent a single concept (e.g. "global warming" or "United States"). After this, the connection between those concepts is set using the proximity between them and the frequency with which they are related. The final result is a collection of concepts and relationships that is represented internally in the form of a graph. The process is similar to the one proposed by Schenker [19].

This mining tool has already been used in the development of a system to assist teachers to evaluate students' contributions in discussion forums [20]. Another recent application has discussed the use of a pedagogical agent to mediate collaborative chats in English as a foreign language [21]. Here we propose the integration of the mining tool with the collaborative inquiry-based learning environment to inform the recommender system and the pedagogical agent with the concepts extracted from the students' writings and the texts provided by the teacher. The agent uses these concepts to help students focus on their writings. By keeping track of students' activity in the learning environment, the agent also recommends students with peers that have obtained a high score in the activities developed in the course.

III. THE TUTOR-USER INTERACTION

The agent-student interaction occurs in different moments in the learning environment. Initially, the agent introduces itself to the student, presenting the ways they may interact and how it can help him. After that, the system (through the use of text mining) provides the agent with information regarding the main concepts in the questions being introduced by the student. This information is used to search for complementary material that may help the student to find appropriate answers. Besides, the agent may help the students to improve their writing skills by answering questions regarding vocabulary, and by instigating them to reflect and write about relevant topics they still have not considered in their texts.

At the end of an interactive session with the agent, the system sends a feedback message to the teacher reporting problems faced by the student: spelling mistakes, difficulty in answering his/her own questions or in focusing on the topics proposed.

IV. IMPLEMENTATION

The virtual learning environment proposed here is under implementation to be distributed in the future as open source code. In order to use the system, one must install it on a server, which can be later accessed by users through the web. This server presents features to include all necessary components and classes, making it easy to create new classes and tasks, as well as serving as a database for all questions created. In that way, all the work done by one group of students may be viewed and used by other students, fostering the creation of a collaborative community.

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Explaining Semiconductor Device Physics with a Fusion of Lectures and Videos

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Abstract - **Concepts that describe the operation of semiconductor devices tend to be some of the most difficult for students to grasp. Hands-on experimentation can be used to demonstrate the concepts discussed in lectures or course readings and to stimulate student interest through visual applications of the concepts. However, such activities can be impractical to integrate into the classroom. Thus, multimedia tutorials have been developed on some of the concepts to support student learning and to address why a solid foundation in semiconductor device physics is critical to their development as electrical or computer engineers. Each tutorial includes a review of the theory that is demonstrated in the experiment, which is then presented. Reinforcement of their learning occurs immediately in the form of a brief video from an expert (not necessarily the course instructor) with his or her explanation. Assessment on student learning has been initiated using an assessment tool developed to evaluate hands-on learning at Georgia Tech.**

Index Terms – Semiconductors, Device physics, Video tutorials.

INTRODUCTION

Concepts that describe the operation of semiconductor devices tend to be some of the most difficult for students to grasp. The idea that a hole moves through the semiconductor can stump some of the best abstract thinkers in the classroom. The equations to calculate the intrinsic carrier concentration and the contribution of drift and diffusion currents to the total current are some of most complex that the second semester electrical and computer engineering (ECE) sophomores have had to apply by that point in their academic careers. There are additional barriers to learning this material. First issue is that many ECE students question why they need to know the material. Semiconductor device physics has not be presented as an ECE discipline when they visited campus as high school students or during their exposure to ECE during freshman year. At Virginia Tech, the multidisciplinary nature of the field is no longer supported by a year-long chemistry sequence and a one-semester material science course; both were eliminated during a curriculum revision more than a decade ago. Unfortunately, engaging students in hands-on activities that demonstrate the concepts discussed in lectures or course readings and that stimulate their interest through visual applications of the concepts has proven to be impractical, even for some of the simplest experiments, because of resource limitations. Educators have developed Java applets [1] and MATLAB programs [2-5] to provide visual demonstration of semiconductor concepts to promote student learning. However, many of these learning materials do not include a link between the concept and the physical devices and circuits. Thus, video tutorials have been created that show students the operation of real devices and circuits, and describe how the equations from semiconductor device physics influence specific behavior, and how students can calculate the physical constants from measurements collected from the devices and circuits.

PEDAGOGICAL APPROACH

The video tutorials combine PowerPoint slides, still images, and videos that have been recorded with the assistance of Virginia Tech Video Broadcast Services (VBS). A formal process, guided by Gagne's hierarchical theory of instruction [6], has been used to organize the presentation of learning materials for each topic. The PowerPoint slides are used to introduce the students to the learning objectives of the multimedia tutorial and provide guided learning by presenting or reviewing the abstract concepts that will be applied when the students are asked to explain the reasons for the behavior observed during the experiments. Audio tracks for the multimedia presentations are recorded using Audacity and Adobe Presenter. The video content are recorded experiments as well as clips on how the materials and devices used in the experiments were fabricated in the Virginia Tech cleanroom and how the experimental setups were assembled. Some of the tutorials are viewed during class with open discussions afterwards to connect the conclusions about the experiment to theory. When the tutorials are assigned, brief quizzes have been designed to encourage students to view the tutorials and to prompt students for their explanations and conclusions drawn from the multimedia material. Reinforcement of their learning occurs immediately in the form of a brief video from an expert (not necessarily the course instructor) with his or her explanation. The topics covered in the videos that have been developed thus far are listed in Table I as well as the ones

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that will be addressed in videos that will be made during the fall semester.

Table 1. Topics of Videos

Topic	Status
Parameter extraction from diode I-V characteristic	Completed
Half-wave rectifier	Completed
Full-wave rectifier with transformer	Completed
Full-wave rectifier bridge	Completed
Diode logic circuits (AND and OR gates)	Completed
Parameter extraction from MOSFET I-V characteristic	Planned
Parameter extraction from BJT I-V characteristic	Planned
NMOS, PMOS, and CMOS inverter	Planned
TTL inverter	Planned

While it would be preferable to have the students perform the experiments in class, the surface area and flatness of student desks and the number and distribution of power outlets available in several classrooms do not support in-class hands-on activities. Whenever possible, the circuits are constructed from components that are available in the parts kits that are distributed to all electrical and computer engineering students in the department. Most of the measurements are performed using the same model digital multimeter and the USB powered oscilloscopes that the students purchase during their first semester circuits laboratory course. Thus, the students are able to repeat the experiments shown in the video tutorials.

CONCEPTS FROM SEMICONDUCTOR DEVICE PHYSICS

It is important for students to have a good grasp of the ideal diode equation to understand the operation of diodes and bipolar junction transistors, as explained using the Eber-Moll equations, and the origin of certain leakage currents in these devices as well as in field-effect transistors. The relationship between the concentration of acceptors and donors on the drift current across a p-n junction influences the magnitude of the reverse saturation current. The intrinsic carrier concentration of the semiconductor also affects the magnitude of the reverse saturation current. The basis for the piecewise model of a diode is also critical to understand. The donor, acceptor, and intrinsic carrier concentrations influence the built-in voltage and the series resistance of the diode, which determine the values of the parameters in piecewise model of the forward-biased model.

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EXAMPLE TUTORIALS

Several tutorials have been developed on the ideal diode equation, the piecewise model of the diode, and that describe the operation of the diode in a full-wave bridge rectifier. As part of the first two tutorials, the current-voltage (I-V) characteristic of a light-emitting diode is plotted after measurements of the resistance of resistor R (nominally, 10 kΩ) and the measurement of the voltage drops across the resistor and diode as the input voltage is swept from 0 V to 5 V are made on circuit shown schematically in Fig.1.

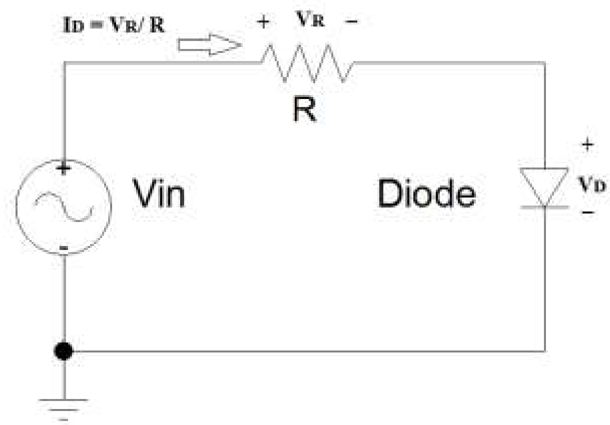

Fig. 1. Schematic diagram of the circuit used to measure the diode voltage and diode current as Vin is swept from 0 V to 5 V.

In the tutorial on the ideal diode equation, the PowerPoint slides that precede the video of the measurements on the circuit describe the drift and diffusion currents that flow across a p-n junction as a function of diode voltage. Following the video of the measurement, the analysis of the data to determine the reverse saturation current, I_S, and the ideality factor, n, is presented (see Fig. 2). In the second tutorial, an explanation about the turn-on voltage and the series resistance of the diode is given with a discussion on why the internal resistance of the diode causes the I-V characteristic to deviate from the ideal diode equation. The same I-V plots that were generated for the tutorial on the ideal diode equation are used to calculate the turn-on voltage, V_J, and series resistance of the diode, R_S

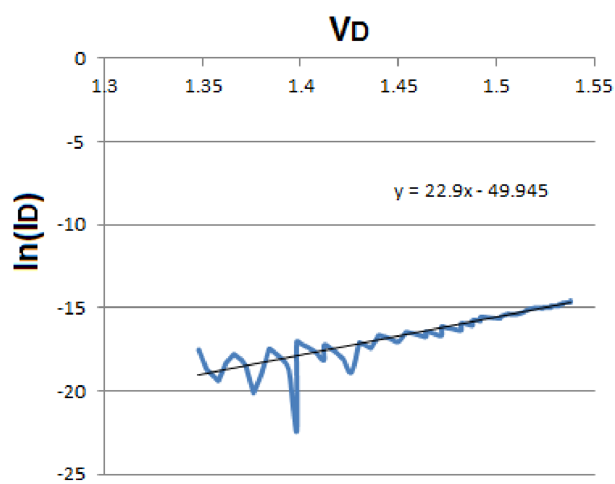

Fig. 2. Plot of the natural log of the diode current vs. diode voltage where the slope of the line is equal to q/(nkT) and the y-intercept is equal to the reverse saturation current I_S.

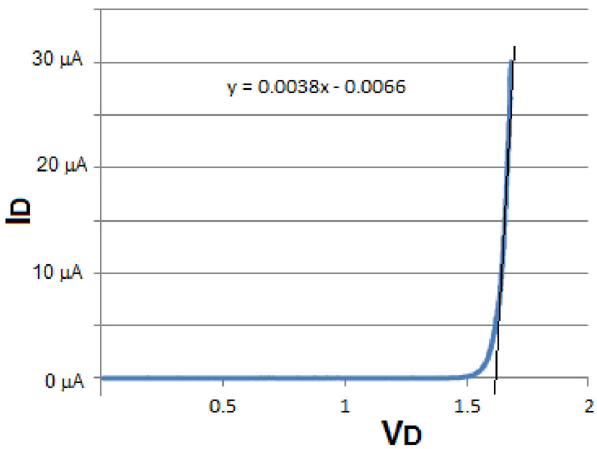

Fig. 3. Plot of the diode current vs. diode voltage. The slope is equal to $1/R_S$ and the x-intercept is equal to V_J.

(see Fig. 3) and a piecewise model using these parameters is constructed for the diode, demonstrating the connection between the ideal diode equation and the piecewise model of the diode. In addition to the tutorials, an Excel spreadsheet containing the data used to calculate the diode parameters is made available to the students. Students are asked to consider how changes in the acceptor and donor concentration and in the material used to fabricate the diode will affect the I-V characteristics and diode parameters.

Typically, full-wave bridge rectifiers are analyzed using the piecewise models of a diode. However, as the magnitude of the load resistor is increased, the operation of the diode is more appropriately modeled using a combination of the piecewise models and the ideal diode equation. In Fig. 4a, the load resistor is small, 270 Ω; while in Fig. 4b, the load resistor is 270 kΩ. The ranges of diode voltages where the ideal diode and the piecewise models should be applied can be determined by a review of the range of voltages used to determine the parameters in the ideal diode equation and the diode voltages used to calculate the turn-on voltage and series resistance.

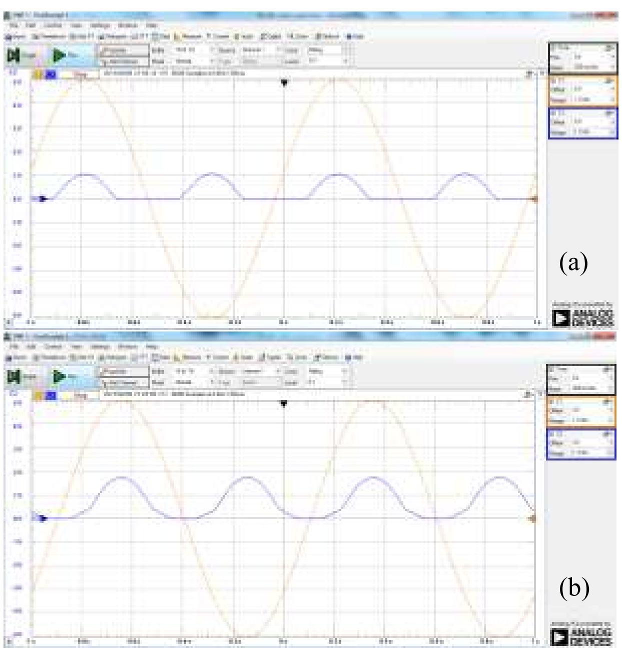

Fig. 4. Plot of the voltage across the load resistor in a full-wave bridge rectifier where the value of the load resistor is (a) 270 Ω and (b) 270 kΩ..

The explanation about the regions where the ideal diode equation and the piecewise model of the diode should be applied is reinforced by overlaying the measured voltage on top of the voltages across the load resistor as calculated using the ideal diode equation and the piecewise model. The measurements are imported into MATLAB using the Data Acquisition Toolbox Support Package, which is integrated as an application in MATLAB R2013 [7]. The students can then see how well each of the approximations predicts the performance of the diode in the circuit.

CONCLUSION

The video tutorials were introduced in the Spring 2013 academic year to support the instruction on semiconductor device physics. The analysis of the initial assessment results is on-going. A longitudinal study on the students' retention of the fundamental concepts in semiconductor device physics that are reinforced by the video tutorials as compared to those concepts that are not presented in one of the video tutorial are planned.

ACKNOWLEDGEMENTS

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Development of a Concept Inventory for Microelectronics Courses

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***Abstract*—This paper describes our initial attempts at developing a concept inventory for a microelectronics course. The methodology for selecting the core concepts to be tested and the development of the questions are described. Results of the assessment data indicate some areas where student conceptual understanding is weak. The proposed method to improve the concept inventory is also detailed.**

***Keywords*—Concept inventory, microelectronics, nanotechnology**

I. Introduction

Rapid advances in the microelectronics industry, including the scaling of electronic devices to nanometer-scale geometries and the development of radical new nanotechnology-based devices, mandate that curriculum revisions be continually made in electronics and integrated circuit (IC) design courses. These revisions, encompassing the enhancement of existing courses in IC design and the development of new ones in nanoelectronics, are necessary to ensure that graduates from electrical engineering programs are well-prepared to design and innovate in an increasingly nanotechnology-based world. As new material and pedagogies are introduced into microelectronics courses, it is essential to have an accurate assessment of student understanding of the core concepts in this discipline. This paper describes the initial development of a concept inventory (CI) targeted at microelectronics courses with introductory nanoelectronics content. A CI allows an assessment of the conceptual understanding of the students with regard to a specified body of knowledge, typically the core content for a targeted course. Hence, a CI is an invaluable diagnostic instrument for uncovering student misconceptions about the course material and for planning improvements in the curriculum to remove these misconceptions. An effective means of curriculum assessment will combine the results of a CI test with other assessment data obtained from student interviews, self-assessment surveys, and faculty observations [1].

The Force Concept Inventory (FCI), developed by David Hestenes and his colleagues to assess student conceptual understanding in a freshman physics course, was the first prominent use of CIs in the STEM fields [2]. The results provided the motivation for curriculum innovations involving interactive engagement activities in the classroom [3]. In the past decade, CIs have been developed for several disciplines, including biology, chemistry, and geosciences [1]. Some CIs have been introduced recently for core courses in the electrical engineering curriculum, including electronics, digital systems, and signal processing courses [4-6]. However, most CIs target lower-level courses, with few developed for upper-division courses. Our CI targets a senior-level course in microelectronics, with two main objectives in mind:

1. Assess the conceptual understanding of students of the core concepts for a course with nanoelectronics content
2. Determine the impact of new pedagogical methods of interactive engagement used to introduce nanotechnology principles into the course

Our initial set of CI tests was administered in an IC design course called VLSI (Very Large Scale Integration) Design in Fall 2012 in which nanoelectronics concepts were introduced. The development of the CI for this course is motivated by our overall goal of integrating nanoelectronics material into an existing integrated circuits (IC) design course. The expectation is that a stimulating introduction to nanotechnology will motivate our students to take more advanced courses in this area either as senior technical electives or in graduate school. The details of the actual course implementation were reported elsewhere [7].

II. Development of the Concept Inventory

For the initial development of our CI, twenty-five questions were created that were distributed over three separate tests. Our methodology followed the standard approaches reported in the literature. The first step is critical: identifying the core concepts for the course. For this initial attempt, the author surveyed several popular textbooks on VLSI design [8-10]. Future work, discussed below, will look to ensuring a recognized standard of core concepts is included. Second is the creation of the questions. Generally, multiple choice questions are preferred since appropriate distractors can be included to probe for common student misconceptions. The questions do not require any use of formulas and aim to contain language that is comprehensible to all students. The use of any special terms should be widely recognized. Three to five choices for the answers are usually optimum [1]. Most questions prompted the student to provide a brief written explanation for their answer in order to gain further insight into their conceptual understanding.

The first CI test consisted of nine questions. This test was given on the first day of class to fulfill objective one – providing a basis for assessing student understanding of some core concepts upon entering the course. Courses such as Digital Systems and Electronic Circuits are important prerequisites for this course. As such, we used existing concept inventories that have been developed for these courses for our source of questions [4-5]. The instructor selected questions that are important for VLSI design from three key areas: digital logic, device operation, and circuit analysis.

For the second objective, the student conceptual understanding of material taught in the course was assessed by the second and third CI tests, each consisting of eight questions. The second one covered some of the core concepts of the course such as device scaling, physical layout of devices, and transistor-level logic gate design. The third CI test covered advanced logic gate design and low power design methods.

III. DISCUSSION OF RESULTS

On the initial CI test to assess objective one, several areas that presented difficulties to the students were evident. This included basic device concepts such as identifying the different regions of operation and circuit analysis which depends on an understanding of device characteristics. For example, the question that caused the students the most difficulty is depicted in Figure 1. Only two students out of twenty correctly identified (a) as the answer. The question probes for an understanding of body effect and its impact on the threshold voltage. (The answers were equally split between (b) and (c)).

In the n-channel MOS circuit shown, $V_{in1}=V_{in2}=V_{DD} > V_{T0}$, where V_{T0} is threshold voltage of an nMOS device with zero bias. Let V_{T1} and V_{T2} be the threshold voltages of FETs M1 and M2, respectively. Select the best answer.

(a) $V_{T1} > V_{T2}$
(b) $V_{T1} < V_{T2}$
(c) $V_{T1} = V_{T2}$

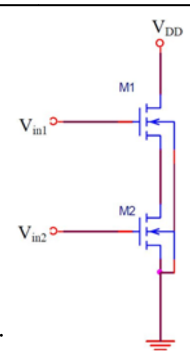

Figure 1. CI question on body effect [4].

Their written answers reveal a lack of conceptual understanding as well. This type of question is likely difficult for the students because it requires the ability to analyze the circuit at the transistor level and to recall a device-level concept (i.e., the body effect). This is a good example where the instructor used the results to plan an appropriate intervention: in this case, a review of threshold voltage and body effect and circuit analysis in a class lecture. An interesting contrast was between a question on a logic gate with a resistive pull-up and a standard CMOS logic gate. Only 4 out of 20 students could correctly identify a NOR gate in the first case, but most could identify the operation of the standard CMOS logic gate (14 of 20). The difference is that the first question requires some circuit analysis, while the second can be analyzed with a simple switch-level FET model (the transistor is either on or off) that is covered in their electronics courses. On the tests given later in the semester, several other important areas of student struggles were identified. One area that stood out was the confusion of related concepts. For example, a pair of questions probing for a conceptual understanding of the importance of the dielectric material in the scaling of IC processes indicated most students confused the need for a high dielectric constant under the gate of a device with the need for a low dielectric constant between the interconnect. This could be due to the need for more time to review and reflect on the material. Some correlation between student difficulties with nanoscale concepts and their work on the course project was evident. For the course project, the students were asked to select a circuit from a CMOS logic family discussed in class and simulate it at a nanoscale technology node as well as provide some analysis of the impact of scaling on the circuit's performance. Overall, this component of the project was rated at an average of 7.53/10. On the second CI test, four of the eight questions were related to issues with scaling transistor geometries to the very deep submicron (VDSM) regime. On those four questions, the students selected the correct answer an average of 58.5% of the time, indicating on average their struggles to grasp scaling issues. Detailed results will be presented at the conference.

A focus group discussion was conducted with four students to obtain additional feedback. The aim was to assess communication validity from the test-taker's perspective, i.e., whether the students understood the questions in the way they were intended. Some useful feedback was obtained, especially in regards to confusing terminology. A CI test should use language which is familiar and considered standard terminology and should not be confusing or ambiguous to the students. For example, on the discussion of the MOS pass-transistor, some students did not understand the reference to a "weak" logic level (i.e., a threshold voltage drop). Our suspicions regarding the trouble with the body-effect question mentioned above were also confirmed from these interviews.

IV. SUMMARY AND FUTURE WORK

This paper has summarized our initial attempts at developing a CI for a microelectronics course. The results from this assessment have given some indications of the conceptual areas that students find difficult to grasp and the impact of our attempts to introduce nanoelectronics concepts through active learning exercises reported in [7]. Further development of this microelectronics CI is planned. This will include a more rigorous determination of the core concepts for the course by getting expert feedback through the Delphi process, a structured multi-step process designed to obtain consensus on a subject [11]. More questions will be added so concepts are covered more than once in order to measure the reliability of the test. To ascertain the validity of the test, three things are planned. First, feedback from instructors of VLSI design courses on the suitability of the questions will be obtained by circulating an alpha version of the test. Second, we plan to have a beta version administered at several other institutions to obtain further data. And third, semi-structured interviews and focus groups will be planned with students to assess the communication validity of the questions.

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Online laboratories as a cloud service developed by students

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***Abstract*— On-line laboratories (virtual or remote) are widely used in experimental engineering subjects as part of the learning process. In order to develop these laboratories, a development framework called RELATED (Remote Laboratories exTendED) is used by the Communications and Control System Department of the Spanish University for Distance Education of Spain (UNED). This framework defines a structured and methodological development procedure, allowing the students the generation of their own laboratories. Once the laboratory is developed (based in its components), students have to configure their own computing resources in order to make their labs available. However, several problems must be faced by students in the "deployment" of their labs: network configuration, hardware availability, and so on. So, in order to solve these problems, an automatic system based on cloud providers is defined to allow students having their own cloud network/resources for their developed labs. This system simplifies the lab deployment and avoids common errors/mistakes in the development of laboratories with RELATED.**

Keywords—remote/virtual laboratories, development, cloud service model, laboratory deployment

I. INTRODUCTION

On-line laboratories (virtual or remote) [1], [2], [3] are widely used in experimental engineering subjects as part of the learning process [4]. In order to develop these laboratories, a development framework called RELATED (Remote Laboratories exTendED) [5] is used by the Communications and Control System Department of the National Distance Education University of Spain (UNED). This framework defines a structured and methodological development procedure, allowing the students the generation of their own laboratories. Also, students can integrate different elements included in other laboratories provided by the department due to the modular approach in the development. These student's laboratories are considered as part of the evaluation process in several subjects offered by the department in the EHEA (European Higher Education Area).

In the development and laboratory deployment steps, some resources are required in order to use the framework's tools (configuration validation and deployment process application). These resources are based on the availability of a java virtual machine and a correct network configuration (needed for laboratory access). The first software requirement is easy to meet (java versions could be another problem, but it is resolved updating the java distribution) but not the network configuration. Most of students usually use their own hardware (pc, laptops, etc.) with a fixed network configuration (ADSL modems routing ports not available, private ips, etc). So, in order to get a solution for students to resolve the before requirements, a cloud service model [6], [7] can be used to provide software/hardware/network resources. This means that a private/public cloud be used in order to provide these resources, and students could have a cloud panel to have control over their "cloud" deployments.

The "cloud" deployment of remote/virtual laboratories developed using RELATED uses the same elements as the "standalone" deployment, i.e., using the local deployment tool provided by RELATED. These elements are: 1) a configuration file with the lab structure which is XML based; 2) code implementations for "run-able" entities defined in the laboratory (modules and views, in RELATED terminology). With this new deployment option, student gets a full laboratory with an automatic network configuration ready to be used. Thus, lecturers can test the performance of student's labs, in order to evaluate them without running them in their own limited computing resources. It will also prevent the local execution of labs in lecturer's computers as usually it's done in the evaluation process (this simplifies the evaluation process and saves time for lecturers/students).

The paper shows the differences between deployment process using the cloud and standalone approaches, using the same development methodology defined in RELATED. In section II, a brief introduction of development process for remote/virtual labs is presented. The fundamentals of RELATED framework will be presented. In section III the "standalone" deployment process for a virtual/remote lab is reviewed. In section IV, details about cloud configuration and service model will be shown, and how it is managed. Finally, statistical information about lab cloud service used by students will be presented, focusing in two subjects, which are part of Computer Science Degree of the UNED: Distributed systems and Distributed Applications.

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II. Methodological Development of Virtual/Remote Labs

In order to use the RELATED framework facilities, an RLAB (Remote LABoratory) system must be defined. This can be done using a formal specification which is named LEDML (Laboratory Experimentation Description Markup Language). LEDML is based on XML language, and it is used to define structured components for the laboratory. The laboratory description, LEDML based, is really a lab configuration, and it is used in the same way as other configuration files in other software tools (for example, the server.xml configuration file in Tomcat). Every component in a RLAB XML file is represented by its corresponding XML fragment. These fragments are text based, so they can be reused in a simple way including them in the configuration files of RELATED laboratories.

The main component is an experiment, so lecturers/students can run these experiments using RELATED facilities as, painting data from the laboratory, change any relevant variable or have a look to the laboratory structure. In order to integrate the laboratory as an RLAB system, researchers/lecturers/students only have to develop local access to equipment using Java technology. The element responsible for carrying out this function is called a module.

A module is a run-able entity, executed into the RELATED server facilities. The module is responsible to get/set data from/to the equipment. They can be seen like a "black box" used to describe a component as a set of input/output variables. Considering modules are "black boxes", and using the RELATED modular architecture, it is possible to flow data between modules. Developers must provide read/write functions to get/set data for these variables. Java programming language is used to develop these read/write functions and XML tags are used to set-up a laboratory and to specify the module configuration.

There are also other main components in a RLAB LABORATORY, the views. Views are responsible of human interaction with the lab and provide the lab GUI. As it can be seen in figure 1, modules and views are the main components of an experiment. One or several experiments compose a laboratory (RLAB). One of the most interesting features in RELATED is that RELATED uses the "module paradigm" and, this way, modules and views can be reused in several experiments, even in several laboratories distributed on different Internet locations (for example, laboratories developed by students that can have modules running in the own student's equipment).

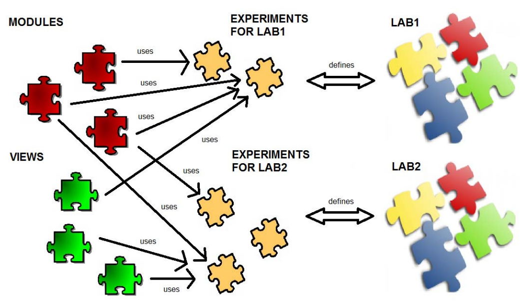

Fig. 1. RELATED modular structure.

As mentioned above, views provide the visual information to the final user (students, teachers, etc.). So, graphical interfaces (GUI, Graphical User Interface) can be included in these views in order to get a better user experience. These views use data from modules to update the experiments state, and it is possible to change and send values from the GUI to the modules.

Experiments define the behavior expected from the lab, so one or more experiments can be defined on the lab. Basically, it is possible to define an experiment by stating the set of modules and views that will be used in the experiment. Any convenient combination of modules and views can be used as an experiment.

III. Standalone Deployment for the Student's Lab

Once the lab definition and components are available, the next step is to deploy/run the lab. In this study case for Distributed Systems and Distributed Applications subjects, the student has to develop a virtual lab [8] representing a simple signal generator with three signal types (Sine, square and triangle) which will be connected (the module component) to a real equipment (magnetic levitator). First, student develops the module representing the behavior of signal generator (module named "SG_MODULE" in figure 2) and a view to get a visual representation of the module. Both of them are developed following the RELATED guidelines. In order to test the generated lab, an experiment is defined in the lab specification file (experiment "Generate signals" in figure 2). Once the specification file is ready (and also the components), students have to deploy their labs using the RELATED tools.

```
<?xml version="1.0" encoding="UTF-8"?>
<system description="Signal generator for SINE, SQUARE and TRIANGLE modes WITH GLG Generated View" type="0"
name="Rafael Pastor Vargas: GUI BASED SIGNAL GENERATOR VIRTUAL Laboratory">
  - <module name="SG MODULE">
      Signal generator module for SINE, SQUARE and TRIANGLE modes
      <param type="double" name="SampleTime" value="0.01"> Sample time for sigmal generator thread</param>
      <var type="double" name="amplitude" units="N/A" min="0" max="10" initial="1">Signal amplitude</var>
      <var type="double" name="frequency" units="Hz" min="0" max="100" initial="1">Signa frequency (Hz)</var>
      <var type="string" name="wave" units="N/A" min="0" max="1" initial="SINE">Signal type</var>
      <var type="double" name="output" units="N/A" min="-10" max="10" initial="0">Generator Signal output</var>
      <var type="double" name="time" units="Seconds" min="0" max="10" initial="0">Generator Signal generated time</var>
      <implementation type="JAVA" classname="es.uned.scc.grados.appdist.related.modules.SignalGeneratorModule"
         helperUrls="../examples/signal_generator/code/SignalModel.jar"
         jarfile="../examples/signal_generator/code/RLABSignalGeneratorModule.jar">Module for generation
         signal</implementation>
    </module>
  - <view name="SIGNAL_GENERATOR_GLGVIEW" classname="es.uned.scc.rlab.views.signalgenerator.SignalGView"
    helperUrls="../examples/signal_generator_gui/code/GlgCE.jar,../examples/signal_generator_gui/code/GlgGraphLayout.jar"
    jarfile="../examples/signal_generator_gui/code/SignalGeneratorGLGView.jar">
      Show virtual view
      <use name="amplitude" as="amplitude" module="SG MODULE"/>
      <use name="frequency" as="frequency" module="SG MODULE"/>
      <use name="wave" as="type" module="SG MODULE"/>
    </view>
  - <experiment name="Generate signals" concurrentUsers="1" slotTime="5" logging="no" sampleTime="10">
      Test
      <duration type="time" time="300"/>
    - <run module="SG MODULE">
         <interactives show="true,true,true" names="amplitude,frequency,wave"/>
         <paint names="output" colors="black"/>
         <paint names="time" colors="blue"/>
      </run>
      <open view="SIGNAL_GENERATOR_GLGVIEW"/>
    </experiment>
    <manager name="rpastor"/>
    <student name="demo"/>
</system>
```

Fig. 2. Signal generator's lab definition using LEDML.

To do the lab's deployment, student has to configure a properties file which defines several hardware/software/network parameters (See figure 3):

- Local path of lab's definition.
- Local path of logs generated by the RLAB server which is responsible of the laboratory's execution.
- Network configuration for the RLAB server (the lab) which will be run on the local host of student.

The network configuration parameters are especially important due to the laboratory will listen client connections on the defined ports. So, if these ports are not available to external clients, there will no opportunity to run experiments from the experimentation client. Usually, students use their own personal computers to develop the laboratories, and these personal computers have private ip's. This is a big problem to lecturers and students in order to check the online laboratory, due to lack of visibility of private ip's on the internet network.

```
# Properties file for initiating values for server

# XMl file with LEDM Specification
xmlfile=../examples/signal_generator_gui/LEDML_Specification/signal_generator_gui.xml
#Show GUI (values --> yes, no )
show=yes
#Debug (values --> yes, no). If yes, output will be redirected to log/rlab.log
debug=yes
#log_file
log_file=./log/signal_generator_gui/rlab_signalgeneratorGUI.log
# Publish (values --> yes, no). If yes, rlab system is publish as public from
# rlab website, once the LEDML file is parsed
publish=no
# Rmi port, port for start rmi registry
rmiport=1099
#RMI Service port. RMI service port for an RLAB system --> It is different of rmiport
(assigned to naming service)
rlabserviceport=1095
#UDP port. Port for data communication
udpport=10003
# REST Server port assigned. Jetty needs a port to listen REST request
restport = 9996
```

Fig. 3. Properties file needed for run a RELATED laboratory.

Once the properties file is configured, then the student has to run the publish application tool provided by RELATED. This application checks the xml definition and creates the laboratory using the parameters defined before. Now, students can carry out the experiments defined in the lab specification from the related web server, showing the experimentation client like in the figure 4.

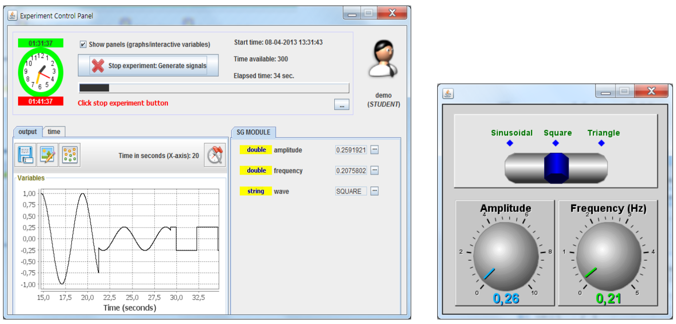

Fig. 4. Experiment client running the experiment defined in the student's laboratory.

Students claim that they waste so much time in a correct configuration for the parameters for their computing nodes (their personal computers). This hide the main objective of the evaluation task: the development of their own laboratories. So, the first problem to face is the simplifying of lab's configuration process. Also, another big problem consists in to get a public availability of the lab, avoiding the use of private ip's. This availability must consists not only in terms of public access across Internet, but using computing resources (computing nodes) to get a "full time" availability of lab. This feature allows to lecturers and students the testing of their lab, and in the lecture's case the evaluation of the tasks associated to the developed lab by students.

IV. USING CLOUD PROVIDERS TO DEPLOY RELATED BASED LABS

In order to solve the problems detected in the above section, it's mandatory to get computing resources using public/private available resources. For this objective, the well-defined cloud service model [9], [10] (see figure 5) can be used. The idea is to use the public/private resources defined in several cloud providers to get "computing nodes" which will run the student's labs [11]. Nowadays, RELATED was using the cloud model for the management services [12] but not for the lab's execution. To move the lab's execution to the cloud, the PaaS (Platform as a Service) layer of cloud computing model is used to develop a new "deployment" application for RELATED laboratories named "RELATED Cloud Labs". The PaaS layer focus on applications and the "RELATED Cloud Labs" application provides the lab's deployment services for users, as it is required in this case.

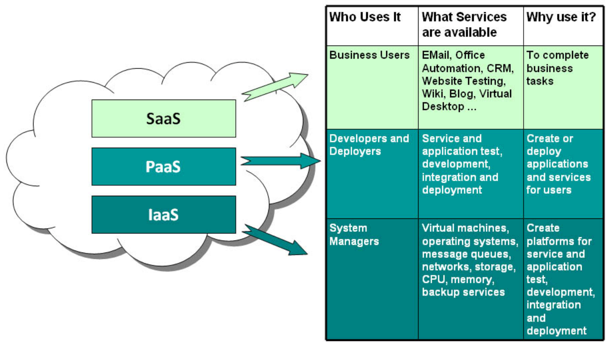

Fig. 5. Cloud service model. Referenced from http://info.apps.gov/content/what-are-services.

This application represents a computing node, and it will take care of the student's laboratories, running them inside the "computing node". The computing node will be represented as a Java Web Application running inside a Java EE 6 container. Thus, any compliant PaaS provider can be used to create "computing nodes". There are several options for public PaaS providers which offer this kind of environment, hosted in the cloud. Actually, three nodes are available for students in order to be used:

- http://cloudlabs.rpastorvargas-uned.cloudbees.net. Running in the public PaaS provider name "Cloud Bees" [13].
- http://cloudlabs-rpastor.rhcloud.com/. Running in the public PaaS provider name "Openshift" [14].
- http://lab-app.scc.uned.es:8080/CloudLabsDeployer/. Running in a private node owned by RELATED project.

The process of adding "computing nodes" is quite simple: installation of the "RELATED Cloud Labs" application in a cloud provider with PaaS/J2EE support. Thus, to get more computer nodes is easy and other PaaS providers like CloudFoundry [13] or AWS Elastic Beanstalk [14] will be added as computing nodes providers in the future.

Students can select the "computing node" to deploy their labs from the RELATED web server. Even, they can deploy and run the same laboratory in several nodes (up to three now) to test the performance of the computing node.

V. DETAILS ABOUT THE DEPLOYMENT PROCESS IN THE CLOUD

Once the student selects the computing node, he/she has access to the web application (RELATED Cloud Labs). This application allows to student the uploading of their xml definitions for labs, and also the components which compose the labs (basically the implementing jar files of views/modules). In figure 6 is represented the main window for the web application (with the student "demo" logged in the system) running in the computing node provided by Cloud Bees. From this window (a web page in a browser), the student can view their cloud labs deployments and upload new laboratories using the corresponding options.

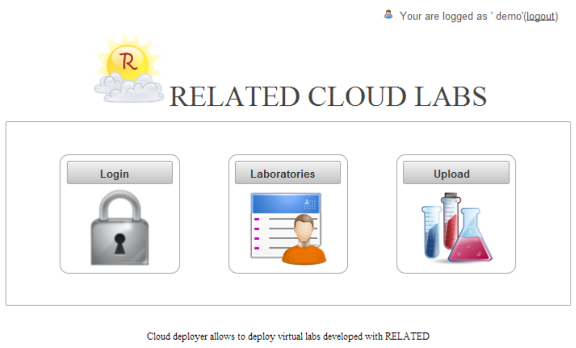

Fig. 6. Main form for the computing node hosted by CloudBees.

In order to upload a new laboratory, students simply click the "Upload icon" (see figure 6) and a new form will be presented to upload the lab's definition. This form is presented in figure 7. The first step is the uploading of the xml file and its validation. The validation is used to detect components and definitions errors in the laboratory specification.

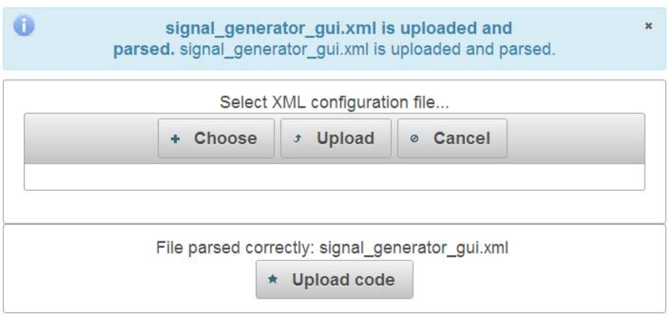

Fig. 7. Uploading and verifying of laboratory specification.

If the laboratory's definition is ok, the "Upload code" button is enabled in order to allow to students to upload components defined in the lab, as it seen in figure 8. In this case, the student's lab is composed by one module representing the signal generator and a view to interact with the lab. As mentioned before, these components are developed using the RELATED methodology. Every component must have at least one main jar (implementing the behavior of component) and optionally, one or more "helper" jar files. These helper files allow including third part libraries in an easy way.

In order to upload lab components, the "Choose" button must be clicked to upload all the implementing jar files. Students can upload all the files in one step, using the multiples items capability of the upload component (see figure 9). Once all the files are uploaded, the lab is ready to be added to the student's cloud labs using the corresponding button (enabled when all files are uploaded and checked) in figure 10.

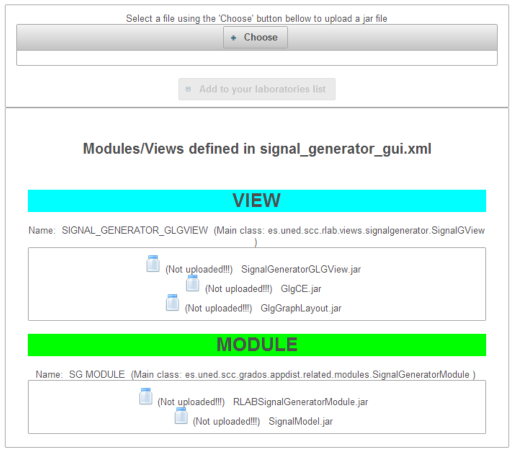

Fig. 8. Uploading laboratories components: modules and views.

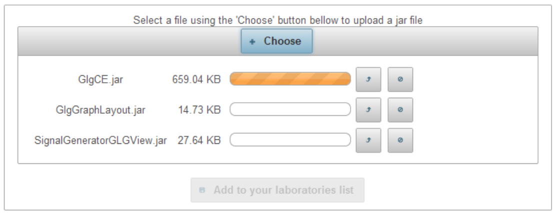

Fig. 9. Uploading multiple laboratories components at the same time.

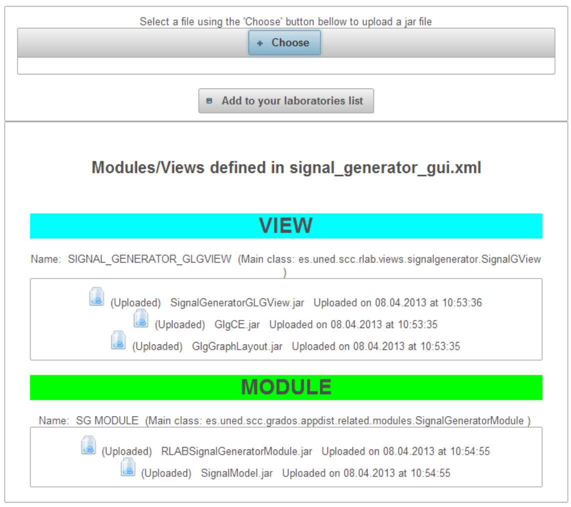

Fig. 10. Laboratory components uploaded and ready to be deploy/run in the cloud.

Finally, once the laboratory is ready, it will be available in the laboratory list (see figure 6). Now, students can get details about their clouds labs, like it is shown in figure 11. In this case, the student's lab being deployed is shown in figure 11 (marked with a red box). From every cloud lab defined, the name and description are presented and also, the deployment options and management options.

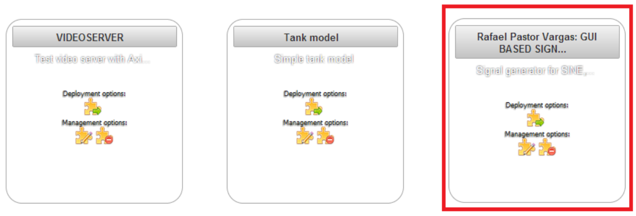

Fig. 11. Laboratories deployed on a computing node.

The last step to get the public availability of lab consists in changing the state of cloud lab. This is done using the icon. Clicking this icon, it starts the running of the laboratory in the computing node, making available from the laboratory list in the related web server. At the start of lab running, the computing node assign automatically the parameters for the configuration of a RELATED laboratory (see figure 3), based on the availability of resources in the computing node (network ports and paths to logs for laboratory). This feature allows students and lecturers forget all about the configuration file and focus on the testing of the laboratory.

In figure 12, the running laboratory list in related web server [17] is presented. In this figure, two laboratories with the same name are showed, one running using the "standalone" deployment process and the same running on the cloud.

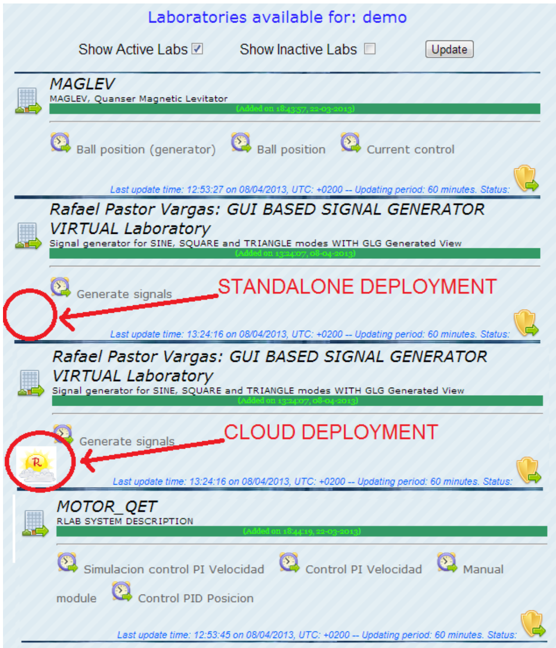

Fig. 12. Laboratories list available from the related web server.

Students can manage their cloud labs from the details panel of lab. They can delete (undeploy) the laboratory using the icon or edit the components in order to upload new versions of the components (using the icon).

VI. STUDENT'S CLOUD LABORATORIES AND SURVEYS

Once the practical experience with virtual/remote laboratory is over, students must perform a survey used to get development/services satisfaction information. This survey is mandatory and it has 20 questions, classified in 5 main areas (questions/ratings are shown in Table 1 only for the main interest area of this paper, focused on deployment options). The survey was performed by 45 students from 151 enrollment students in the two subjects considered. Due to the university's regulations, students can deliver the practical homework in two dates (February 2013 and September 2013), so only the first date surveys are included in this paper.

TABLE I. QUESTIONS AND RATING

Question (scored 1-5)	Code	Average rating
Deployment options (A4)		
Consider the two deployment options for your labs; do you consider that cloud options have a lot of advantages over the standalone deployment?	Q17	*4.9*
Consider the cloud deployment option; do you think is easy?	Q18	*4.8*
Consider the standalone deployment option; do you think is easy?	Q19	*2.7*
In the standalone deployment process, have you had a lot of problems with the network parameters?	Q20	*3.2*

All students have to do both deployments: "standalone" deployment in order to debug the code associated to the laboratory's component. Once the laboratory is fully tested and debugged, they have to deploy their labs to the cloud in order to be evaluated with no need of sending to lecturers their solutions.

In table I, it can be seen as all the students prefer the cloud deployment, due to the easy procedure defined for the uploading of laboratories and their execution without the use of their own resources. Also, they complain about configuration process in the "standalone" deployment process, but in general they are satisfied with both deployment options.

VII. CONCLUSIONS

Components of a laboratory in RELATED are defined by XML fragments and its corresponding implementing files, so the "deployment process" must deal with these components in an easy way. In the "standalone" deployment process, a previous configuration step is needed in order to run the laboratory, complicating the testing of laboratories for students and lecturers. Also, the testing of a RELATED laboratory implies the use of own hosted hardware/software/network services.

To solve these problems, and to get an automatic configured laboratory and computing resources related, it is introduced the concept of "computing node". This computing node represents an application running in the cloud, using the PaaS layer of the cloud service model. Using this concept, it is possible to use public PaaS providers like Cloud Bees to have computing nodes running RELATED laboratories in a simple way.

The use of options like the automatic configuration and cloud deployment, allows students to run their own laboratories using external computing resources. Also, lecturers avoid testing their student's laboratories in their own personal computers, getting a better experience in the evaluation of the tasks associated to the laboratories' development.

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Real-time FM Radio for Teaching DSP and Communication Systems

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***Abstract*—In digital signal processing (DSP) and communication systems courses much of the material is theoretical. There are some students who are more motivated to learn if they can see a connection to the real world, but unfortunately many real-world communication and DSP systems are very complex, and including them as part of a course is difficult or impossible. The FM radio, however, is a relatively simple system that is in some ways ideal as a real-world example because it includes both analog and digital signals. The analog signals transmit the audio and the digital Radio Data System (RDS) signal transmits auxiliary information such as the name of the artist, song, current time, etc. This paper describes an FM radio with RDS decoder based on an inexpensive FM module and an affordable DSP board. The system runs in real-time, demodulates FM radio, plays the music through speakers, displays the name of the song and artist, and allows access to the internal signals. This real-time receiver can be used in demonstrations in a lecture course or as the basis for a series of laboratory experiments.**

Keywords—Digital Signal Processing, Communication Systems, Real-time, FM Radio, Radio Data System, Receiver

I. Introduction

One of the toughest challenges in teaching is finding effective ways to motivate students to learn the material. Some students are more motivated to learn the material if they can see how the material is used in the real world. One way to provide students this connection to the real world is through in-class demonstrations. Various commercial communication systems provide excellent examples of how digital signal processing techniques are used in practice, but unfortunately it is difficult to use these systems in classroom demonstrations because they are complex and do not allow access to the internal signals. Another way that real systems can be incorporated into a course is to have students build a working system in the laboratory. This provides context for the theoretical material, however many communication systems are just too complex to be built as part of a course.

There have been several approaches to teaching communication systems that attempt to bridge the gap between real systems and the theoretical material. A popular approach is to use simulations to demonstrate various concepts [1,2,3,4]. Simulations have the advantage that they can be very effective and are inexpensive regardless of the number of students, but some students do not find them compelling since they do not interact with real systems. Another approach is to capture the RF signals from real communication systems and demodulate them offline [5,6,7]. This approach has the benefit of having a direct tie to real systems and allowing the use of a high level computer language such as MATLAB. The disadvantage of this approach is that the programs do not run in real-time. Others have used hardware that was specifically designed to demonstrate communication system operations [8,9]. These systems come closer to real-world hardware but can be expensive and some cannot process signals from real RF systems since they do not operate at RF frequencies. Some others have used DSP's to demonstrate and teach communication systems [10,11], which has the advantage of using a more real-world hardware platform. The disadvantage of this approach is that DSP boards are not usually designed to process RF signals. And finally some courses use software defined radio to implement real systems in software that can operate on RF signals, but the hardware is complex and expensive [12,13,14,15]. The method described in this paper is to use an FM module and a DSP platform to implement an FM radio with an RDS decoder. Some advantages of this approach include: the hardware is inexpensive (less than $100), the system operates in real-time, most of the processing is performed in software, and the system allows access to the internal signals. Through lecture demonstrations or laboratory experiments, this platform can be used to help motivate students in a communication systems or DSP course by providing real-world context for the course material.

II. BACKGROUND

FM radio is in many ways an ideal system to provide the context and real-world connection for many concepts in communication systems and DSP. FM radio employs both analog and digital signals, is available in most populated areas, is a familiar system for students, is simple enough for use in an undergraduate course, and does something useful and interesting when it is completed.

FM radio stations transmit several signals in the stereo multiplex signal including analog mono (L+R), pilot carrier, analog stereo (L-R), and the digital RDS signal (see Fig. 1).

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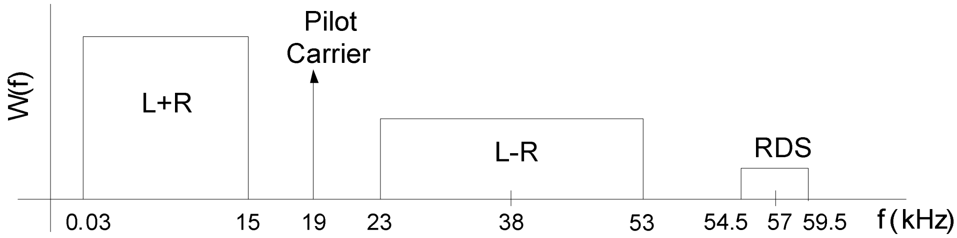

Fig. 1. Spectrum of the FM Stereo Multiplex Signal

The RDS signal, which in the United States is also called Radio Broadcast Data System (RBDS), is a digital signal that encodes auxiliary information such as the name of the artist and song, current time, etc. It has a fairly low bit rate of 1187.5 bits/sec and uses bi-phase (or Manchester) encoding and a raised cosine pulse shape [16,17].

III. HARDWARE

The hardware used to implement the FM radio with RDS decoder was selected to be a low cost and flexible solution that provides access to internal signals for instructional and debugging purposes. The hardware consists of a simple antenna, a very low cost FM module, DSP board, and a computer (see Fig. 2).

The FM module demodulates the RF signal from the antenna to produce the stereo multiplex signal called MPXO in Fig. 2. The module used in this project is based on the TEA5767HN module since it is very inexpensive (about $2) and is one of the few such modules that produces the full multiplex signal instead of just the left and right audio signals [18]. This module appears to be an obsolete part, but it is still readily available. Power for the module is supplied by the DSP board.

The DSP board converts the stereo multiplex signal to a digital signal. Since the highest frequency in the stereo multiplex signal is about 60 kHz, the DSP board must support a sampling rate of at least 120 kHz. The DSP board used in this project is the inexpensive TMS320C5515 eZdsp USB Stick from Spectrum Digital which supports sampling rates up to 192 kHz [19]. It contains a low cost fixed-point DSP (TMS320C5515) and comes with a copy of the compiler Code Composer Studio from Texas Instruments. A tutorial for this board is available from Texas Instruments [20]. The DSP board is connected to the FM module through an I2C port, which is used to initialize the FM module and tune to the desired radio station.

A computer is used to program the DSP board and to plot signals for debugging and instructional purposes.

IV. SOFTWARE

Most of the processing is performed in software which allows the students to learn about the algorithms by building them themselves and allows access to the internal signals so that they can see the signals from a real system. The software initializes the FM module through an I2C port using the TMS320C55x Chip Support Libraries [21]. It also uses an example program from Texas Instruments to transfer data to and from the codec using a double buffering scheme with direct memory access (DMA) [22]. The example program was modified to increase the sampling rate from 48 kHz to the maximum possible sampling rate of 192 kHz. When one of the buffers is full, an interrupt is generated which sets a flag. A program monitors the flag, and when it is set, calls a function to process the data in the buffer.

The FM mono receiver takes the stereo multiplex signal and passes it through a lowpass de-emphasis filter to undo the emphasis that is performed at the transmitter, and then the output is written to one of the output buffers and sent to the codec so that the students can listen to the mono signal through speakers or headphones (see Fig. 3).

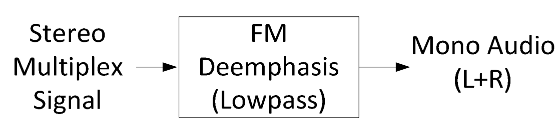

Fig. 3. Mono Receiver Block Diagram

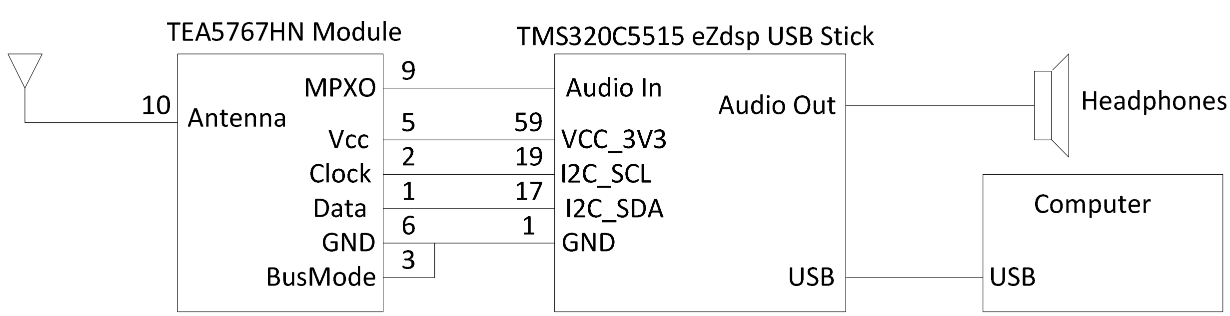

Fig. 2. Hardware Diagram

The RDS demodulator is more complex (and interesting) than the mono receiver for the analog signal. As shown in Fig. 4, the RDS demodulator includes a Costas Loop to estimate the carrier signal frequency and phase and to shift the RDS signal back to baseband [23]. The pilot carrier signal could be used in place of the Costas Loop to demodulate the RDS signal, but the authors chose not to use this method since most wireless systems do not send a carrier signal and some radio stations do not transmit a stereo signal, in which case the pilot carrier will not be present. The Costas Loop is followed by a matched filter that reduces noise, completes the pulse shaping, and decimates the signal to lower the sampling rate. The DSPLIB library [24] was used to implement the sine function and the filters required in the Costas Loop and the matched filter.

The matched filter is followed by the timing recovery algorithm [4] that estimates the best time to sample the signal. This algorithm is similar to the one that maximizes the average power of the samples but has been modified for use with the RDS pulse shape. The samples are quantized by the slicer which outputs 1 if the input is positive and 0 if the input is negative.

The output of the slicer is processed by a differential decoder to remove the differential encoding that is performed at the transmitter. This process allows the receiver to recover the correct bits even if the signal is inverted, which would otherwise complement the bits (change the 0's to 1's and vice versa).

The bits from the differential decoder are buffered up until a full 26-bit block is received and then the CRC checksum is computed. If the checksum shows that one or more bit errors occurred, the program advances one bit and checks again in order to discover the correct word alignment. If the checksum shows no bit errors, the decoder checks to see if the block is part of a radioText group that carries the text that shows the name of the song, artist, and program. If so, the characters are extracted and, after the entire radioText message has been received, it is displayed on the screen on the DSP board.

The program can also route internal signals to the codec so that they can be viewed on an oscilloscope, spectrum analyzer, or sent to speakers for listening.

Possible future enhancements for the project include designing a printed circuit board for the FM module, fixing a software issue that causes a short beep in the audio each time the processor updates the display because updating the display takes too long, adding the ability for the user to control the radio using the pushbuttons on the DSP board, adding support for displaying other RDS data such as the station, current time, traffic information, etc., and adding a stereo receiver for the audio signals.

V. USE IN THE CLASSROOM

This project has two main uses in a communication systems or DSP course. The project can be used as a demonstration tool to show students how a typical receiver works by allowing them to see the internal signals, or it can be the basis of laboratory experiments.

The advantage of this project over a commercial receiver as a demonstration tool is that it allows access to the internal signals, which would be very difficult to access in a commercial radio. Students may find course material more interesting if they are able to watch the signals on an oscilloscope and spectrum analyzer while listening to the audio signal. It is also very easy to demonstrate the noise, distortion, and interference that occur in real communication systems. This project can also be used in a series of laboratory experiments. The software is simple enough that it could be written by students and would culminate in a working analog and digital receiver.

The project could also be used to motivate the study of any single part of the receiver such as the filters, Costas Loop, timing recovery algorithm, or the CRC check. Students could write the software to implement any of these algorithms and then test their code by inserting it into the rest of the software to see if it works in the whole system. Thus the system could provide a more compelling way to test any of these parts than just a simulation.

In the fall of 2014, one of the authors plans to teach a new course on real-time digital signal processing where the students will develop and test most of the FM radio with RDS decoder in a series of projects. Since the hardware is inexpensive, it should be possible to supply each student with an FM module and DSP board so that they can work on the project outside of the laboratory.

VI. ASSESSMENT

Currently, the FM radio with RDS decoder is used as a demonstration in an undergraduate course on communication systems. In this course, the students use a real-time spectrum analyzer to record the RF signal from a radio station and write software (in MATLAB) to demodulate both the analog mono audio signal and the digital RDS signal off-line. The demonstration is used to show the internal signals of a receiver running in real-time and to hopefully increase interest in the material. The demonstration was first used in the spring 2013 semester. A survey was given the day before the demonstration and after the demonstration to try to assess the effectiveness of the demonstration. The following questions were on the survey:

1. How would you rate your current knowledge about communication systems?
2. How would you rate your current level of motivation to learn more about communication systems?
3. How interesting do you currently find communication

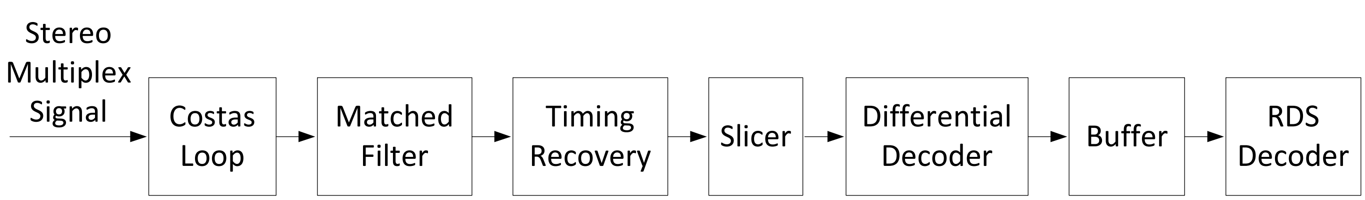

Fig. 4. RDS demodulator block diagram

systems?

4. List the major parts of a receiver in a digital communication system.

The first three questions were self-scored on a scale of 1 to 5, with a score of 5 indicating very knowledgeable, motivated, or interested, and a score of 1 being not at all knowledgeable, motivated, or interested. The answer to Question 4 was graded by the instructor on a scale of 0 to 5, with 0 indicating no answer or no correct answer, and 5 being a complete list of the major parts of a digital receiver (demodulator, matched filter, timing recovery, quantizer, and decoder). The results of the survey are summarized in Table 1.

TABLE I. TABLE 1. SURVEY RESULTS

Before Demo (N=10 students)	Mean	STD
1. Knowledge	3.30	0.48
2. Motivation	3.20	0.92
3. Interest	3.90	1.20
4. Major Parts	2.90	1.73

After Demo (N=12 students)	Mean	STD
1. Knowledge	3.50	0.67
2. Motivation	3.67	0.78
3. Interest	4.00	0.95
4. Major Parts	3.58	2.07

Table 1 shows that the average score on all of the questions increased after the demonstration, which is encouraging. With the small sample size, however, none of the differences was large enough to be considered statistically significant at the 5% significance level using the two-tailed t-test for differences in population means assuming identical but unknown variances.

VII. CONCLUSION

This paper described a real-time FM radio with RDS decoder that can be used in teaching communication systems and DSP courses to give the students exposure to a real system and to increase students' interest and motivation. It uses a hardware platform that is much less expensive than most DSP boards, software defined radio systems, or specially design hardware. Furthermore the proposed radio is a real-time system that operates on real RF signals. The software is available for free from the authors for educational use.

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Engaging a Variety of Students in Digital Design with Competition

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***Abstract*—This paper highlights the successes of contestants enrolled in an Introduction to Engineering class that took on the task of designing and building a robot to solve a problem with little or no background in electronics or programming. The semester long project started with developing a problem statement and from there timeline followed the Digilent Design Contest. Students had deadlines and formats for design documentation required by Digilent for the contest. While some students were attracted to the challenge of creating and implementing a design of their very own, other students are excited to compare their design against projects from students at other institutions. These competitions are designed to feed the excitement of the students and also fuel creativity.**

Keywords—Robotics; Introduction to Engineering; Student Contests; Assessment

I. INTRODUCTION

Digital systems are ubiquitous. College students carry a computer, smart-phone, tablet and/or music player everywhere they go. Growing up with so much technology means they are not easily impressed with flashing lights or even fairly complex graphics. It takes something a little more physical to motivate interest in digital systems. In a first year course this might mean connecting the digital system to an autonomous robot.

Early engagement of students in hands-on activities in the lab is a widely known technique to get and keep students interested in engineering [1] [2]. For electrical engineering and mechanical engineering students these activities are often within the field of robotics. Kits are available for a wide range of ability levels and range such as kits that can be used in elementary or middle school from LEGO® MINDSTORMS® to large manufacturing robots used in industry. Finding a kit or individual parts to provide an appropriate challenge for students in engineering can be difficult if budgets are tight. Often, materials that are suitable for juniors or seniors are too complex for first year students. However, the advent of single board microcontroller systems such as the Arduino [3], have made interfacing and programming robotics systems very accessible to first year students. Some introduction to the fundamental concepts such as analog-to-digital conversion, timing issues, and electrical power is needed. However, in-depth knowledge of the implementation of each individual component is not necessary to apply the technology to a small project.

Electrical engineering and mechanical engineering projects require access to laboratories and tools to build and test mechanical and electrical systems. It is these hands-on activities that are critical to student learning [1]. Keeping labs and shops open for student use can be expensive. Costly and sometimes dangerous equipment needs to be monitored and students need training in handling the equipment. A lower cost, safer alternative is needed. An engineering design contest sponsored by Digilent Inc. and Xilinx Inc. allows students to get the electronics hardware they need without cost to the students or their institution. Students must provide a well thought out design proposal upon entering the contest. Digilent then provides the FPGA or microcontroller-based hardware and interface circuits for controlling motors and sensing physical quantities such as light and distance.

Contests are a popular method to engage students in learning [3] [4]. But, most contests are designed for upper classmen who have extensive background in either electrical or mechanical engineering. We describe a contest where first year engineering students were able to dive in and create something with little or no knowledge of microcontrollers.

II. THE DESIGN CONTEST

The Digilent Design Contest has been held at Technical University of Cluj-Napoca, Romania since 2005 [4],with the first US contest at Rose-Hulman Institute of Technology, Terre Haute, Indiana in 2007 [5]. Initially, the contests were only open to students from the host institutions. In 2011 and 2012 the contest expanded to four separate regional or "continental" contests. A "World Finals" event was held each year to bring the top projects from all areas together to share their projects and compete. While most of the students are juniors and seniors with multiple courses in digital systems design there are now opportunities for students with little or no experience. The Digilent Design Contest has proven to be a strong motivator for first year and upper class students as evidenced by the number of students who enter the contest from a small college in the Midwest.

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At the 2012 Digilent Design Contest held in Indianapolis, the backgrounds of the students ranged widely as did the variety of institutions represented. Backgrounds ranged from first year engineering students through graduate students working toward a Ph.D. in majors such as computer engineering, nuclear science and engineering and computer sciences. Institutions represented ranged from a small liberal arts college to average-sized technical schools to medium-sized research universities

This paper highlights the successes of students in an Introduction to Engineering class that took on the task of designing and building a robot to solve a problem. The semester long project started with developing a problem statement and from there followed the timeline of the Digilent Design Contest. Students had deadlines forced upon them from Digilent and formats for design documentation that were required for the contest. Informal reflections with students indicated that many students were attracted to creating and implementing a design of their very own. Other students were more excited to compare their design to projects from students at other institutions, that competition was inspiring for them. In such a contest, participation is not just about competing; it is also about seeing what others have been able to do and learning from the successes and failures of others. These competitions feed the excitement of the students and also fuel their creativity.

III. First Year Engineering Course

Most engineering programs require a one or two semester introduction to engineering course(s) during the first year of study. The courses are designed to orient the student to engineering problem solving, engineering communication methods (including CAD), and the engineering design process. At schools where there are multiple engineering programs the first year courses often provide a glimpse of the different types of engineering to help students decide upon an initial career path.

Loras College offers a single general engineering program that emphasizes electromechanical systems. The first semester of the two course introductory sequence concentrates on the use of CAD to model parts and communicate designs. Students work as individuals or in teams on one or two small design projects, such as a business card holder and a fan powered car with a light sensor. CAD drawings are part of the project and a heavy component of the first semester. In the second semester the course includes a larger design project of an electromechanical system. The instructor has enough freedom to shift emphasis to/from electrical systems and mechanical systems given his or her interests. The instructor assigned for the spring semesters of 2012 and 2013 has a background in electrical and computer engineering and so the course was centered on a microcontroller based robot design and implementation.

A. Course Outcomes

Defining a set of measureable outcomes is a critical first step in designing a course. The following outcomes were set based on the needs in the curriculum and the lab projects designed for the course. Students will demonstrate the ability to:

1. Employ the engineering design process to design and create a prototype.
2. Organize a project with a timeline and appropriate documentation.
3. Present a design with proper written and graphical documentation.
4. Present a design with an oral presentation.
5. Write a simple computer program.
6. Reflect upon a project to practice skills of critical thinking, decision making, self-learning, and teamwork.

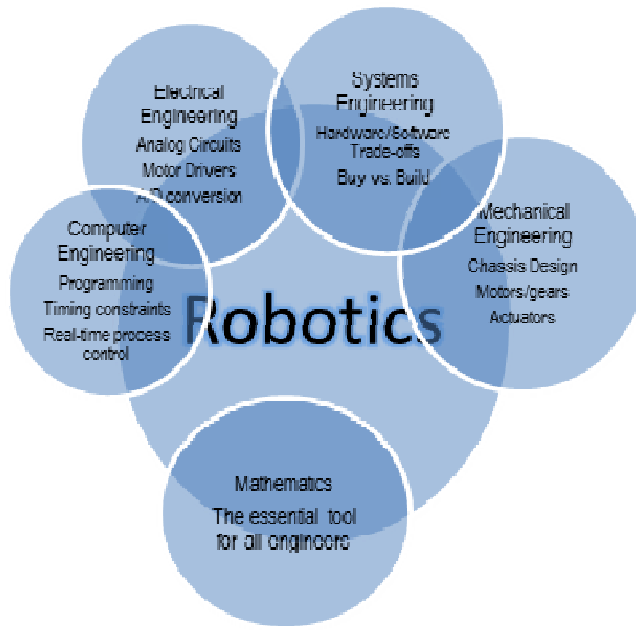

Fig. 1: The many disciplines within Robotics.

B. The Case for Robotics

A robotics project can meet the needs of introducing students to electromechanical systems as well as providing practice with the engineering design process on a project that lasts most of the semester. The project is complex enough to require some redesign and rework when the original design does not meet the design specifications. Thus students can demonstrate the iterative nature of the design process. Even if the project comes off without a hitch (highly unlikely), students are able to reflect at the end of the semester see how to improve their design.

The field of robotics spans several disciplines as shown in Fig. 1. Students are not expected to master all of the subjects within one course or even with one entire program. The goal for the instructor is to present enough knowledge for student success without overwhelming the students. For example students need not know how to design an H-bridge circuit in order to use on as a motor driver circuit. However, presenting the H-bridge as a “black box” can make the students overconfident and lead to motivational issues later on. The Digilent Pmod™ devices that are designed to be plugged into the microcontroller board provide a way to get students started on robotics projects without having extensive knowledge of analog circuit design.

In the course described here, the students are limited to chipKIT™ Uno32™ with the I/O interfacing provided by the Digilent Pmod™ devices. A sample set of hardware is shown in Fig. 2.

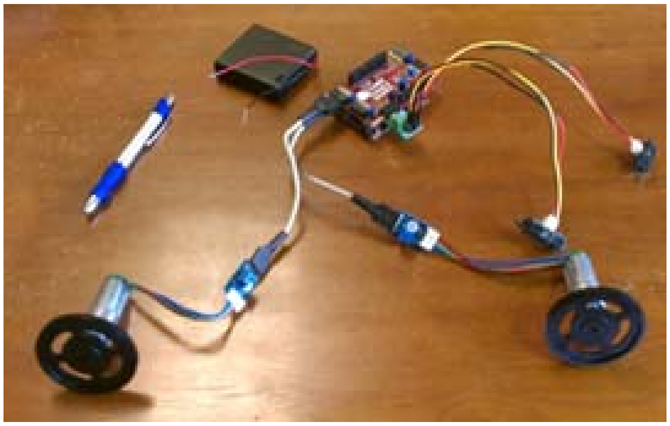

Fig. 2: ChipKIT, H-bridges, gear motors and IR Range sensors

C. Integrating Lab Work, Assignments, and the Contest

Given the course outcomes a sequence of lab projects was designed to lead the students through the material enough to complete their robots in time. The sequence of labs is shown in Table 1.

TABLE 1: ORDER OF LABS AND GENERAL SECHEDULE FOR THE SEMESTER.

Lab	Title	Topics/Activity
Lab 1	Introduction to the Design Process [8]	Build-a-boat contest using modeling clay
Lab 2	Electrical circuit analysis and construction	Ohm's Law, Resistor networks, V-I characteristics of a diode
Lab 3	Circuit Design (H-Bridge with discrete components)	Transistors as switches, Logic Design, h-bridge construction
Lab 4	Analog and digital input/output with the chipKIT™	Analog and Digital I/O
Lab 5A	Programming Fundamentals	Loops and selection structures (if-else-if)
Lab 5B	Project Planning	Project Management, Gantt charts
Project Work time		
Lab 6	Project Update	
Project Work time		
Other topics	Ethics, spreadsheets, etc.	
Final Presentation		

D. Example Projects

In 2012, the majority of projects were Sumobots. Other students looked for something different from the rest and chose projects such as a Lego™ collection device, a line following robot that could be used in factory automation and a maze traversal robot. Fig. 3 shows the maze traversal robot early in the build and test phase of the project.

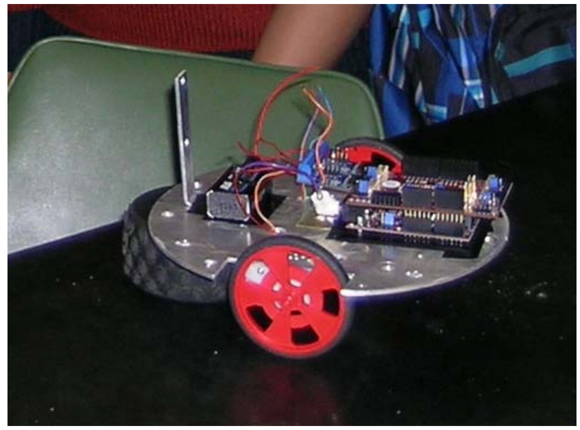

Fig. 3: Maze traversal robot.

IV. ASSESSMENT DATA

Assessment of course outcomes is done via embedded assessment. Performance on outcomes is measured against a predetermined expected score on a specific assignment, lab, or exam problem, or a combination of two or more items. After the course is complete the instructor writes a Course Assessment Report (CAR). The data and analysis from the CAR is used to improve individual courses as well as for continuous improvement of the program. As a side note, the Course Outcomes from each course are mapped to the ABET a through k Student Outcomes from criterion 3. Results from the CAR are shown below for each Student Outcome.

TABLE 2: ASSESSMENT MATRIX SHOWING MATERIALLS USED TO ASSESS COURSE OUTCOMES.

ASSIGNMENT	COURSE OUTCOMES					
	1	2	3	4	5	6
Specific Lab Projects	x				x	
Course Project	x	x	x			
Project Oral Presentation				x		
Final Exam and quizzes	x					x
Reflection Paper						x

A. Course Outcome assessment data.

The following is taken from the Course Assessment report. These data are taken to determine if the course outcomes are being met and where changes may be needed to improve student learning.

*1) **Outcome 1**: Employ the engineering design process to design and create a prototype.*

Lab 1 required the students to design and build a boat made of modeling clay to float as many pennies as possible. The average score on lab 1 was 89.7%. This is probably due to the simplicity of the design project. All thirteen students achieved better than 70% on this assessment. The course project also provides a measure of this design outcome. The project requires some knowledge electrical and mechanical systems as well as programming and microprocessor interfacing. The scores on the final design documentation for the course project averaged 78.8% with 11 of the 13 students receiving a grade of 70% or higher. One problem on the final exam also measured the students' knowledge of the design process. The average on that exam problem was 88.1%. 12 of 13 students scored above 70%. Outcome 1 was met.

*2) **Outcome 2**: Organize a project with a timeline and appropriate documentation.*

Lab 5B required the students to develop a project timeline and plan out the rest of the semester. No measurement was taken to determine if their plan failed or was even followed. Students were graded on the detail level of the plan. The average on lab 5B was 71.2%. Two students did not turn in the assignment, but the remainder of the students scored above 70%. Overall outcome 2 was met.

*3) **Outcome 3**: Present a design with proper written and graphical documentation.*

All students were required to present to the class their final product. Grading was done with the Oral Presentation Rubric also used in the Senior Capstone. The average score on the presentation was 77.3%. One student missed class on the day of the presentations. The remainder of the students scored above 70%. Overall outcome 3 was met.

*4) **Outcome 4**: Present a design with an oral presentation.*

All students were required to present to the class their final product. Grading was done with the Oral Presentation Rubric also used in the Senior Capstone. The average score on the presentation was 77.3%. One student missed class on the day of the presentations. The remainder of the students scored above 70%. Overall outcome 4 was met.

*5) **Outcome 5**: Write a simple computer program.*

Labs 4, 5A, and 6 all required a significant component of programming and are thus used to measure Outcome 5. The average score on these labs was 84%. 11 of the 13 the students scored 70% or above. Overall outcome 5 was met. The two students who scored below 70% did not complete some of the lab assignments.

*6) **Outcome 6**: Reflect upon a project and practice skills of critical thinking, decision making, self-learning, and teamwork.*

One homework assignment required the students to analyze one of two ethical scenarios. The average on this homework assignment was 72%. 9 of 13 students scored above 70%. Three students failed to turn in the assignment. The outcome was also measured with multiple choice questions on the final exam. 6 of 13 students attained a level of 70% on this portion of the exam. This outcome was not met due to the lack of participation of some students and poor performance on the final exam.

B. Student Survey Data

Students were surveyed at the end of the semester to determine their view of the course material and the project itself. Student survey data must be reviewed with some skepticism as with all survey data. Students are just as prone to bias any human and perhaps more so. Survey data often shows how students felt about the course in general and is not a direct measure of their learning. In particular, the last survey question might be considered inappropriate since first year students do not yet know what is required for engineering practice. This is a measure of customer satisfaction. The data show that students felt they were learning some of the skills and techniques they will need as engineers. Perceived relevance can be a strong motivator for students.

TABLE 3: STUDENT SURVEY DATA, SA=STRONGLY AGREE, A=AGREE, N=NUETRAL, D=DISAGREE, SD=STRONGLY DISAGREE

	SA	A	N	D	SD
*This course is a good introduction to the field of Engineering.	10	2			
*The robot design project was a valuable tool for learning engineering design.	10	2			
*I am better able to design a system to meet desired needs after taking this course.	8	4			
*I am better able to function on a team as a result of taking this course.	3	6	3		
*I am better able to communicate effectively as a result of taking this course.	7	2	2	1	
*I have learned important techniques and skills necessary for engineering practice.	8	4			

The data in Table 3 shows that most students feel their intro to engineering course gave them a good feel for what engineering and engineering design are all about. The one exception might be in how students felt about their ability to communicate. Even in this area, the majority students feel their ability to communicate has increased as a result of taking the course. This survey coupled with data from scores on labs, the project, and the final exam show that students did learn the engineering design process. Of course, the depth of that knowledge is only appropriate for first year students and not graduates of an engineering program.

V. JUDGING

Judges were instructed to evaluate the projects primarily on five criteria: technical complexity, conceptual innovation, a written report, a formal presentation and product marketability. Each area is equally important in the evaluation. The detailed evaluation criteria are shown below.

I. Technical/Software/Hardware
   a. Is the project complex?
   b. Was the hardware used to its capacity?
   c. Was the software original and fully functional?
II. Concept
   a. Is the core, underlying idea understandable, believable, innovative, creative, feasible, path-breaking, etc.?
   b. Was there feedback from the community? Did the feedback influence the project?
III. Written Report
   a. Is the written report thorough, clear, compelling, logical, elegant, and professional? (see Sample Written Report outline attached)
IV. Presentation
   a. Are presenters professional, confident, comfortable and enthusiastic?
   b. Is the presentation thorough, well structured, clear, compelling, logical, informative, and professionally delivered?
V. Market
   a. Does the project solve a problem? Could the idea be commercialized? Did the presenter make a good sales pitch?
   b. Was the video compelling?
   c. Was there any feedback from community members on the feasibility of the idea?

VI. CONCLUSIONS:

Survey data shows that students' are of the opinion that they have learned the basics of engineering design and something of the tools used in engineering. Data from embedded assessments within the course agree with the survey data. Although the initial experiment with the design contest has been a success further experimentation is needed. The course and contest were repeated in the spring of 2013. Improvements in assessments can be made by further student surveys to get information about the specific course outcomes.

For the 2012-2013 academic year the contest began in Fall semester before registration for the spring semester was complete. This made it difficult to get first year students engaged when they were not yet signed up for classes for the spring semester. The design contests are also held in Europe and China in in 2013. These contests have appealed well to upper-class students and graduate students who are capable of developing sophisticated FPGA-based designs. With the introduction of the chipKIT, an Arduino compatible system, it is now possible for the Digilent Design Contest to appeal to first year students in Engineering and Computer Science.

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Motivating and Preparing First-Year Students in Computer and Engineering Science

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***Abstract*—During recent years the interest in Engineering Studies has declined at universities both in the United States and in many Western European countries including Sweden. In addition, among those students that do enroll, an increasing number drop-out. This paper presents an attempt to mitigate these worrying problems in the form of a new kind of introductory course for first-year engineering students studying on a 5-year long Master of Science program in Computer Science and Engineering. The course is novel in that it takes a holistic approach to motivate and prepare students for their further studies. Core subjects and useful tools are mixed together into an intense 10-week course with 12 separate course modules on different topics, often running in parallel. The course has a total of 21 individual examinations to take, tasks to carry out, and deadlines to meet. The examinations and tasks are chosen among those common in our School of Engineering. Evaluations show that, although demanding for the students, the course works well and fulfills its goals.**

***Index Terms*—Engineering education, Computer science education, motivation, preparation, first-year student, freshman education, retention.**

I. Introduction

During recent years the interest in Engineering Studies has declined at universities both in the United States and in many Western European countries including Sweden [3], [15], [20], [24], [34]. In addition, among those students that do enroll, an increasing number fail their first theory courses in Mathematics and Physics and even drop out of their educational programs at an early stage. At our university, we have had a similar situation. Since the 90:s, and in particular after the IT-boom around the Millennium, the number of applicants to our 5-year long Master of Science[1] in Computer Science and Engineering (CSE) program had decreased quite substantially. First-year students had (increasingly) trouble coping with the first math courses and, in general, weak motivation, which is why many performed poorly and dropped out.

One natural approach is to address these problems as early as possible on a national, or even international, level and long before potential engineering students get to the point that they could actually apply to university [15], [19]. Examples involve information campaigns and the reformation of public schools. Also, universities carry out various activities to attract and keep engineering students [11], [12], [22]. Still, despite these efforts, many students do not go through with their studies. Becker [3] puts focus on an important reason for this, namely that university degree programs are poorly adopted. While engineering is fascinating and exciting to learn, many educational programs in engineering start with a lot of theory and hardly no practical content, which puts-off potential students who then instead go on to other advanced educations. From an industrial point of view, it would also be desirable to loosen up the traditionally very theoretical education in favor of a more holistic engineering education [28]. There is today indeed a trend among universities to develop courses in this direction [7], [17], [18], [33].

A. Contribution

To address these worrying problems, we have developed a new kind of introductory course designed for first-year engineering students in our 5-year long Master of Science program in CSE. Like many other introductory courses that seek to motivate by addressing core Computer Science topics without going into depth – Brookshear [6] give an example on what can typically by covered – this new course takes a holistic approach providing students with an overview and understanding of the vast area of CSE, its role and importance in the modern Information Society, its relation to Engineering Science as well as how it relates to and is used in business and academia. Integral parts focus in on technical problem solving and engineering while others teach students skills and tools that support them during the remainder of their studies. The course is independent of, but runs in parallel with, a first course on computer programming, and the two complement each other quite well.

The novelty, however, of this new course lies in how the topics covered are varied and combined during the course, and in how the course is setup and given by the instructor. In 10 weeks the students complete 12 separate course modules, all on different topics and activating the students in different ways. In total the students pass 21 examinations of different kinds chosen among those common in our School of Engineering.

To give some examples of activities, students interview research groups at the department and give presentations in conference-like settings. They learn about the professional engineer hands-on during study visits to companies. They program embedded systems using Arduino boards [2], create

[1] Students in Sweden enroll in these engineering programs for 5 years and go directly for a MSc degree without getting a BSc on the way. However, it is also possible to stop after 3 years with a BSc degree.

Q1	Q2	Q3	Q4
D0009E Introduction to Programming	M0009M Discrete Mathematics	D0010E Object-oriented Programming and Design	D0011E Digital Design
D0015E Computer and Engineering Science	F0004T Physics 1	M0029M Calculus	M0030M Linear Algebra and Calculus

Fig. 1. Courses in year 1 and the order in which they are given. Q1, the first quarter of study, starts in September, while Q4 ends in June. (D0015E is the course we present in this paper.)

3D-worlds and animate them in Alice [8], learn to typeset documents with LaTeX [26] (which they use later on in the course to write reports) and use UNIX [29] commands to go beyond what can be done in window-based operating systems. They study the historic developments that lie behind the engineering discipline, as we know it today, and read about scientists' views on what the future might bring.

The result is very pleasing. In questionnaire-based evaluations many students testify to the effectiveness of this course, how it brings them up to speed, and makes them interested. Even elder students, who took the course some years ago, still remember it and point out how it motivated and prepared them. Moreover, students, also those that do not show any clear signs of such abilities at the beginning, become more diligent, timely, accurate with details, and good at planning as the course progresses – all signs of a successful student and a good engineer.

B. Outline

Below we will go into detail about the course, its contents, design, and realization. Then follows an attempt to explain how the course works, and that it indeed works as intended. But first a few words on the local context in which the new course resides.

II. Background

The decline in interest among potential applicants, the difficulty first-year students had with their courses in Mathematics, and the ever falling retention rates had not gone undetected. In particular, the long trend of ever worse results in Mathematics troubled not only the faculty at our department but also the Department of Mathematics and the faculty board. So, in 2008, a decision was taken to redo the curriculum. Essentially, two changes were made in an attempt to give the first-year students a better start.

The first was that the start of the standard block of three consecutive courses of Engineering Mathematics traditionally given at the beginning of the first year – in the form of the three courses Calculus, Linear Algebra, and Differential Equations – was pushed forward half-a-year from Quarter 1 to Quarter 3. Instead an early CSE start was created (Fig. 1). The first semester was remade into containing courses on programming, an introduction, Discrete Mathematics, and Physics. Since students increasingly had such trouble with the Engineering Mathematics the idea was also to have the physics course, in essence classical mechanics, act like a warm-up mathematics course before reaching the Engineering Mathematics. Discrete Mathematics is – of course – a mathematics course, but one of more interest and direct use for CSE students.

The second change was that among the courses in this new CSE-early sequence, a new introductory course – the main subject of this paper – was added to give students an overview of the field of Computer and Engineering Science, motivate them, and prepare them technically, theoretically, and practically for the years to come and ultimately their carriers afterwards. It is beyond the scope of this paper to go into detail about the changes in the curriculum, how courses were re-arranged, and the reasons thereof. This paper is mainly concerned with the new course.

III. Course description

The course, known as *D0015E Computer and Engineering Science* [9], earns the student 7.5 ECTS[2] credits once completed. The course is given in Quarter 1, a roughly 10 week long period that starts in September, and designed so that the intended student spends a total of 200 hours studying in class and at home[3] (Fig. 1).

The course is part of our MSc degree program in Computer Science and Engineering, which is officially accredited under public Swedish law [32] and highly inspired by the ACM/IEEE Curricula Recommendations [1]. In the Fall of 2012, 62 students enrolled, which is a typical class size in the School of Engineering at our university.

A. Entry requirements

Apart from general requirements regarding on what level an applicant must master Swedish, English, and Mathematics to at all enroll at a Swedish university, engineering students are required to have a substantially stronger background in Mathematics and Natural Sciences. In practice, the largest obstacle for students interested in applying is the Mathematics requirement.

Being a first-year course, D0015E naturally has the same requirements. One should, however, note that although many students do also have a background in programming and other engineering related subjects, no such background is formally required. The youngest, and typical, applicant is 18 years old, and have been schooled for 12 years prior to applying.

B. Course aim

The course aims to provide an understanding of the vast area of CSE and its role in the modern Information Society. This is done in several dimensions. For instance, its relation to Engineering Science and how it relates to and is used in

[2]The *European Credit Transfer and Accumulation System* [13] aims to harmonize higher educations in Europe.

[3]One week of full-time study amounts to 40 hours and grants the successful student 1.5 ECTS credit. Students normally take two courses in parallel, studying 20 hours per week in each course.

business and academia. Integral parts of the course also focus in on practical problem solving and small engineering tasks where solutions are built using a combination of computers, electronics, and software. To be precise, after the course, the successful student

- can define the area of CSE, in particular with relation to other engineering disciplines but also Engineering Science in general by demonstrating an ability to integrate knowledge critically and systematically;
- is able to solve small technical problems using computers, and do so based on proven experience rather than theory and formal analysis;
- can identify and handle computer components, programs, and common computer equipment, in order to change the performance and function of a computer;
- knows about the main history of the area of CSE and can discuss the consequence the area has on the development of modern technology, sustainability, integrity, the equality of opportunity between women and men, and internationalization (globalization) by demonstrating an ability to make assessments informed by relevant disciplinary, social and ethical aspects;
- can account for how engineers with a degree in the area of CSE work, what their typical work tasks are and what methods they use in research, development, and administration, and show insight into current research and development work;
- is familiar with and can make use of modern computer-based technology for both spoken and written communication and collaboration over computer networks, and demonstrate a capacity for teamwork and collaboration with various constellations;
- is able to independently find scientific information, and use such information correctly and objectively,
- can plan and use appropriate methods to complete his/her own studies as well as advanced tasks within predetermined parameters for a successful academic career within the broad area of CSE.

C. Contents

The course consists of a multifaceted study of CSE as a subject area of its own, its history, distinctive character, and artifacts. These are theoretical artifacts like (formal) languages, models, computational problems, instances, and solutions as well as physical artifacts like computer programs, digital media, and electronics. In broad terms, the area is contrasted with Engineering Science in general, that is areas directly concerned with matter and physical building materials rather than instructions and computational devices.

The modules introduce to the students a number of problems and questions. Some of these are investigative in nature while others involve problem solving with computers or pen and paper. Computers and various software are used throughout the course. All problems or questions more or less highlight various aspects of the area of CSE as well as Engineering Science in general, and are carried out in connection with ongoing research projects at the department.

The students are also introduced to some useful tools, both technical and non-technical, handy not only during their years at the university but also as graduated engineers. They are taught, for instance, how to work in teams, give presentations, and perform interviews. Moreover, they get useful advise on techniques that improve their own studies, how they can get information from various sources and report scientific work.

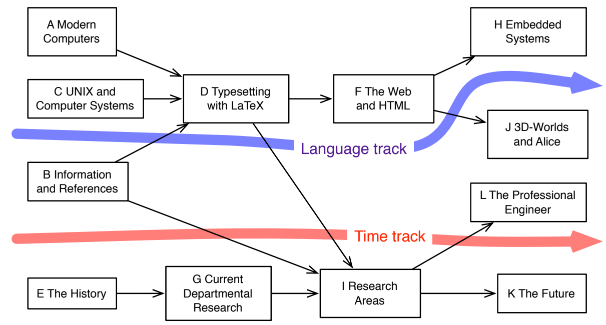

Fig. 2. Dependencies among the course modules and the two major tracks *(Formal) Languages* and *Time*.

D. Structure

The content of the course is divided into 12 separate *modules* labeled A-L. Each module is centered around a topic of its own, and is examined separately. These modules form two, although only loosey connected, parallel tracks (Fig. 2).

The first has as its theme *languages*, as in “formal languages for instructions”. It consists of the modules C, D, F, H, and J and introduce UNIX, LaTeX, HTML [23], Alice, and C [25] (which is used to program Arduino boards).

The second track is structured around *time* - the past, now, and the future. This track starts with a module on history (E), goes on to current research performed at the department (G) and vital areas of research (I), and ends with the future (K), as well as it can be predicted right now, and a glimpse of the life of the professional engineer (L) - the future of the majority of the students.

Below we list and describe each module. One should keep in mind, while reading the list, that the course is shallow in the sense that we do not go deep into theory and analysis in the modules. There is simply no room to squeeze in what would take several years of study into the course. On the other hand, this works fine and is sufficient because our goal is (merely) to motivate and prepare for future studies.

1) Module A – Modern Computers: In this module students learn about the major components that can be found in modern computers like the CPU, the mother board, cards (graphics and network), primary memory, external storage units (hard disks, DVD-readers, SSD devices, USB memory sticks etc), power units, common connectors, cords etc. In a theory part, they learn their function and are questioned orally. Then, in a practical part, they work in groups and disassemble a computer into its parts and open up components. (For this purpose, we keep a stash of old and broken hard disks and media readers through-out the year, and let the students break them before they are trashed.)

2) Module B - Information and References: This takes place in the university library and under the guidance of experienced librarians. Students are taught how to search for and retrieve trustworthy and peer-reviewed information – not just google for it as so many do – and use such information in a honest way in their own work. They are also informed about the rules concerning Academic Honesty. The module contains a test that is taken on-line in an LMS [16].

3) Module C – UNIX and Computer Systems: While all students are very tech-savvy, this module introduces something new to many: The operating system UNIX and low-level control of a computer via a command line interface. We cover commands for handling files, navigating file systems, and controlling processes but leave out more advanced topics like shell programming and system configuration. For most part of the course, although UNIX (or, in practice, Linux [30]) might run "under the hood", students use computers via one of the well-known window-based graphical user interfaces.

To pass, students first must write up experiences of their first week of study in a short document, convert it to pdf, and email it in from their university email account. Then they must complete a set of command tasks and document them with the UNIX command `script`.

4) Module D – Typesetting with LaTeX: Here students learn the basics about how to typeset documents with LaTeX. We go through the most common commands and environments ranging from overall document structure to details in mathematical formulas. The idea is to give the students the same academic typesetting tool as their professors, as well as to expose them to a formal (artificial) language with rigorous syntactic rules and semantics that resembles a programming language[4].

The examination has two parts. First, students are to produce a LaTeX-document identical to a master provided by their instructor. Then, their task is to complete and typeset a given (hand-written) solution to a high school mathematics problem.

5) Module E – The History: As the name suggests, this module covers – in a very broad sense – the history behind the IT revolution and modern engineering. Starting with prehistoric inventions like writing and alphabets we leap through the centuries while relating new technologies to human need and the development of society. At the end, we reach the age of electricity, mass production, computers, nuclear war, space explorations, the internet, gene technology, mobile phones, and much more. The module ends with a written test.

6) Module F – The Web and HTML: Here, the students are introduced to another formal language: Hyper-Text Markup Language (HTML). They are also taught the basics about the Web. Using a given set of tags, the task is here to produce a detailed webpage describing the organization and function of our university.

[4]TeX, and (of course) also LaTeX, is known to be Turing complete(!)

7) Module G – Current Departmental Research: In this module students interview research groups at the department about their research projects, and present their findings to the class in a conference-like setting. To do so they are taught how to prepare an interview, carry it out, documenting the result, and presenting it to the class.

8) Module H - Embedded Systems: Most computers are embedded and this module introduces the concept of embedded systems in the form of Arduino units that the students get to experiment with. This experimentation entails both hands-on wiring of electronic components on a board and programming different functionalities (using a simple subset of the programming language C). This is known as *physical programming*, as the system normally causes some noticeable effect. To pass, the students must complete a set of lab assignments.

9) Module I – Research Areas: In an attempt to give further insight into our research, and bring the students closer to the department, three professors give talks about their research areas. After each talk, the students write a short, but proper, report on a topic given by the professors. They must do so using LaTeX and on their own over a period of two weeks.

10) Module J - 3D-Worlds and Alice : Alice is a graphical programming system where programs are constructed to a large degree without typing. Alice is known for rapidly introducing someone to the ideas behind programming without having to go through the hassle of learning an old-fashioned programming language (which these students, of course, also eventually get to do).

Here students get the task to make up a 3D-world of their liking, and write instructions that describe what should happen in these worlds.

11) Module K – The Future: This is a group activity in which students investigate some given sources in the literature on likely future developments in the field of Computer and Engineering Science. Findings are reported back to the class in a presentation.

12) Module L – The Professional Engineer: Here, finally, the students go on study visits to companies and meet with professional engineers. Based on these visits, the students write up their observations in the form of a short report.

E. Realization

Although modules are separate as far as their contents is concerned, at any given instance of time, two, and often even three, of them are simultaneously going on (Fig. 3). This is intentional in order to have students plan their work on the various tasks and problems themselves in a diligent manner.

The course is taught via lectures using AV-equipment (not writing on blackboards), educational study visits and field trips, lab assignments, writing assignments, and project work. Students also take active part in presentation, feedback, performing interviews, and interacting in (and between) groups they have been assigned to.

The teaching is based on *Constructivism* (see, for instance, Biggs [4]), where the idea is that students construct their

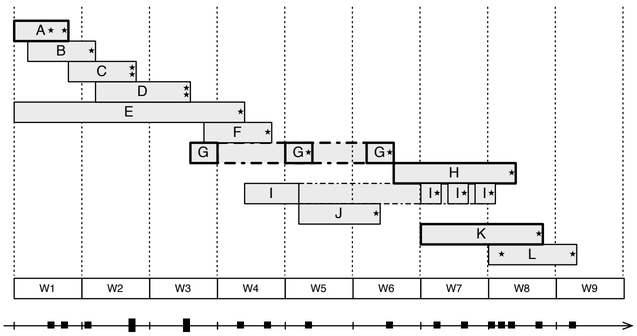

Fig. 3. A sketch of the timetable from W1 to W9, week 1 of study to week 9. Rectangles stand for modules, labeled A-L as listed in Section III-D. Stars indicate deadlines of examinations. Stars have also been projected down to black squares on the time-axis below the diagram in order to more clearly show the continuous nature of the examination that takes place during the course. Thick frames denote modules in which students work in groups.

Examination	A Modern Computers	B Information and References	C UNIX and Computer Systems	D Typesetting with LaTeX	E The History	F The Web and HTML	G Current Departmental Research	H Embedded Systems	I Research Areas	J 3D-Worlds and Alice	K The Future	L The Professional Engineer
1 Oral questioning	P/F					P/F				P/F		
2 Hands-on demonstration	P/F					1-3		P/F		1-3		
3 Submission on paper				P/F								
4 Written test					1-3							
5 Mail-in			P/F						P/F			
6 Task completed in an LMS		P/F										
7 Written report / reflection				1-3					1-3			1-3
8 Active participation							P/F				P/F	P/F
9 Oral presentation							P/F				P/F	
10 Interview							P/F					

TABLE I
KINDS OF EXAMINATIONS AND WAYS OF GRADING.

own understanding and knowledge of the world, through experiencing things and reflecting on those experiences, *Active Learning* [5] but with (passive) guidance first and (active) practice after that, and *Inductive Learning* [27]. The actual instruction is inspired by *Visible Learning* [21] in that the instructor, for instance, a) defines clear goals and criteria for achieving these goals, b) is clear about organization, explanations, examples, procedures, and assessments, and c) builds honest and trustful relations to the students by respecting their different backgrounds, listening to them, showing empathy and attention. The idea is that the student's confidence in the instructor creates a feeling of security, and that this leads to better results.

Each module starts with one lecture in which the instructor introduces the topic of the module. Then, students start working on the tasks, module E on the history being the exception in that it instead contains some additional lectures. In module H on Embedded Systems, for example, there are a number of lab assignments to carry out. For this purpose, students are divided up into groups of three people and lent a box containing an Arduino board together with some electronic components. It is then up to the groups to organize their work with the assignments either on their own at home or on certain scheduled lab sessions, when an instructor is also present (most do the latter). During lab sessions, students build small electronic circuits that they program, and have them checked. Guided by feedback from the instructor, they improve their circuits, in case they do not meet expectation, until they have gotten everything right. There is also an assignment in which it is up to the group to also come up with what to do (within reason) and then do that. Students build technical solutions in this manner also in modules C, D, F, and J. In contrast, G, I, K, and L are similar in that students are asked to gather information on their own and synthesize it. However, while students give presentations in G and K they write reports in I and L.

To aid the students in their work, and their planning, a publicly available course webpage [10] is maintained by the instructor. This page serves as a connection point and information central for the students. It contains slides, instructions, deadlines, extra material, and various links to useful resources. This web page, together with a book on history [31] and some unpublished material written by the instructor, makes up the course literature.

F. Examination

The examination is continuous throughout the course. Fig. 3 shows the distribution of the deadlines of examinations over time in a “Gantt chart”. In this chart, a rectangle corresponds to a module (identified by the letter). Rectangles are laid out horizontally in time-order going from left to right starting with modules A and E in Week 1 of study (W1), and ending with module L in Week 9 (W9). While module A starts and ends in the first week, module E goes on into Week 4. Each star denotes a deadline. The downward projections of stars onto small black boxes on the time-axis below the Gantt chart is provided to more clearly visualize the continuous nature of the examinations.

The methods of examination are deliberately chosen among those that are common within our School of Engineering such as written tests, reports, lab work and demonstrations, and conference-like oral presentations of findings to the class (Table I). The methods of examination varies throughout the course to prepare students for courses to come. In addition, participation on presentations, field trips, visits and other joint activities is mandatory.

G. Grading

Each module has one or more examinations each of which is graded. Although some problems require students to work together in groups, and be collectively examined as a

Year:	2008	2009	2011	2012	
Number of students filling out the questionnaire:	20	24	16	45	Average
"My overall impression is that this was a good course."	80,0%	82,0%	85,0%	75,0%	80,5%
"The workload is appropriate for the credits given."	78,0%	72,0%	81,7%	71,7%	75,8%
"The aims of the course are clear."	-	-	86,7%	71,7%	79,2%
"The examination was in accordance with the learning objectives."	-	-	81,7%	78,3%	80,0%
"I spent at most 20h/week (the intended amount) on the course."	-	-	93,6%	91,1%	92,4%

TABLE II
STATISTICS FROM QUESTIONNAIRES[5].

D0015E
Antal som klarat av kursen efter hur lång tid

		Students passing per semenster									
Year	Students	1	2	3	4	5	6	>6	∑ Failed	∑ Passed	% Passed
2008	33	0	28	0	1	0	0	0	4	29	87,9%
2009	53	37	5	2	0	2	0	0	7	46	86,8%
2010	49	38	1	2	0	0	0	0	8	41	83,7%
2011	47	30	3	0	0	0	0	0	14	33	70,2%
2012	62	48	8	0	0	0	0	0	6	56	90,3%
∑	244	153	45	4	1	2	0	0	39	205	
		62,7%	18,4%	1,6%	0,4%				16,0%		84,0%
			81,1%		2,0%						

TABLE III
NUMBER OF STUDENTS THAT PASS THE COURSE AND WHEN THEY DO SO.

These are high numbers. The imply that students cope with the highh workload.
62,7% pass directly after tthe course (all should idealy do this but that's unheard of).

Snittet: 83,8%

Pappa dog, experiment, första gången kursen gavs

Skulle vi bortse från 2008 så ännu fler klarar sig direkt efter kursen:

2009	53	37	5	2	0	2	0	0	7	46	86,79%
2010	49	38	1	2	0	0	0	0	8	41	83,67%
2011	47	30	3	0	0	0	0	0	14	33	70,21%
2012	62	48	8	0	0	0	0	0	6	56	90,32%
	211	153	17	4	0	2	0	0	39	205	84,02%
		0,725	0,081	0,019	0,000				0,160		
			0,806		0,019						

Snittet: 83,80%

group (shaded in Table I), all grades are set individually. Some examinations only give as result passed or failed while some individual examinations earn the student that pass a numerical score ranging from 1 (lowest) to 3 (highest, best). Table I also summarizes the two forms of grading done. Here, "P/F" means "Pass or Fail", and "1–3" means the grading results in a score. The final grade on the course is calculated from the scores obtained on the individual examinations only. To pass the course, however, a student must pass all examinations, not only those that give numerical scores.

IV. EVALUATION

To evaluate the course we have looked at three dimensions: The course itself, effects on the educational program it belongs to, and other effects. Regarding the course itself we have used a) summaries of feedback given on questionnaire-based evaluations all students fill out directly after the course (Table II), b) protocols from meetings with the educational board at the department, and c) official statistics over the number of students that pass the course and when they do so (Table III).

The questionnaires contain many questions and we choose here to only include results on five general ones, listed in Table II, that relate to the overall function of the course. As they are based on answers not only from students that have passed, but also all that had failed or were not yet done at the time the questionnaire-based survey was conducted, the numbers are very high compared to many other courses. Despite the high workload experienced by almost 25% of the students, still 92.4% of them spend no more time studying than what is expected. These are signs of a course functioning well.

In the protocols of the board, in which also higher-year students take part, the course is, in somewhat loose but still distinctive terms, deemed intense and demanding but in general good. We choose not to include them here since they only state summarized testimonies of those that are members of the board. The protocols are available from the university webpage [14].

The official statistics in Table III has been extracted out of the university database containing student records. These numbers are also very high compared to other courses. Directly after the course (after Semester 1), 62.7% of the students have passed; after the first year of study (Semesters 1 and 2), in practice just a couple of extra months, 81.1% have passed. If we would disregard the first, rather turbulent, year the course was given (2008), the number of students immediately passing the course would increase to 72.5%. The reason $10\% - 15\%$ never pass could depend on drop-outs. Furthermore, from student feedback given on other questions in the questionnaires than those listed in Table II, it is clear that the average student studied a bit differently in 2011. In 2011, the average level of attendance was for instance 4% lower than in 2012, and the amount of preparation/reading ahead before class was 9% lower. This difference might (perhaps) explain the sudden drop in Table III down to 70.2% that year. However, the course was given in the same way 2011 as in other years, so the reason why students studied somewhat differently in 2011 remains unclear. Anyhow, the overall results show that the course works well and fulfills its goals of motivating and preparing students in line with the aims of the course. Moreover, introductory courses, modelled and designed after the course we have described, have today also been created and included in the program in *Applied Physics and Electrical Engineering* as well as the program in *Space Engineering*, two other engineering programs at our department.

V. CONCLUSION AND DISCUSSION

We have presented a kind of introductory course designed for first-year engineering students in our 5-year long Master of Science program in Computer Science and Engineering. Like many other introductory courses it takes a holistic approach providing students with an overview and understanding of the vast area of Computer Science and Engineering. As we have

[5]Data from 2010 is unfortunately missing. The reason data is missing in 2008 and 2009 is because in these years the questionnaires were shorter and did not contain the same questions as they do now.

described, the course is novel in how it is divided into 12 separate modules with a total of 21 examinations in roughly 10 weeks. Despite being tough and demanding, the course works well and manages to motivate and prepare students for further studies in line with the aims of the course.

The first batch of students in the re-made educational program (see Section II), to which the new introductory course belongs, are soon about to graduate. This makes it possible to determine what effect, if any, the course might have on the retention rate through-out the engineering program, for instance via a study of student records. Here, a challenge is how to isolate effects caused by the course from those caused by the re-arrangement of the order in which courses are taught and other changes in the curricula.

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Evolution of a First Year Project Based Design Course

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***Abstract*—First year project based design courses may face several obstacles. The students have very limited experience in design, construction and realization of prototypes, and in testing and evaluation of their designs. Most first year introduction to engineering courses cover a wide variety of important topics, but lack a strong emphasis on design. Originally our Introduction to Engineering course was similar to those offered at other institutions. In 2004 the format and focus of this course was transformed into a project based design course for first year students. This paper discusses the changes that have been implemented over the past nine years, to the point where this first year course now contains most of the elements of more advanced design courses at our institution.**

Keywords—first year courses, design courses, project based education, prototyping, realization and evaluation of designs

I. INTRODUCTION

Many students choose to study engineering because they have a strong interest in design and the realization of their designs. Precollege programs and competitions, such as the FIRST Robotics competition [1], have capitalized on this interest and attracted large numbers of participants who later go on to study engineering. However, even in these programs, it is unlikely that a participant will be immersed in the complete design process from identification of need through to testing and evaluation of a prototype. For example, the FIRST competition defines the need for the robot as well as many of its critical design specifications.

Most engineering programs have a course directed toward first year students that introduces engineering. The goals of these types of courses are to introduce students to the engineering profession, provide advice on studying to become an engineer, introduce basic analytical, graphical and project management tools used by engineers, and develop communication skills. These courses may also include short sections on design methodology. There are many excellent textbooks available for use in these courses [2-4]. These courses and textbooks fulfill a well-defined need and have been very successful. Prior to 2004 WPI offered a similar course, Introduction to Engineering (ES 1020), that is offered every fall during the first 7 week term of the academic year. The course meets for one hour, four times per week. This course provided a general introduction to engineering and included topics such as explanations of different engineering majors, presentations from practicing engineers, computer programing and use of spreadsheets, problem solving techniques, project management tools and communication skills. At the end of the course there was a brief project where teams of students undertook a common project such as construction of a mousetrap powered vehicle or an egg drop container. The class usually culminated in a competition between teams. This course was very successful in fulfilling its objectives. However, the course project did not focus on using a structured process to achieve the final design nor did it require a realistic process for the realization of that design. While valuable elements were included in this course, it was felt that first year students would be better served by a course that focused exclusively on the design process. Thus, in 2004, ES 1020 was revamped into a project based design course directed towards entering first year students. Details of the initial offering of this new format have been previously published [5] and are briefly described in the following section. This paper reviews the evolution of this course over the past 9 years into its present format where it now contains most of the basic elements of more advanced design courses at our institution.

II. INITIAL COURSE FORMAT (2004)

It was anticipated that a first year, project based, design course would face three major obstacles. First, students would be relying almost exclusively upon their high school background. Second, most students would have little or no prior design experience and very limited hands-on realization experience by which to construct and evaluate a prototype device. Third, selection of appropriate project topics might prove to be difficult since the topics must be interesting and exciting as well as be able to be successfully completed within our 7 week term. Briefly, the students' design experience was rapidly built through the use of a design text that emphasizes case studies [6]. Early lectures focused on design methodology and the process of developing and weighting design specifications. Weekly quizzes and homework were used to insure that students kept pace with the material presented in the lectures and readings in the book. A reverse engineering laboratory was used to develop hands-on experience as well as an understanding of the role of components in achieving design objectives. In the initial offering, eight teams of 4-5 students worked on the same design project for a period of 4 weeks. Three weekly written progress reports were required. Each team was responsible for constructing a working prototype device and reporting their results in both oral and written form.

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In summarizing the outcomes of the initial offering of the course under the new format, we emphasized that proper selection of the project topic was the most critical component of implementing a project based, first year design course [5].

III. EVOLUTUTION OF THE COURSE

Successful elements of the course have been maintained, including the goals, format, textbook and general subject matter. Coverage of professional ethics, product liability, and failure analysis has been considerably enhanced. Weekly quizzes are still used to insure that students keep pace with the course. Several significant changes have occurred in the project based portion of the course. These changes include the method of forming student teams, the length of the project, the number and types of design projects available to the students, introduction of library research training, budgeting, increased focus on written and oral reporting and the use of peer and self-evaluation within the project teams.

Formation of student teams: Initially the students were responsible for self-assembling into project teams of four or five. Hence teams were randomly assembled to include newly made friends or simply from students sitting near each other in the classroom. The project topics were announced after the teams had been formed. This method often resulted in the formation of teams that lacked the full range of skills to develop a design, create a prototype and evaluate its performance. To partially alleviate this problem, a previously developed method for forming design teams based upon a company officer model was introduced to the class [7]. This method was already used in our upper level design courses and requires each student to interview before the entire class for one of four company officer positions on the project team (Chief Executive Officer, Chief Technical Officer, Chief Information Officer and Chief Manufacturing/Financial Officer). In addition to contributing to the overall project, each officer is responsible for managing/overseeing the specific tasks associated with his/her position. Student teams are then self-assembled based upon these interviews. The fact that ES 1020 enrolls 45-50 students ruled out conducting individual interviews in the classroom. Instead, the company model was introduced during the 4th class period and the students were instructed to consider its implications prior to forming project teams in the next class.

Length of the project: The project topics are now introduced in the 6th class period. This allows the teams to work on the project for 5 ½ weeks.

Project topics: Initially there was considerable concern about selecting appropriate project topics for the course. In the first offering, all teams worked on the same project. This approach had two significant disadvantages. Since the problem was not that sophisticated some of the designs were quite similar. In addition, unstructured design teams of five students seemed to result in unequal distributions of effort. In subsequent offerings, the instructor supplied 2-3 project topics and restricted teams sized to a maximum of 4 students. Meanwhile, our upper level project based design courses began to allow students to select either a structured (instructor defined) project or an unstructured (student defined) project [8]. In an unstructured project the student team has to develop the need for the project. Based upon the successes achieved in the upper level courses, student defined projects were introduced into ES 1020 beginning in 2011.

Library research training: Design projects require that students locate appropriate references for several aspects of the project including background research, benchmarking, patents, and sourcing materials for construction of prototypes. The majority of first year students lack the skills and/or knowledge of how to conduct proper literature searches in the areas related to design projects. Originally the instructor attempted to cover this material in lectures and encouraged the students to seek further help from the library staff. This type of approach proved to be unsuccessful. The instructor's coverage of the material tended to lack sufficient detail and the students usually did not follow up with the library staff. In 2011 the instructor asked a university librarian to help in present this material with the goal of improving the students' information literacy skills. The librarian now presents formal instruction to the class and directly encourages students to follow up if they encounter any difficulties. Additional details and results from directly involving a librarian in this first year project based design course appear in a companion paper [9].

Budgeting: Initially, the student teams were given an upper dollar limit that they could spend for supplies for building their prototype. With instructor approval and a good design, the project team could ask for addition funds. This process was later changed to better reflect the realities of the real world. The teams are now required to submit a budget application and have it approved by the instructor prior to ordering or purchasing any materials. The budget application must include a drawing of the design and a bill of materials related to the parts shown on that drawing. It is clearly indicated that better designs will receive higher levels of funding. There is a deadline after which budgets will not be accepted.

Peer and self-evaluation: Each student receives a small amount of credit (~1.5% of the total grade) for submitting a peer and self-evaluation form at the end of the course. The form asks the students to assess their own and other team members overall effort, their most significant contribution to the project and their overall opinion of working on the design team.

IV. PRESENT COURSE FORMAT (2012)

In the fall of 2012, 46 students enrolled in ES 1020. Twelve design teams, each comprised of 3-4 students, were formed during the fourth class period and the project lasted approximately 5 1/2 weeks. Four project topics could be selected from an instructor supplied list. Two projects were well defined and were oriented towards designing devices for persons with stroke. One of the structured projects was "to create a device to allow a person with one arm to dispense toothpaste onto a tooth brush" (Fig. 1). The second project was "to develop a device to enable a person to insert and remove a contact lens with one hand" (Fig. 2). In order to maintain diversity in the final designs, each of these topics was restricted to a maximum of 4 teams. Seven project teams chose one of these two topics. The two additional topics only defined broad areas in which the teams could develop their own project. These broad topic areas were “to develop an assistive device for a person(s) with a disability” and “to develop a toy for a young child with a disability”. Five project teams chose to develop their own projects within these two areas. These project descriptions are very general and were used in both 2011 and 2012. Fig. 3 shows an attendant pushed curb climbing wheelchair attachment that was developed in 2011. This device allows the attendant to sequentially first lift the front wheels of the wheelchair over the curb as shown in Fig. 3. Then the wheelchair is pushed forward so that the rear wheels touch the curb. The attendant then stands on the rear of the platform to raise the rear wheels of the wheelchair. In 2012 a student team developed a 3 dimensional cube puzzle for children who are blind or have low vision. Each cube has braille and a tactile raised figure on each of the six sides. Each face of the cube is also color coded to categorize similar objects such as clothing and body parts. This feature makes the puzzle attractive to both sighted children and those with low vision. Another 2012 project was to design a drawing board for a child with cerebral palsy. The writing/drawing instrument was attached to the board by a mechanism that provided damping for unintended motions. Another project developed an alarm clock for a deaf person based upon bright flashing lights. Weekly quizzes and homework were used to evaluate understanding of the course material developed in the text and lectures. A librarian created a website specifically designed for this course and appeared before the class to explain how to utilize it. Contents of the website include benchmarking against existing products, patent searching, utilizing design handbooks, sourcing components for constructing a prototype and referencing sources in written reports [9]. The design project constituted about 1/3 of the overall course grade and was based upon the 3 progress reports, the budget submission, the prototype and the final oral and written reports. For the oral reports, the student teams are required to submit their presentation slides to the instructor and teaching assistant on the day before the presentation.

Fig. 1. One handed toothpaste dispenser

Fig. 2. Contact lens applicator

Fig. 3. Attendant pushed curb climbing wheelchair

Fig. 4. Puzzle for children who are blind or have low vision

V. DISCUSSION

Many high school students are motivated to choose engineering due to a strong creative interest in design. Often, introduction to engineering courses focus on a variety of significant topics, while only giving limited attention to design and realization. Many engineering programs delay introducing true design courses until the second year or beyond, preferring instead to first build the students' backgrounds in mathematics, physics and engineering fundamentals. For creative students, this 1-2 year delay before they can express their creative talents may have a chilling effect on their overall interest in engineering. Others have noted that underclassmen tend to be more creative than their older peers but at this earlier level there is a need to focus this creativity into a more structured process [10]. First year project based design courses fulfill a significant alternative by allowing entering students to become immersed in real life engineering activities at the very beginning of their college careers.

The transformation of ES 1020 into a true project based design course occurred through a series of well-defined steps with each succeeding step based upon the success of the preceding ones. The initial step was to transform the academic content of the lectures through the use of a design textbook [6] and to introduce a 4 week design project into the course. It was felt that project topics had to be very carefully selected [5]. In the initial offering only a single project topic was offered to the class. In succeeding years, the time devoted to the project was increased as were the number of project topics offered to the student teams. The method of selecting teams was altered to encourage forethought as to the set of skills the group would need in order to successfully complete the project. As the course evolved some instructor supplied topics became less well defined and in 2011 students were allowed to define their own projects within broad guidelines.

The three required progress reports define general milestones that should have been reached within each preceding time interval. The progress reports allow the instructor to intercede with groups that are falling substantially behind the expected timeline for successful project completion. Students tend to chronically underestimate the amount of time that must be allocated to obtaining materials and constructing the prototype. Introduction of a formal budgeting process better modeled engineering experiences in the real world and created a firm milestone for developing a final design.

Historically, the overall quality of the final written reports had been a continuing problem due to the lack student understanding of how to access and utilize a wide variety of sources. Relatively few references were cited and most of those were websites of widely varying quality. Directly collaborating with a librarian has greatly improved this situation and is an ongoing effort [9].

First year students are generally not experienced in evaluating others, particularly peers. Peer and self-evaluation within project teams was originally introduced as an exercise, since it was a topic covered in the textbook [6]. The students are promised that their remarks will be confidential. When coupled with the company officer model of forming teams [7], peer and self-evaluation creates a situation where each student can objectively evaluate each team member's contributions including themselves with respect to their expected roles. The students' evaluations are generally very insightful and fair and reveal how groups of students with limited prior design team experience adjust and overcome difficulties in working with others. This information would not otherwise be available and has enabled the instructor to better understand and manage student project groups at this educational level.

Since most students lack prior design experience, the instructor has to balance the presentation of subject matter concerning design methodologies with the development of realization and construction skills for the project. Course evaluations reveal that the project based format of the course is very well received. Most students are enthusiastic about the project experience. The major student criticism is the "large amount" of work required by the course. However, these same evaluation forms show that most students report spending approximately 12 hours per week (including class time) on the course which is somewhat below the general expectations of our institution. It is important to note that most of our entering students graduated from high school near the top of their class and may not have been challenged to the same extent as they now are at the college level. The other significant student criticism is the number of required written reports. In addition to the progress reports and final report, the weekly homework assignments often include short written reports. It is clear that the value of developing written communication skills is not yet fully appreciated by this segment of the class.

In summary, project based design courses can play an important role in the first year engineering curriculum. These courses allow entering students to express their creative talents and engage in significant design activities that yield useful outcomes. Contrary to our initial concerns, it has been relatively easy for the instructor or even the students themselves to develop design projects that are suitable for this first year course. While projects and content in our upper level design courses are more sophisticated, our first year course now contains most of the elements found in these upper level courses.

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STEM Explore, Discover, Apply – Elective Courses that Use the Engineering Design Process to Foster Excitement for STEM in Middle School Students

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***Abstract*—Engaging students early in meaningful STEM experiences will help them maintain a level of interest in STEM fields later in life. However, the key is developing meaningful courses in STEM for K-12 students. These students not only need to have a "fun" experience, but a meaningful one, where they connect with, and develop deep understanding of the material being presented.**

STEM Explore, Discover, Apply (STEM EDA) is being created by the Cyber Innovation Center, a 501c not-for-profit as a middle school elective course. STEM EDA is designed as a three course progression through topics that foster excitement for STEM. The curriculum is designed to enhance the core science and math classes taken in middle school. STEM EDA begins by exploring STEM concepts (STEM Explore, 6th grade) then transition to discovering fundamental concepts (STEM Discover, 7th grade), followed by the application of the concepts (STEM Apply, 8th grade).

This work in progress will outline the framework for STEM EDA, including the various modules of the courses. Additionally, this paper will discuss how the engineering design process is integrated into the modules, how other disciplines are highlighted, and showcase a specific module in this innovative middle school elective curriculum.

Keywords*— *Middle School; Engineering Design Process; curriculum

I. Introduction

Research has shown that engaging students with valuable STEM experiences early can help students maintain their interest in STEM later in life [1]. Introducing middle school students to STEM topics in a meaningful manner can increase their likelihood of staying engage with STEM in high school and college [1]. Thus, there is a need for creating worthwhile STEM experiences for middle school students. This is evident by the national common core initiative. The common core standards for mathematics include incorporating lessons learned from previous classes to build on the students' knowledge [2]. Additionally, the Next Generation Science Standards (NGSS) outline the need for engineering to be included in K-12 classrooms [3]. Incorporating engineering principles early can build the students' problem solving and critical thinking skills as well as provide real applications to problems that students normally see as abstract [1]. Additionally, NGSS discusses the need for incorporating multiple disciples in classrooms [3]. By learning through a multi-disciplinary lens, students can make connections throughout their classes and the world around them, rather than looking at each course as a discrete subject [4]. Incorporating these aspects in the middle school classroom can provide the meaningful experience needed to maintain student interest in STEM later in life.

A difficulty, though, is creating that meaningful STEM experience; this is no easy task. Project-based learning, a popular pedagogical style, is typically employed in order to engage students. This pedagogy has been shown to be beneficial [5]. However, in many cases that pedagogy is abused; and so often, the intent of "project-based" is lost. Rather than using the projects to enhance the course and drive to the fundamental topics, the projects become the main focus and the fundamentals are neglected. This is not to say that the project-based learning should no longer be used in classrooms, but it should be used in that manner by which it is intended. A more "project-driven" approach should be employed, where the fundamental topics are the main focus and the projects are used to enhance the curriculum, engage the students, and most importantly "drive" to the fundamental concepts.

In order to address this issue on the middle school level, the Cyber Innovation Center was asked to create elective STEM courses for 6th, 7th, and 8th grades. In order to develop these courses, the curriculum designers decided to use "classic" science projects, while leveraging the engineering design the process to provide continuity, depth, and meaning to curriculum. Additionally, liberal arts context for each project will be included to provide deeper meaning to the projects as well help students make connections to the world around them, physically, culturally, and ethically. Thus the curriculum designers are developing STEM Explore,

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Discover, Apply (6th, 7th, 8th, respectively) using these characteristics.

II. Framework of Courses

The curriculum is being designed using a modular approach to each of the courses. STEM Explore, Discover, and Apply (STEM EDA) will capitalize on the "classic" science projects (e.g. the egg drop, volcano, catapult, bottle rockets) to drive to fundamental STEM topics as well as cultural and society applications. In order to provide continuity, depth, and meaning, within the various modules the curricula will leverage the engineering design process. The modules will incorporate a social studies, historical, and/or societal context to provide intellectual applications to the projects. Each level of the course will use the same themed project (e.g., module 1 is an egg drop for all grades), but will have different context and parameters, such that students will being doing completely different projects in each course. Additionally, the level of the fundamental concepts will increase gradually with each grade of the curriculum. Table I outlines the projected modules for each course in STEM EDA.

TABLE I. Outline of Course Modules

Weeks	Module
1 – 3	Egg Drop (Engineering Design Process)
4 – 6	Volcanoes
7 – 9	Musical Instruments
10 – 12	Catapults/Trebuchets
13 – 15	Electricity
16 – 18	Solar Ovens
19 – 21	Trusses
22 – 24	Boats
25 – 27	Bottle Rockets
28 – 30	Earthquakes
31 – 33	Racecars
34 – 36	Roller Coasters

Each module will span approximately three weeks. The students will follow the steps in Figure 1 throughout each three-week module. Students will be guided through each step by the instructor, while building their own inclination for the process.

In Step 1, students will learn how to interpret information and write a concise, but informative problem statement. In Step 2, student will learn to interpret information from articles. Step 2 will be a large focus of the modules, allotting for many of days in the three week module. Students will be given, and when appropriate find for themselves, applicable articles. Students will be challenged to read the articles and extract pertinent information. Students will have open discussions and sharing opportunities which will drive the learning of the fundamental content. During Step 3, students will learn to plan ahead. They will think of various solutions to the problem and organize their ideas accordingly. For Step 4, students will use their critical thinking skills and the information they learned in Step 2 to choose the best solution to the problem. After they have chosen the solution, they will begin to build the prototype of their design in Step 5. This will put their construction skills to the test as well as help them realize how something they design on paper and in their minds can be built in the physical world. Once the prototype is built, the students will move to Step 6 Test and Evaluate the Prototype. This is an essential step; students will see if what they built performs in the manner they intended. Finally, after testing and evaluating the prototype the student will reflect on the design and determine ways they can improve upon their design, Step 7.

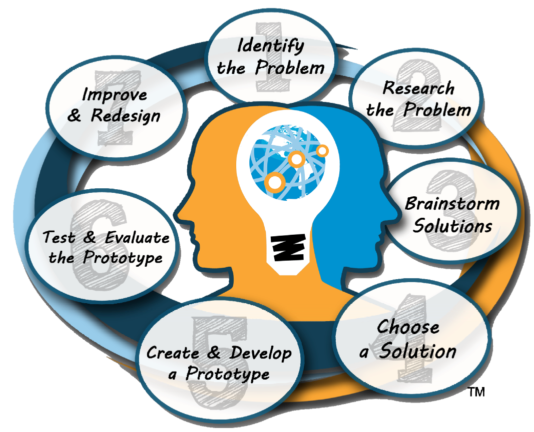

Fig. 1. Engineering Design Process

In addition to the engineering design process steps, the students will learn the overarching themes of the process: iteration, communication, imagination, and creativity. Students will learn that design is never completed and the process is based on iteration so that improvements can be made. Throughout the modules, students will be challenged to maintain communication with not only their teammate, but the instructor and other classmates as well. Heavy emphasis will be placed on imagination and creativity such that students are able to express themselves through the projects.

With each module, students are tasked with developing a creative story element related to the context and their design. Including the creative writing assignments will help the students develop their writing skills, while also helping them think through the context of the module and how their design applies to the context. Additionally, the creative writing assignment adds another layer of depth to the curriculum such that students are applying elements from other classes, like English, to a STEM course.

III. Example Module

The egg drop module will be first for each level of the curriculum. This project is based on the classic, "create a vessel to protect an egg from breaking as it falls from a specified height." Typically this project is completed over a two day time span, with one day for building a vessel. The next day, students drop the vessel hoping that the egg will not break. When done in this manner, often the fundamentals are over looked, and the activity itself takes the main focus. However, in STEM EDA, because of the engineering design process, time will be allotted to the research component. Therefore, the fundamentals concepts will be at the forefront. Additionally, since the egg drop is the first module of the curriculum, it will serve as the vehicle to frame the importance of the engineering design process. In STEM EDA, students will complete the egg drop module in the typical manner first, where they will build a vessel with little to no research or discussion on the fundamentals. The following day the students will drop the vessels. Many students will fail; this is okay because now the teacher has an opening to discuss why the vessel may not have performed as planned. This will be a natural lead into the engineering design process, where students will redo the project; this time, however, using the engineering design process as a guide. In each course, heavy emphasis will be placed on open discussion, where students will be asked to share their thoughts and designs with the class throughout the engineering design process.

A. Explore (6th grade)

The context for the Explore egg drop module is based on a stuntman jumping from a building. Students will be required to use only a select amount of materials such as cotton balls, Styrofoam cup, Styrofoam bowl, straws, limited amount of tape, and twine to build their vessel. Through the research process students will learn the concepts of gravity, force, velocity, acceleration, Newton's second law of motion, center of gravity, and mass versus weight. Prior to dropping the vessels students will have to calculate the force at which the vessel will hit the ground, and during the drop, students will determine the average velocity of their falling vessels. After constructing the prototype vessel, students will have to write a creative story on why the stuntman is jumping and how their vessel will keep a stunt man safe as he jumps out of a building.

B. Discover (7th grade)

The context for the Discover egg drop module is based on a skydivers jumping from a plane. Students will only be given straws, tape and a garbage bag to construct their vessels. Through the research component, students will learn about gravity, velocity, acceleration, law of conservation of energy, kinetic energy, potential energy, air resistance, and parachutes. Students will have to calculate the potential energy for their vessel. During the drop they will have to find the velocity of their falling vessels to determine the kinetic energy. Knowing the law of conservation, students will make the connection that energy was dissipated elsewhere since the kinetic and potential energy will not equal each other due to the parachute. They will then determine the amount of energy dissipated due to air resistance. Also, students will be tasked with writing a story about the skydiver and how their design will keep him/her safe.

C. Apply (8th grade)

The context for the Apply egg drop module is based on a dropping supplies to refugees in a foreign country. Students will be able to use various items like straws, tape, garbage bags, cotton balls, Styrofoam cups, Styrofoam bowls, and twine to construct their vessels. However an added element to the Apply lesson is the consideration of cost efficiency. Students will be given a budget, and must purchase the items for their vessels within the budget. The size of the vessel will also have a cost associated with it. The larger the vessel the more money the students will have to spend. Students will have to research the same concepts as Discover, as well as calculate potential/kinetic energy and drag. However, in addition to these concepts, the students will have to find articles of supplies being dropped to refugees in a foreign country. They will then use this information to write their creative story on the vessel design. Students will have to choose refugees from one of their articles, and incorporate factual information about them as they write their story from the view point from the pilot dropping the supplies.

IV. Conclusion

Currently two modules, the egg drop and volcanoes, have been created for all three levels of the curriculum, Explore, Discover, and Apply. The egg drop, which is used as the vehicle to demonstrate the necessity of the engineering design process, is being piloted at a local middle school. For the Fall 2013 school year, three to four middle schools will be piloting the curriculum. The designers intend to have five to six modules fully developed for the beginning of the school year. As the first semester concludes, the designers aim to have the remaining six to seven modules completed.

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Sparking Creativity in Computer Science for Interdisciplinary Students

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Abstract— **A class on Technologies for Creative Learning was designed to investigate the answers to a well-researched question: "What learning mechanisms spark creativity?" The class was offered for the first time at Oklahoma Baptist University during the Winter 2013 semester, and was structured to introduce computer science concepts to an interdisciplinary group of students. A key enabler of most learning mechanisms today is technology, and this class explored the use of various platforms in the design and functionality of learning through technology, using computer science as the learning objective. This work addresses the implications of programming and robotics to foster creativity in computer science and discusses the outcomes of the class.**

Keywords—computer science; interdisciplinary; robots

I. INTRODUCTION

"What learning mechanisms spark creativity?' was the question we sought to answer as we designed a new course in Computer Science at Oklahoma Baptist University (OBU). OBU is a liberal arts school, and students majoring in a wide spectrum of disciplines could be sought to understand the learning mechanisms that encouraged creativity. We designed a class on Technologies for Creative Learning to encourage creativity in Computer Science through the design platform of robots. We were inspired by similar classes at Massachusetts Institute of Technology [1] and at University of California, Berkeley [2] and at, where the classes were designed to study the impact of educational technologies. Our class, however, was designed to introduce computer science to interdisciplinary students through robotics [3]. To accomplish this, students were first introduced to various learning theories and programming environments [4]. These lessons were then applied to design creative projects using robots to form a culmination of computer science, creativity and learning by discovery in student-created projects.

II. CURRICULUM DESIGN

The curriculum was divided into three modules: Introduction to the Theory of Learning, Learning Computer Science Concepts and Creativity and Collaboration. Each module comprised of a learning phase and a testing phase. Information about each of these modules and associated activities are as follows.

A. Introduction to the Theory of Learning

The first week of class introduced students to the theories of learning [5] and innovation [6]. Students were encouraged to approach the class with the mindset of a kindergarten student whose learning mechanism can be represented by a spiral [5]. Since learning is a lifelong activity, it was chosen to be the key element of investigation and it was explored through the medium of computer science. As part of the design phase of this module, students were introduced to Scratch [7] through a two-fold assignment where they were asked to familiarize themselves with Scratch and build a simple project to introduce themselves to the class through a Scratch project. In the second part, students built a gallery of projects around a theme. For both of these assignments, students noted that while Scratch was intuitive to learn, the most challenging part of the assignments was figuring out the theme of the individual project and the gallery of projects. This simple experiment demonstrated the utility of programming platforms that could be explored by students of various backgrounds. Through Scratch, students were introduced to computer science concepts such as decision structures, loops, I/O, synchronization, functions, algorithms and OOP.

The second half of the design phase introduced students to multi-agent modeling using Netlogo[8]. Students were encouraged to explore the library of models available in Netlogo and modify the simulation parameters of the models and observe the varying outcomes. Through this assignment, the class was introduced to concepts in randomness, swarm intelligence and simulation mechanisms. Scratch and Netlogo formed the cornerstones of learning about computer science in this class.

B. Learning Computer Science Concepts

The second module on Learning CS concepts expanded on the knowledge of Scratch that the students gained in the first modules. Using the software environment supported by Alice [9], students used the design platform of the Finch robot [8]. This module focused on learning by discovery, where they explored Alice based on their knowledge of Scratch and programmed a Finch robot. Robotics was chosen as the design platform in the design phase, since robotics is an important tool in cultivating an interest in computer science. Since robots are a cultural construct in our world, robotics can inspire cross-

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disciplinary interest in students and foster creativity and collaboration. The individual projects were judged by a panel of judges for their novelty and execution. The projects that were built consisted of robots that danced, moved around a maze, a robot that hid from light, a robot that avoided obstacles and a name-tracing robot. The programming of these robots required students to understand the functionality of the various sensors in the robot, and use their knowledge of programming concepts introduced in the first module.

C. Creativity and Collaboration

This final module on Creativity and Collaboration was designed to tie in computer science concepts, learning theories, collaboration and creativity. The final module was a group project whose theme was 'The Social Life of Robots'. The interpretation and implementation of this theme was left open to students. The students decided to program the robots around a pursuit-evasion game called Zombie tag. The rules of the game were designed as follows:

1. The game starts with one robot being the Zombie, and the rest of the robots are Humans. Zombies move slower, and only in straight lines, while Humans (who can launch into panic at the sight of a zombie) can move around in any direction and faster than Zombies. A Zombie's LED (the beak of the Finch robot) is green, and that of the Human is purple.
2. The Zombie's aim is to tag (pursue) a Human, while the Human seeks to evade the Zombie(s). The tag is accomplished by touch between the robots. As soon as a Zombie tags a Human, the Human Finch's beak turns green to signal that it is now turned into a Zombie and adopts all the characteristics of a Zombie. The game continues with two Zombies pursuing to tag the remaining Humans. This process continues till there is one Human left, who now becomes the initial Zombie for the next round of Zombie tag.

The design of this game is interesting for two reasons: first, a group of interdisciplinary students designed a game around a classic game-theory concept, and second, it involved distributed programming. The Zombie that started the game could be any robot, and all the robots seamlessly switched from Human mode to Zombie mode upon being tagged. The initial computer science concepts and multi-agent modeling were implemented through robots at the interface of computer science and game theory. Considering that there was no requirement for previous programming experience, in the true spirit of interdisciplinary learning, this class touched on educational research in the areas of cognition, psychology, education, computer science and programming.

III. Class Outcomes

Surveys were conducted to assess the outcomes [11] of this pilot offering. At the start of the first module, students were asked to note their most challenging experience out of the following three choices: learning to program, learning to share and learning to ride a bike. This question was adopted from [5], and the responses were typical. The non-computer science majors unanimously chose 'learning to program'. At the end of this class, this response changed, with 75% of the non-computer science students choosing an option different from 'learning to program'. Additional questions on the survey asked students to reflect on the kindergarten model of learning: (Imagine, Create, Play, Reflect, Imagine) and to note their most interesting and challenging parts of this spiral in learning about computer science. 'Imagine' and 'Create' emerged as the top two answers for the entire class. The entire class picked 'Programming the Finch' as the most fun task out of a list of options that included reading assignments, maintaining a blog, programming in Scratch and exploring Netlogo. However, the cost of the robots was a limiting factor in the breadth of robotics assignments that could be made possible for the design of this curriculum, and was stated by students as an element that needed to be addressed for future versions of this class.

IV. Results and Future Work

The pilot offering of this class generated a huge amount of interest on and off campus. We are planning to offer this class every Winter term, and expand the offerings available to students in terms of robotics projects that students can work on. Plans are underway to establish a robotics lab, and we are investigating various modes of curriculum design to continue sparking creativity in computer science in a liberal arts environment.

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Increasing Student Interest in STEM via the Kensington Kinetic Sculpture Derby

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Abstract—**This paper will explore a project associated with the National Science Foundation STEM GK-12 Program at Drexel University titled "Catalyzing STEM Education via the NAE Grand Challenges" (http://www.engineeringchallenges.org) that serves to address the need for more STEM educated workers. Specifically, the Drexel NSF STEM GK-12 program pairs ten College of Engineering graduate students (Fellows) with ten School District of Philadelphia high school teachers to help introduce engineering concepts to high school students through the context of the National Academy of Engineering (NAE) Grand Challenges. This work in progress explores a high school vehicle design project as part of the Kensington Kinetic Sculpture Derby (KKSD) facilitated by a fellow/teacher partnership at Central High School, an urban school in Philadelphia comprised of 40% underrepresented groups in the STEM fields. A unique feature of the project is that students from the IB Design Technology course were grouped in an interdisciplinary team with other students from World History and Sculpture classes to develop a vehicle based on the structure of a bicycle.**

Keywords— STEM; K-12; Engineering Design

I. Introduction

The Kensington Kinetic Sculpture Derby (KKSD) (http://kinetickensington.org) is a design competition featuring human powered kinetic sculptures on display in a parade. It was started in 2007 and has since grown to have dozens of entries and thousands of spectators. For this project, twenty-three juniors from the IB Design Technology class, twenty-five juniors from the Sculpture class, and sixty-six freshmen from the World History class at Central High School in Philadelphia were split into eight groups of fourteen to sixteen students with about three IB Design Technology, three Sculpture, and eight World History students per group. World History class students led the project team in researching the culture and historical time period of the vehicle design and acted as clients presenting a product idea/request to the IB Design Technology students. IB Design Technology students were then tasked to incorporate what they had learned about product design, mechanical design, system design, as well as other topics from the course to design a vehicle. The World History students were tasked with building the kinetic sculpture, while IB Design Technology students designed and built three kinetic devices to affix to the sculpture that would satisfy the kinetic requirement of the derby; these devices had to move due to human power. The Sculpture students were the aesthetic design leads of the project.

The goal of the project is to not only improve interest in STEM career paths for the IB Design Technology students but also to increase aptitude for STEM fields in the liberal arts students.

II. Methodology

To measure the students' abilities and interest in STEM fields, a survey was given to all of the students at the beginning of the project. It asked three questions of the students: 1) Rate your ability in math and science; 2) Rate your interest in STEM fields; and 3) Rate your likelihood of majoring in a STEM field. These questions were all answered on a scale of 1 to 4 with 1 being not interested at all or not very likely, 2 being somewhat interested or somewhat likely, 3 being interested or likely, and 4 being very interested or very likely.

In order to determine the effectiveness of this project, an after project survey will be given to the students to determine the impact the project had on the students perception of STEM fields. This survey will have the same questions as the first survey but will have additional questions in order to more accurately quantify the impact this project had on the students as well as gather feedback from the students to use in improving future implementations of the project. These additional questions will be: 1) Would you recommend this project to your peers; 2) What did you like about this project, what did you not like about this project; and 3) What would you change about this project.

III. Preliminary Findings

About 80% of all the students (82% of the IB Design Technology students, 72% of the sculpture students, and 83% of the world history class) said they had above average ability in math and science. However, there was a marked difference between the classes in the responses to the other two questions.

In the IB Design Technology class, 68% of the students were very interested in STEM fields, but only 8% of the Sculpture students felt the same about STEM fields. Fifty-nine

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percent of those same IB Design Technology students said they would be very likely to major in a STEM field in college (Figure 1), but compare that to the Sculpture class where 12% said they would be very likely to major in a STEM field in college (Figure 2). This is to be expected somewhat because these students are juniors who are in specialized elective classes that interest them. They already are in the process of thinking about what they want to do after high school and have been evaluating what interests them leading to a marked difference in the survey results about which students are interested in STEM fields.

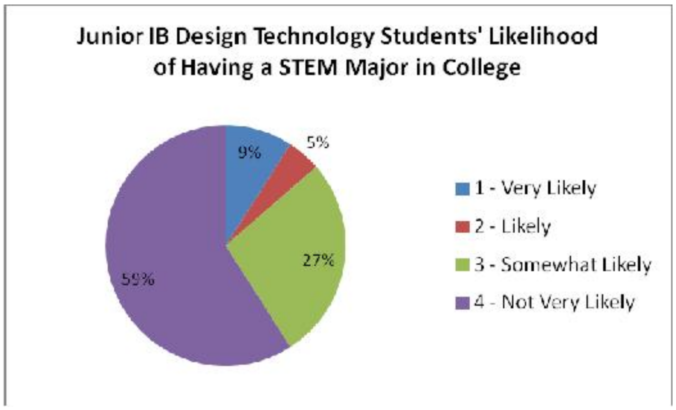

Fig. 1. Pie Chart of Junior IB Design Technology Students' Likelihood of Having a STEM Major in College

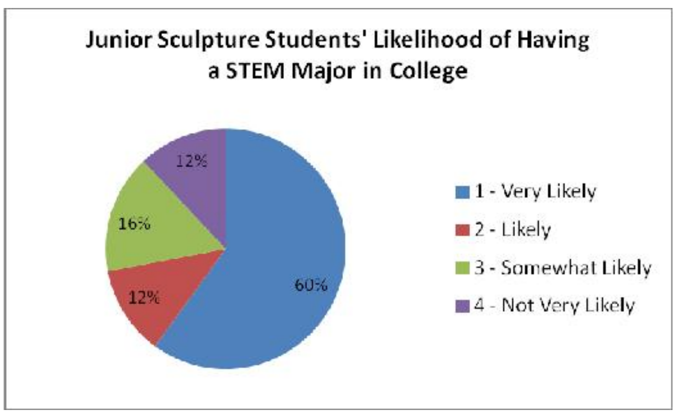

Fig. 2. Pie Chart of Junior Sculpture Students' Likelihood of Having a STEM Major in College

Looking at the freshman World History students shows that 32% are interested and 37% are somewhat interested in STEM fields. The students split the last question pretty evenly with each response receiving about 25% of the selection from students on whether they would likely major in a STEM field in college (Figure 3). These freshmen have the most variation in the survey responses out of all the classes, which makes sense since they are the youngest students involved in the project. This is also the group of students with the most potential for change because they are only freshmen and have not had much experience with STEM fields before, so this project will hopefully increase their interest in these fields.

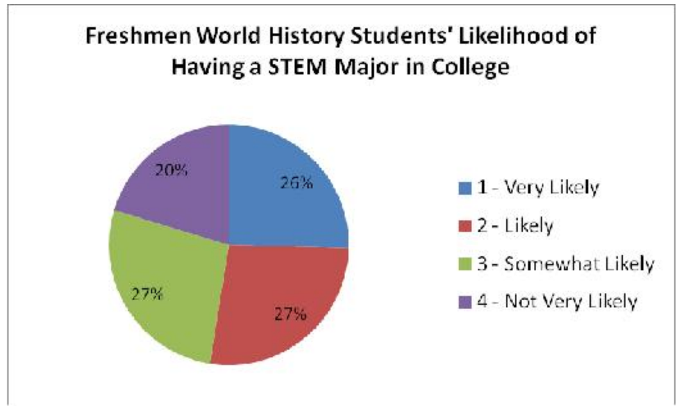

Fig. 3. Pie Chart of Freshmen World History Students' Likelihood of Having a STEM Major in College

IV. Conclusion

Using the survey to broadly characterize the students, it can be said that the IB Design Technology students are the most interested in STEM fields, the Sculpture students are the least interested in STEM fields, and the World History students have no clear consensus among them. However, students from all classes learned through inquiry what aspects of STEM related fields do or do not interest them. Student interest in STEM fields is evaluated by a pre and post project survey that asks students to rate their interest in STEM fields and their likelihood of majoring in a STEM field in college. The post project survey has not yet been given, but will given once the KKSD has finished. These survey results will be compared with the pre project survey results at the conference.

Additionally as a result of the project, the IB Design Technology students discovered a way to practically apply the engineering concepts they have learned in a meaningful project as well as explored the nature of customer relations by translating customer desires into a manageable reality by working with their clients, who in this case were the World History students.

V. Future Work

As previously stated, in order to determine the impact this project had on students, an after project survey will be given to the students. The results of the final survey will be compared with the pre project survey and used to help improve the project for future iterations.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. DGE-0947936. We would also like to thank the Drexel University Department of Electrical and Computer Engineering and College of Engineering as well as the School District of Philadelphia. Many thanks to all Drexel GK-12 partnership schools, Teachers, Fellows and project co-investigators for your efforts.

Curriculum Integration for the ECE Undergraduate Core Courses in Electronics

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Abstract - **This paper discusses the work in progress to restructure the Electronics curriculum in the Department of Electrical and Computer Engineering (ECE) in order to improve the system integration learning experience gained by the undergraduate students. The goals of restructuring the ECE Electronics curriculum are as follows: a) train and prepare students to design and analyze complex electronic systems first at the subsystem and system level before teaching and learning electronics at the component level; and b) strengthen the infrastructure for the system integration learning experience with other courses such as power electronics through the use of integrated projects developed for the Electronics curriculum. To realize these goals, the curriculum of Electronics I and Electronics II are redesigned. Electronics I is designed to focus on the design and analysis of electronic circuits, devices, and processes at the system and subsystem level. Electronics II is designed to focus on the study, operation, and analysis of electronic circuits, devices, and processes at the component level. Centralized projects are selected as platforms to allow students to develop the skills in designing and analyzing electronic systems. The students' performance and survey show that the Electronics curriculum restructure has a positive impact on students' learning.**

Keywords - Curriculum Integration; Electronics; Restructuring.

I. Introduction

Curriculum integration is getting more and more attention [1-3]. The subject matter of *Electronics* constitutes one or more core courses taught to electrical engineering students. In the ECE Department at our University, both Electronics I and Electronics II are offered. Traditionally, the focus of Electronics I has been the study, operation, and analysis of electronic circuits, devices, and processes at the component level. Topics include the "I-V" characteristics, the DC load line and operating point, the AC load line, large signal and small signal analysis of electronic circuits comprising diodes, transistors, and operational amplifiers. Electronics II focuses on the design and analysis of electronic circuits, devices, and processes at the system and subsystem level. In our ECE Department, students can focus on one of the two tracks: *Electrical and Electronics* track and *Computer Engineering* track. Students in the *Electrical and Electronics* track are required to take Electronics I and Electronics II. Students in the *Computer Engineering* track only need to take Electronics I. As a result, students in the *Computer Engineering* track miss the opportunity to learn electronics at the system or subsystem level or know how to integrate the learning at the component level with electronic system and subsystem design. In addition, we learn from our past experience that students in general have difficulty to integrate what they learn in electronics with advanced subject matter such as Power Electronics. The Electronics curriculum is restructured to better prepare students' system integration skills in both tracks first so that at the minimum students will know how to integrate what they learn to other courses.

In the new infrastructure, Electronics I is designed to focus on the design and analysis of electronic circuits, devices, and processes at the system and subsystem level. Electronic circuits and processes are explained through the integration of subsystems comprising electronic devices such as oscillators, voltage regulators, and switching circuits. The electronic devices and operational amplifiers are studied from a cause-effect standpoint. Centralized projects are selected as platforms to allow students to develop the skills necessary to design and analyze electronic systems. The laboratory activities are redesigned to deliver the required training to students in system design and integration skills and needed for related subjects such as Power Electronics. Electronics II is designed instead to focus on the study, operation, and analysis of electronic circuits, devices, and processes at the component level.

With the new infrastructure, *Electronics I* prepares students with knowledge of electronics at the system and subsystem level. By successfully completing this course, students will have the ability to analyze and design complex electronic systems. Students can apply software skills learned in the course to the analysis and design of electronic systems.

Electronics II provides the students with an understanding of the characterization and operation of electronic components. The students will acquire skills with contemporary software tools to analyze the characteristics and performance of basic and advanced electronic components.

This paper is organized as follows. The course outcomes are discussed in Section II. The development of centralized projects is described in Section III. The assessment of the effectiveness of the electronics curriculum restructuring is shown in Section IV. Finally, concluding remarks are given in Section V.

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II. Course Outcomes

The course outcomes for *Electronics I* and *Electronics II* are listed below. Each course outcome maps to a specific ABET-approved student learning outcome.

A. Electronics I Course Outcomes:

1. Comprehend the electronic design process at the system and sub-system level
2. Demonstrate skills to analyze and design electronic circuits, devices, and processes at the system and sub-system level
3. Demonstrate skills to analyze and design complex electrical and electronic systems

B. Electronics II Course Outcomes:

1. Demonstrate skills to analyze electronic circuit at the component level
2. Demonstrate the ability to characterize electronic components
3. Demonstrate skills to use contemporary software tools for electronic circuit analysis

The primary aspect of the redesign is to deliver the content in modules which focus on a *central electrical engineering project* that uses the drive board design of a DC motor for an electric GOLF cart [4] as platform.

III. Development of Centralized Projects

To develop the centralized platform, the drive board for the DC motor of the electric golf cart is designed. The schematic design for the drive board of the DC motor is shown in Figure 1. The printed circuit board (PCB) design is shown in Figure 2. This system includes the following subsystems: 1) controller system; 2) power supply; 3) programming status indicator; 4) temperature test circuit; 5) PWM signal connector and MOSFET driver. The drive board system and the related subsystems are used as the centralized platform projects for the redesigned courses. Students use Printed Circuit Board (PCB) design software (Cadence Layout Plus) to design PCB and PCB maker (LPKF ProtoMat) to produce PCB. The projects are done progressively throughout the semester. A set of similar large system projects will be developed and rotated through each semester.

IV. Assessment

The students completed an online survey to rate the effectiveness of the courses through an online Outcomes Assessment system: EvalTools® [5]. The feedback from the students has demonstrated the effectiveness of the courses in delivering critical system and subsystem level skills and competencies. The following are samples of student comments in the course survey.

- *I feel that the material we covered in class was very efficient with what we were doing in lab.*
- *I liked that after having Electronics I, things in Electronics II made a lot more sense and we were able to build upon what we already knew.*
- *I liked that we were able to put into practice with what we were learning in the class.*

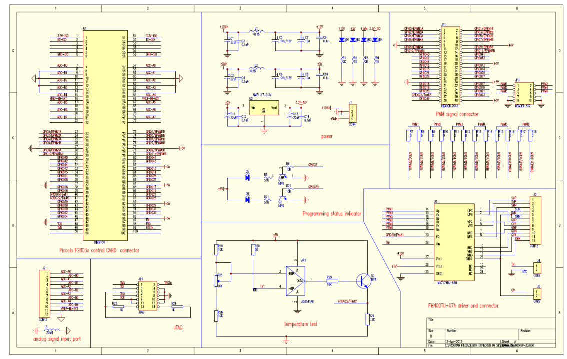

Figure 1. The schematic design for the drive board of the DC motor.

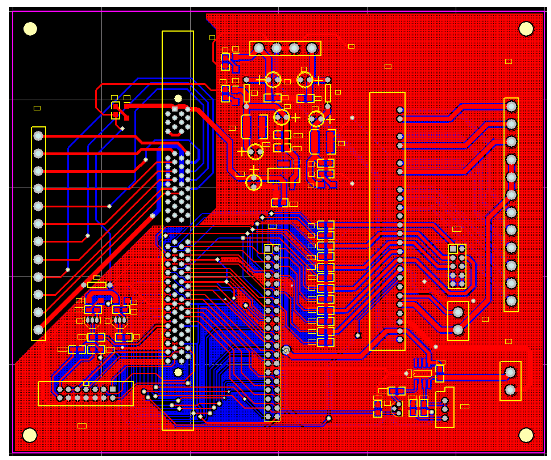

Figure 2. The printed circuit design for the drive board of the DC motor.

The students' performance and survey indicate that teaching with the restructured Electronics Curriculum helps students understand electronics concepts better and improves their system integration skills.

V. Concluding Remarks

The redesigned courses strengthen the understanding and skills required for electronic system design & integration and improve the preparation of students for industrial projects. The centralized projects provide a platform for restructuring the undergraduate electronics curriculum to incorporate the teaching pedagogy. The students' performance and survey demonstrates that the restructure of the electronics curriculum has a positive impact on student's learning. A rubric for assessment of the course outcomes is being developed and will be employed for measuring the effectiveness of system, subsystem, and component level teaching and learning with this curriculum integration.

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First-Year / Senior Year Design Data: Preliminary Results from Ongoing Research on Post-secondary Design Student Activities

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***Abstract*— The College of Engineering at Embry-Riddle Aeronautical University requires its students to take a semester long engineering profession and project-based design course as first-year students and a capstone project-based design course over the span of two semesters as seniors. There is a desire to ascertain the actual and normalized time, process progression, and traffic patterns of engineering student design project teams navigating a design process and gauge these metrics across engineering majors and against faculty impressions and expectations, with an eventual goal of gauging against professional practice as well. Once student design activity application is analyzed with respect to faculty and professional expectations, pedagogical and curricular content adjustments can be made as necessary to align these project-based, experiential learning activities with perceived practice. The analysis of student progress compared to faculty and professional perspectives will provide an opportunity to dissect and reinforce the foundation of engineering design education at the University.**

Keywords—engineering design education; design process; senior design; capstone; first-year engineering; freshman engineering; cornerstone; project-based learning

I. Introduction

Properly designed cornerstone design projects can potentially address most, possibly all, of the ABET 2000 Criteria to varying extents throughout the project. Cornerstone design coursework supports constructionist pedagogical theory and incorporates instructional strategies that are student-centered and promote active learning while addressing a variety of learning styles [1]. When compared to the traditional lecture environment, the enhanced environmental similarity of cornerstone (and capstone) experiences to the engineering workplace fosters more transferability and provides the student with importance and reason for that which they are learning through simultaneously applying content in the instructor-provided context as they learn it, as shown by several studies reviewed by Prince and Felder [2]. The importance of design in engineering education curricula is emphasized by Dym [3].

Freshman and senior level student application of and transitions within the design process are studied using short design scenarios [4, 5] where it is shown through verbal protocol analysis that senior level students showed greater numbers of transitions throughout information processing phases, possibly correlating to greater process efficiency, and a higher quality paper design. These studies of freshman versus senior engineering student applications of the design process through short, open-ended scenarios are somewhat analogous at the micro level to the ongoing study discussed here of engineering student applications of the design process through existing term-length and mini design project-based learning curriculae at the macro level in a full-term project experience.

Teaching in a student-centered manner allows students to incur educational experiences that straddle many learning styles to satisfy the needs of the heterogeneous student body. Project-based learning by its nature incorporates much of the spectrum of learning styles. Project-based learning also invokes many pedagogical approaches and theories throughout its application. This work in progress presents preliminary results from an ongoing study [6-7] on engineering student design activity with the eventual goal of comparing student activities against the practices and prescriptions of design experts in academia and industry.

II. Purpose

This study investigates student application of design process scaffolding provided to students in first-year and senior year engineering design project experiences by measuring student activities as students navigate various phases of the design process and manage their projects.

Questions considered in this ongoing study include:

- Is the design process and project management scaffolding provided to first-year engineering students in cornerstone experiences appropriate?
    - How much time do students spend on each phase of the design process and project management phases of the cornerstone design project?
    - What is the frequency of and what design activities comprise iterations in the phases of the design process and project management?

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- How do student weekly activities compare to desired (expert) practices?
- How do these metrics vary, if at all, across different design projects?

III. Methods / Procedure

In current efforts to address research questions, students' application of the engineering design process is monitored via biweekly surveys throughout their design project experiences. The student team data collection is currently ongoing and uses the information provided by the senior design courses of the Mechanical Engineering Department and the Freshman Engineering Department's EGR 101: Introduction to Engineering project data. The data is collected through an anonymous survey instrument that has a list of potential activities visited during a design effort. The current version of the survey was informed by a pilot study, a literature review, and faculty survey. In this latest version of the survey, students provide section and team identifiers, the time spent on each design activity, the number of group members who participated in each activity, the number of visits to each activity, the two-week time period during which the activities occurred, and the design activity visited prior to each activity being addressed. The Design Process Weekly Survey is shown in Fig. 1.

NUMBER ORDER NOT IMPORTANT; JUST A LABEL	ACTIVITY WITH EXAMPLES / DESCRIPTION	TIME TOTAL HRS:MIN SPENT HERE SINCE LAST SURVEY	PARTICIPANTS NUMBER OF PEOPLE WORKING ON THIS	VISITS TOTAL NUMBER OF VISITS SINCE LAST SURVEY	VISITED FROM LIST PRECEDING STEP NUMBER PRIOR TO EACH VISIT HERE
1	Needs Identification, Problem Definition/Statement/Identification/Analysis				
2	Requirements, Constraints, Limitations, Timing, Resources Identification				
3	Brainstorming, Design Concepts, Idea Generation, Solution Paths, Alternatives				
4	Investigate, Research, Test, Analyze, Evaluate Concepts/Ideas/Potential Solutions, Selections				
5	Modeling/Prototyping, Build				
6	Investigate, Research, Build, Test, Analyze, Evaluate Models/Prototypes				
7	Detailed Design, Production/Working Drawings, Communication/Documentation/Reporting/Presentation				
8	Production, Marketing, Distribution				
PM	Project Management and Teamwork Time and Resource Management and Task Scheduling, Team Communications				

Fig. 1. Design Process Weekly Survey.

This survey was changed from the pilot version from the previous academic year after querying for the students' opinions on ease of survey comprehension and the procedure for populating it. The most significant difference between survey versions is previously each activity was called a step and each step featured only one definition. The current survey has multiple definitions of each activity to better accommodate each professor's choice of terminology and explanation of the design process. Another difference is that the previous survey did not query the students on the originating activity that immediately preceded the current activity for which students are providing visit time and instance quantity data.

A. Data Collection

The surveys were given to observe how student teams work through a design cycle during a project. The design survey was given to two specific groups, the Mechanical Engineering (ME) senior design students and the freshman EGR 101 students. EGR 101 is Embry-Riddle's introductory engineering course. This class takes up 2.5 to 3 hours a week and the projects are mostly done outside of the classroom with a few classes working in a lab. Senior design students work on one project over two semesters and have class for 3 hours per week, but most students work many hours outside of class as well. The students were asked to separate into their project teams to complete the survey. Also, a majority of first-year students complete several mini projects throughout the semester rather than one large project for the entire semester. The EGR 101 surveys collected for this study addressed one mini-project.

B. Frequency and Schedule

The design surveys were given out biweekly throughout two semesters for the senior design students and two to three times in one semester for the first year students. The first year students were given the surveys once after the first week that the project was assigned, one to two times during the middle of the project and once again at the end of the project. The senior design students had a graduate student familiar with the design survey proctor each biweekly meeting. Due to the great number of sections, the first year students were proctored by their professors who received a briefing on the design survey.

C. Faculty Surveys

Engineering design faculty were also surveyed. Faculty were asked to indicate design process scaffolding provided to their students, how students are expected to apply the design process, student levels of preparedness and relative weaknesses before, during, and after project experiences, and how student design application related to their own professional experiences.

IV. Results

The seniors had a classroom size of 8 to 14 students whereas the first year students had a classroom size ranging 28 to 32 students. The largest senior design subgroups consisted of 3-4 students while the largest first year teams consisted of 6-7 students. In the 2012-13 academic year, 47 first-year student teams have provided 1762 design process activity data records and 17 senior design teams have provided 2284 process activity data records. The results of the student team surveys are compared to the faculty survey feedback. Normalized, aggregated student time spent on design activities is graphically displayed and can be seen on Fig. 2 and 3. Design process raw (non-normalized) traffic patterns are also graphically displayed and are shown in Fig. 4 and 5. Table 1 is lists the data from which those figures were derived.

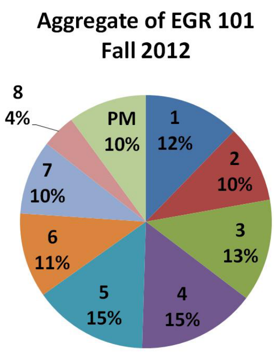

Fig. 2. Aggregate of First-Year Student Survey of the Fall 2012 Semester.

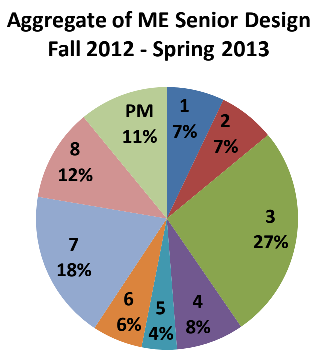

Fig. 3. Aggregate of ME Senior Design Survey 2012-13.

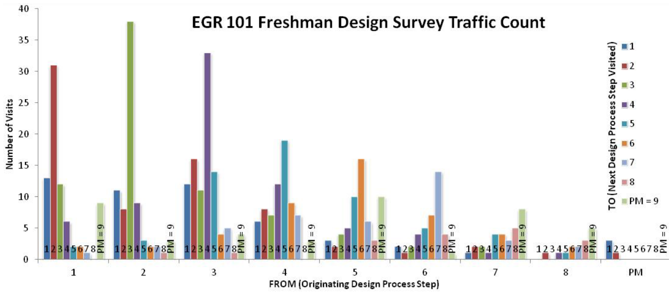

Fig. 4. First-year engineering EGR 101 design process traffic.

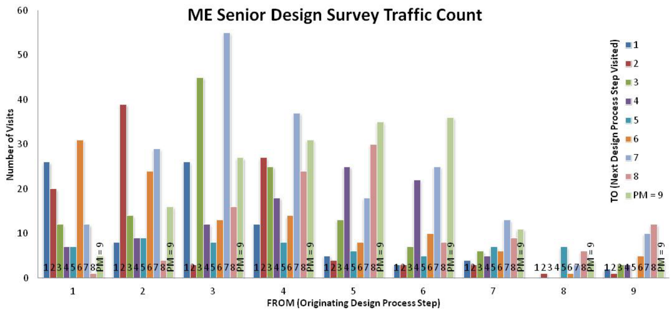

Fig. 5. Mechanical Engineering senior design process traffic.

TABLE I. DESIGN ACTIVITY TRAFFIC COUNTS

EGR 101 — TOTAL: 472

FROM \ TO	1	2	3	4	5	6	7	8	PM
1	13	31	12	6	2	2	1	0	9
2	11	8	38	9	3	2	2	1	3
3	12	16	11	33	14	4	5	1	4
4	6	8	7	12	19	9	7	0	3
5	3	2	4	5	10	16	6	3	10
6	2	1	2	4	5	7	14	4	1
7	1	2	2	1	4	4	3	5	8
8	0	1	0	1	1	2	2	3	5
PM	3	1	0	0	0	0	0	0	0

Senior Design — TOTAL: 1063

FROM \ TO	1	2	3	4	5	6	7	8	PM
1	26	20	12	7	7	31	12	1	5
2	8	39	14	9	9	24	29	4	16
3	26	3	45	12	8	13	55	16	27
4	12	27	25	18	8	14	37	24	31
5	5	4	13	25	6	8	18	30	35
6	3	3	7	22	5	10	25	8	36
7	4	3	6	5	7	6	13	9	11
8	0	1	0	0	7	1	3	6	4
PM	2	1	3	3	0	5	10	12	4

V. DISCUSSION

It is noteworthy that the senior design students generally completed the survey more correctly than the first-year students. It was common to see that the first-year students did not properly indicate which activity was last visited before moving on. The senior design students completed the surveys more willingly and carefully with an instructor present. In some cases, the instructions were given several times and confusion in survey response was resolved through conversation with the students. Survey completion was requested as a team effort, but sometimes only one team member would complete a survey for an entire team.

The pie charts depict a proportion of time student teams spent on the various design activities. As seen from the data in Table 1 and Fig. 4 and 5, the first-year students spent much of their visits in the first third of the design process and visits generally involved less skipping of neighboring steps. The ME senior design students spent more of their normalized time working on Brainstorming / Design Concepts (step 3), Detailed Design / Communication (7), and Production (8), but relatively less time on Research / Testing / Analysis (4), Modeling / Prototyping (5), and Model / Protype Evaluation (6).

Differences in freshman versus senior application of the design process are likely the result of differences in project scope and student experience and advancement.

VI. FUTURE WORK AND CONCLUSION

Aerospace and Civil engineering senior capstone design data collection is planned during the 2013-14 academic year, as is a faculty Delphi study derived from existing faculty survey data to further refine faculty input. The Delphi study will address faculty impressions of student design activities and faculty expertise regarding the most important areas of student focus within the design process and the key process iteration loops to emphasize. This information will be gauged against actual student design activity. Although the survey was changed once and the input and opinions of the students are different every semester, it is important that the survey be adopted on a semester-to-semester basis to better suit varying groups of students. The data collected support programmatic monitoring, improvement, and comparisons across engineering departments of experiential learning via application of the design process by engineering students. The findings were also included in relevant ABET accreditation materials.

ACKNOWLEDGMENT

The authors would like to thank the faculty of the Mechanical and Freshman Engineering Departments and faculty teaching the first-year design topics in EGR 101 for continuing to allow the authors to use their classrooms, survey their students, and survey the faculty themselves as well.

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Hands-On Learning with Portable Electronics

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***Abstract*—Advances in technology have made possible the development of low-cost portable electronic instrumentation. Such instrumentation opens the door to new possibilities for hands-on pedagogy related to analog circuits and physics education. This workshop will introduce attendees to the Digilent Analog Discovery platform and pedagogies that have been developed for it. Attendees will see examples of and have opportunities to try activities that have been developed for undergraduate electrical engineering and high-school physics courses. All attendees will be given a memory stick that contains pedagogical materials and an opportunity to receive an Analog Discovery system free of charge.**

Keywords—active learning; hands-on activities; STEM; analog circuits; nonmajors; K-12 outreach

Goals of the Workshop

There are three primary goals for this workshop: 1) to demonstrate how active learning modules using portable compact electronic instrumentation can be integrated into undergraduate circuits and electronics courses for majors and nonmajors as well as into outreach programs for high-school students, 2) to discuss approaches to include active learning modules in lecture in the classroom or as hands-on homework assignments/projects, and 3) to provide supporting instructional materials that will enable participants to rapidly incorporate hands-on activities into their existing courses. Research on active hands-on pedagogy has shown that students are more engaged in learning, develop an intuitive understanding of key concepts instead of just memorizing facts, and gain self-confidence about their knowledge of the subject. The proposed mini-workshop falls under the FIE 2013 topic of research-proven classroom materials or processes for engineering, technology, and physical science education. The active learning modules will include examples that can be integrated into courses on energy engineering.

Description of Workshop Topics

Active hands-on learning pedagogy in electrical engineering, electrical engineering technology, and physics has been facilitated by the recent availability of inexpensive portable compact electronic instrumentation. This instructional approach has been shown to stimulate student interest in engineering, technology, and physical sciences and promote greater understanding of circuits and electronics, particularly in students who struggle when presented with abstract and highly mathematical concepts. Drs. Simoni and Meehan will present an introduction to the pedagogical approach that has been adopted at Rose-Hulman, Virginia Tech, and at high schools and other institutions of higher learning. They will describe the results from assessment of the impact of the active hands-on pedagogy on student learning that they and others have found that demonstrate the benefits of this educational approach. Drs. Simoni and Meehan will discuss several implementation models that have been used to integrate hands-on learning modules into various courses. Participants will engage in several activities from learning modules that have been developed for high school outreach to circuits and electronics courses for ECE majors and nonmajors. The design of hands-on activities, the value of supporting instructional materials, and methods to incorporate these activities into the curriculum will be illustrated through these activities. The instructional and learning materials that are available for free for educators and students will be described. Specific instructional scenarios, suggested by the participants, and techniques to address common barriers to adoption will be discussed.

Workshop Agenda

- Overview of Pedagogy **(10 minutes)**
- Example Learning Modules **(60 minutes)**
  - High School Physics
  - Circuits for Nonmajors
  - Electronics for ECE majors
  - Design Projects Integrated with PSpice and MATLAB
- Discussion on Integration of Hands-On Activities in Curriculum **(20 minutes)**
  - Available Instructional Materials
  - Supplemental Tutorials

Take-Away Skills, Knowledge, and Material

Participants will learn about the active hands-on learning pedagogy, see how others have integrated hands-on learning modules into the engineering, engineering technology, and physics courses, and suggestions on ways in which the participants can adapt the pedagogical approach for their use. Flash drives will be distributed that will include the workshop presentation, files with links to online learning materials that include textbooks, procedures for hands-on activities and design projects, tutorial videos, and other materials geared towards circuits and electronics. Participants will receive a

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card that can be returned at the Digilent booth at FIE 2013 to receive a free Analog Discovery portable analog circuit design kit. Participants may elect to join the online community on active hands-on learning hosted by the Center for Mobile Hands-On STEM, which will be launched in Summer 2013.

THE ANTICIPATED AUDIENCE

The anticipated audience includes faculty members, instructors, and laboratory staff in Electrical and Computer Engineering and Engineering Technology, Mechanical Engineering and Engineering Technology, First Year Engineering Education, Engineering Physics, Physics, and middle and high school teachers in the physical sciences. The maximum number of attendees is 25.

QUALIFICATIONS OF THE PRESENTERS

Kathleen Meehan, PhD, is an Associate Professor in the Bradley Department of Electrical and Computer Engineering at Virginia Tech. Kathleen earned her BS in Electrical Engineering from Manhattan College and her MS and PhD from the University of Illinois. After working in industry, she moved into academia full-time in 1997. She is involved in curriculum development and educational research as well as the growth, fabrication, and packaging of nanoscale and microscale optoelectronic devices. Since 2003, she has collaborated with Dr. Robert W. Hendricks to develop an instructional platform known as Lab-in-a-Box with the assistance of more than 50 ECE students[1].

Mario Simoni, PhD, is an Assistant Professor in the Electrical and Computer Engineering Department at Rose Hulman Institute of Technology (RHIT). Mario earned his BS in Electrical Engineering from Park's College of St. Louis University and his MS and PhD from Georgia Institute of Technology. At RHIT, Mario has taught a range of classes ranging from introductory level to advanced graduate level. His research interests include improving learning in introductory linear systems courses, analog and RF integrated circuit design, and outreach activities for high-school physics education. He has presented papers at ASEE and FIE and published papers in various IEEE Transactions journals[1][3].

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Effective Recruiting for Diversity

based on the Tapestry Workshop Outcomes

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***Abstract*—Women of all colors are underrepresented in most technical disciplines. For example, electrical engineering college graduates have comprised only about ten percent women for many years, and computing graduates only about eighteen percent women, down from about thirty-five percent in the mid-1980s. Gender stereotypes and stereotypes about creators of technology contribute to this underrepresentation. Nevertheless, these prevailing conditions can be overcome to a substantial degree by actively recruiting diverse female students. This panel session will provide an introduction to the reasons for active recruiting, methods for successful active recruiting, examples of effective applications of the recommended methods, and resources to help participants as they attempt to actively recruit underrepresented students to their courses. The panel's focus will be on computing disciplines, but the information applies to other technical disciplines as well.**

Keywords—recruit; diversity; computing; Tapestry

I. Goals of the Workshop

The goal of this workshop is to motivate and explain active recruiting of female students into technical classes. The presenters will explain why it is important to recruit actively from underrepresented groups, and they will give examples of successsful recruiting into computer science at the high school and college levels. Sufficient information will be provided for participants to increase the number and diversity of students in their technical classes.

II. Description of Topics & Agenda

A. *Why actively recruit females*

This topic will cover data showing the lack of diversity in computing and how high school and college contribute to this problem. The presenter will explain how active recruiting can help alleviate the problem and provide the key research-informed ingredients.

B. *A spectacular example of effective recruiting*

A charismatic high school CS teacher will describe how he went from an award-winning teacher with 35 students, 12% girls in AP CS to more than 300 students, 40% girls by creatively applying research-informed recruiting advice.

C. *A modest example of successful recruiting*

Recruiting is more than signing up students. In this session, a high school teacher will describe the broad changes he made to attract more diverse students.

D. *Recruiting through the intro course*

This topic will describe the key ingredients for converting students to CS majors through the introductory course.

E. *Summary and Discussion of main points*

The final five minutes of this session will be dedicated to answering remaining questions and considering any necessary adaptations for different disciplines and institutions.

Questions and discussion will follow each presentation.

III. Knowledgeable Presenters

J. McGrath Cohoon is a Senior Research Scientist at the National Center for Women & IT (NCWIT), and Associate Professor of Science, Technology, and Society at the University of Virginia. Cohoon conducts nationwide empirical studies of gender and computing. Her results are reported in scholarly journals and an award-winning book, co-edited with William Aspray – Women and Information Technology, Research on Underrepresentation. Cohoon's work at NCWIT involves conducting, translating, applying, disseminating, and evaluating research. She also serves on the CRA-W Board, offers professional development to computing high school teachers, trains and supervises consultants, and collaborates on increasing women's participation in volunteer computing. Cohoon presents twice at every Tapestry Workshop conveying information about the why and how of active recruiting. She also offers a resource designed for use when informing others about the importance of a computing education.

Jim Cohoon is a Computer Science professor at the University of Virginia. He is a co-founder and organizer of the Tapestry Workshop initiative. He has received IEEE Computer Science highest education award in recognition of his sustained efforts in Computer Science diversity. He is the author of several award-winning introductory textbooks. He has designed and implemented his Department's three-pronged approach to introductory computing so that it maximizes the interest and abilities of all students. He is a strong proponent of active and group learning. His other research interests include swarm robotics, VLSI physical design, routing, and free flight. His interdisciplinary approach there applies and extends nontraditional techniques such as computational geometry, probabilistic search, genetics, and parallel computing.

Seth Reichelson is a Computer Science an award-winning high school teacher in Lake Brantley, Florida. He has achieved national recognition for his approach to high school computing

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courses in general and AP Computer Science in particular. His efforts in the recruitment, retention, and teaching of a diverse student body currently attract about 1/10th of all the students at his school. About 39% of his students are female. His numbers along with the pass rate of his students makes him one of the USA's most successful AP instructors. Seth is a frequent presenter at Tapestry Workshops. Attendees consider his talks a very important part of the workshops.

After attending the Tapestry Workshop in last summer, Selwyn made a number of changes, including more welcoming room décor, keeping girls together for group project, more hands-on engaging lessons, explaining the opportunities available with a computing career. All of his changes made instruction and learning better for all students. His enrollments increased modestly for female, African-American, and Hispanic students, despite a new school requirement that diverted many of his potential students for one year.

IV. Anticipated Audience

Anyone interested in diversity in technical disciplines, but especially high school and college educators, will be interested in this workshop.

V. Materials Provided

Each participant will recieve multiple copies of materials from the National Center for Women & Information Technology. These high-quality materials are professionally designed for visual appeal and written for research-based and field-tested practical advice by scholars of gender and computing. The materials include Talking Points cards in English and Spanish for explaining to young women why they should learn computer science; a workbook for planning coordinated recruiting efforts; data about the current gender imbalance in computing and the predicted shortfall of skilled professionals, for example.

Pastoral Care and Student Support: Developing a Method of Retention

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Abstract—**The transition from High School to first year Engineering at University can be very difficult for many students. Victoria University of Wellington, New Zealand (VUW), developed an early warning system for student grade performance: Big Sister, and a system of Pastoral Care within the School of Engineering and Computer Science. This paper will discuss how Big Sister supports the identification of at risk students and how this system is integrated into the delivery of effective Pastoral Care. Importantly, this paper will also discuss the information gained from student interviews by the Pastoral Care staff member. In particular, we discuss the findings in relation to student self-efficacy and success and how this is being used to improve the first year teaching and learning environment.**

Keywords- engineering retention, pastoral care, student support, teaching and learning

I. INTRODUCTION

The Bachelor of Engineering (BE) at Victoria University of Wellington (VUW), New Zealand, is a relatively new degree which recently received full Washington Accord accreditation in 2012. This BE has specializations in Electronic and Computer Systems Engineering (ECEN), Network Engineering (NWEN) and Software Engineering (SWEN). The BE programme is the outcome of support from the New Zealand Government which has targeted funding for tertiary engineering programmes to increase the number of tertiary qualified engineers to meet industry demand.

The majority of students gain entry to the BE having passed through the National Certificate of Educational Achievement (NCEA) system which operates throughout New Zealand High Schools. Potential engineering students are required to have moderate final year grades in High School calculus and physics.

Students are required to obtain an above average B grade (65% or above) over their core first year engineering subjects in order to progress further with the BE. Since its introduction in 2007, the BE programme has had a 60-70% failure rate of students not achieving this B average in their first attempt.

In 2009, the New Zealand Government funded a project at VUW to investigate the barriers to success and retention for first year university engineering students. The project conducted grade analyses of High School results, VUW course marks, student focus groups, surveys and curriculum analyses. This project uncovered that much of the failure could be attributed to poor academic preparation by students entering the BE directly from High School. The project also identified a disturbingly poor level of engagement by students with the numerous available support services, and poor engagement with first year courses.

To reduce the high attrition rates and improve student engagement, the School of Engineering and Computer Science (SECS), developed several key initiatives.

A significant development was collaboration with the Te Rōpū Āwhina whānau (Āwhina) programme in the creation of "Big Sister", an at risk student early warning and progress system. The paper will explain how Big Sister fits into the overall student academic performance analysis at VUW and how it allows our pastoral care staff member (a position created in 2012) to identify at risk students through poor grade performance across their first year courses. Pastoral care in our context refers to the efforts made by our staff member to directly contact students and meet with them to discuss any difficulties they may be facing and offer guidance and support. These interviews often lead to follow up meetings throughout the study year.

Crucially, this paper will then detail the findings and solutions developed as a result of the information gathered by the pastoral care interviews with students identified through Big Sister. Importantly, these interviews have some limitations as research data since they have produced what amounts to field notes resulting from the 50 minute intervention interviews, with the primary task of the interview to assist the student rather than gather research data. The interviews notes are taken by hand and shown to the participants during the interview but are not audio recorded and transcribed and then coded for emergent themes as is the case in many qualitative studies, such as the commonly used grounded theory [1]. That said, the interview notes were examined for comparative and consistent themes.

Despite these limitations the interviews have revealed many possible factors affecting student progress, for example, student and teacher teaching and learning behavior in High School

NCEA, coupled with generational factors makes the university's reliance on NCEA as a method of entry assessment criteria for engineering students problematic. Student self-efficacy, or belief in their own ability to succeed, a crucial factor in continued success, can be falsely high as a result of the NCEA assessment criteria and actually form a barrier to student success when they are faced with difficult first year courses.

These findings have been a major contributor to the review of the first year BE programme and have influenced a significant redesign of first year mathematics and engineering courses.

II. Context

To explain Big Sister it is important to understand the context in which it functions as part of the overall work undertaken at VUW to investigate and resolve factors affecting student academic performance. The overall aim of conducting Student academic performance analyses and associated pastoral care at VUW is to:

- Further our understanding of barriers to students in achieving the B average required in first year core courses
- Accumulation of student performance data and trends
- Offer course advice and assistance to students experiencing difficulty in achieving the mandatory B average across core papers first year
- Activate student engagement with support services

Student performance analyses of students during their first year of study at VUW has two main aspects: Immediate analysis and On-going analysis. The first, Immediate analysis takes place within the first two weeks of a student beginning the BE. In the students' first week of classes we conduct Mathematics and Physics Diagnostic Testing. This takes the form of a one hour test. Currently this is only for ECEN students and is primarily used to give students Math and Physics course advice as soon as possible and redirect students into courses more appropriate for their ability.

The diagnostic also functions as a 'wake-up call' activating student engagement with the reality of course demands in the first week of study. The main issues with the diagnostic test is that no comparable test exists for the NWEN or SWEN students whose pathway does not automatically include the stringent physics or mathematics of the ECEN major, but rather includes a large amount of programming courses which the students have no preparation for at Secondary School.

In addition to the diagnostic test, by the end of week two, we obtain a full grade and performance report that details all engineering students' NCEA final year results. A student's final year NCEA results are the main university measure for student entry to the degree. From our earlier analysis these have no 'real' predictive value [2]. However, they do often form a background of a student's 'potential' ability in first year tertiary papers and when combined with an ECEN student's diagnostic test result does form a partial predictor of student success in Part I. Yet, as already reported, this is statistically too small to be used as a stand-alone method [2]. NCEA remains the only form of student academic background available for SWEN and NWEN students.

Students who received marginal to low marks in the diagnostic and those who appear to be lacking in NCEA physics and mathematics at level three are invited to attend a Pastoral Care interview and a study plan is discussed and the student is made aware of suitable help available at VUW.

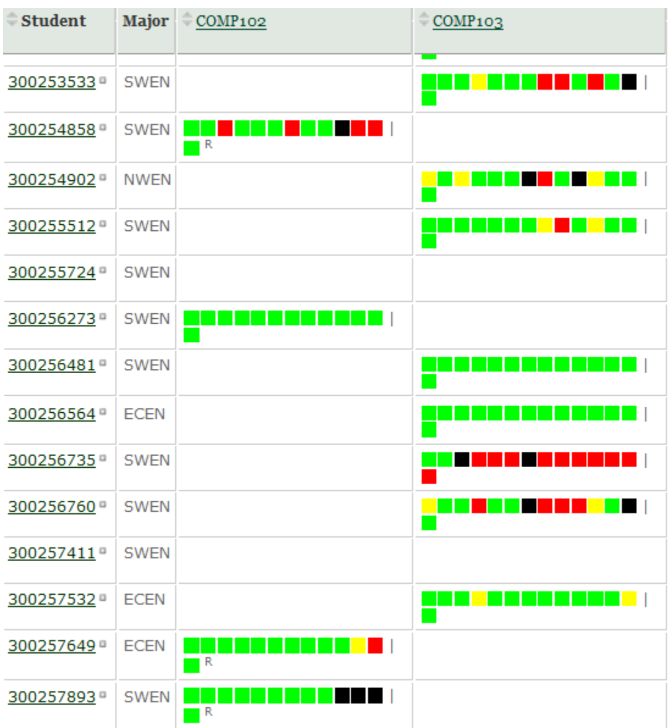
After conducting the Immediate analysis and as students begin to get immersed into trimester one, we begin On-going analysis. On-going analysis has several key aspects:

- Student surveys of first year engineering students conducted at the start and end of the study year
- Collection of Big Sister grade data, identification and contact made with at risk students
- Analysis of at risk student interviews
- Follow up interviews with students who have been seen and results incorporated into analysis
- Continuation of the grade data comparison between NCEA and performance in first year courses

III. Big Sister

Big Sister forms a major component of the On-going analysis and is a means of identifying students who perform poorly. It is a database reporting system which gathers student assignment and test grade data from all course coordinators in the first year of the BE in near real-time.

Picture I. Snapshot of Big Sister



On the screen the student's results run across all of their first year courses (not shown here). For each student, results are displayed to the right of the student ID number. In this instance some students are shown doing COMP102 and COMP103, two first year programming courses. The boxes represent individual assignments, tests or labs results and are color coded. Green is a good pass, yellow a marginal pass, red is a fail and black is where a student has not submitted the work. These can be read in this format or in a grade weighted format. This system also allows subcategories such as individual courses to be examined and also allows for a comparison at a glance of the class performance.

During the creation of Big Sister one of the main challenges we faced was obtaining permission to access the grade data from course coordinators. The first year of the BE is taught across several departments such as Engineering and Computer Science, Mathematics and Physics. Despite gaining ethical approval from the University Human Ethics Committee many course coordinators were of the opinion that the student data still had confidentiality issues and remained the 'property' of the relevant course coordinator and department.

After two years of negotiation this issue was resolved in 2012 and Big Sister could begin across all courses relevant to the BE in first year.

A second major challenge in setting up Big Sister was obtaining the data in a timely manner. The university system does not dictate the manner in which course coordinators store course grades until all grades are finally transferred to the VUW grading database. For example, we encountered lecturers who stored grades in excel spread-sheets, moodle grade books, and on the Blackboard grade system. As such, a staff member must import the results into a common format for uploading to Big Sister. This slows the availability of timely grade data.

In addition, the assignments and tests have to be marked within a short timeframe in order to enable the pastoral care staff member to contact the student and begin assistance. In practice some course coordinators are better than others at providing speedy data. A major outcome of this knowledge has been a new SECS policy from the Dean and Head of School for marking to be conducted at the latest within a two week turn-around.

The Big Sister data report now gives us relatively (within one-two weeks after a grade has been given) up-to-date information enabling us to identify at risk students by examining grade performance across all the courses an engineering student is doing.

After a student is identified as being at risk, the Pastoral Care staff member contacts the student with an offer of assistance and an interview. This is done via email or by phone, and if necessary severely at risk students can be contacted at labs or tutorials.

Students attending the (up to 50min) interview are asked to sign an ethics form allowing the Pastoral Care staff member to record, in note form, the details of the interview. The notes are written in full view of the student and the student is asked to read the notes at several stages throughout the interview and make any changes they feel comfortable with. If a student does not sign the form the interview goes ahead without notation.

The outcome of this interview usually results in students being given advice and appropriate support service and encouraged to use it. Some of these support services include, Āwhina, Student Learning Support Service, Peer Assisted Study Support (PASS) Scheme, Tutorials, the Lecturer, Course Coordinator or Dean of Students. In some cases student counseling, disability support and student health may be contacted.

IV. Interviews

Throughout trimester one, 2012, the pastoral care staff member interviewed over 80 students deemed 'at risk', with 60 agreeing to have information recorded in note form, of 152 first year BE students. An 'at risk' student in this case was a student who showed continued poor performance or who suddenly declined in performance in one or more courses. These interviews produced information on student attitudes and abilities. These themes were grouped together and a selection of common themes, those that occurred in over 80 percent of the participants interviews, identified. Common student interview themes were:

- A belief they are academically prepared by High School for Tertiary study
- A belief that NCEA assessment at High School was easy
- A huge workload increase from High School
- A disconnect with Math, Physics and Engineering lectures, both in content and style
- A lack of understanding about what engineering at VUW is and what subjects are required to study it
- Teaching (lecturing) style very different to School across all of university
- Assessment is completely different from NCEA
- A new realisation that they are not prepared but lacking the motivation to remedy
- A lack of desire to put the work in if it does not interest them
- Computer Science first year courses perceived as hard but more interesting and gets more study attention
- "Game-playing" course work to achieve a pass
- Students perceive of themselves as lazy – but justify this by claiming boredom with courses-material and lecture style
- Students are not comfortable (fear) accessing support help - its help designed for 'our' system
- They are stressed with non-academic issues which compete on an equal footing for their attention with course work

Conclusions gained from the pastoral care interviews point to 'huge' differences between the expectations we have of students and those they have of us, academically, environmentally and behaviorally. It must be emphasized that we can only indicate conclusions for this particular group of students based on their self-reported perceptions and viewpoints.

Students believe the NCEA teaching and assessment system they have experienced prior to university is the norm and for many of these the lack of motivation and transition difficulties could be attributed to patterns learnt while studying NCEA.

A recent study of NCEA noted:

- Teachers and parents were positive about the overall impact of NCEA on many students, particularly those who were low achieving.
- Teachers and parents felt that high achieving students would work hard no matter what.
- Teachers and parents had concerns that some aspects of credit accumulation and assessments could motivate students to "do just enough" rather than do their best.
- Teachers and students were concerned about the possibility that assessment could drive teaching and learning rather than the curriculum.
- There was some concern by teachers that assessment could fragment subject understandings in some areas where integration, synthesis and/or evaluation across standards were seen as critical [2].

While it is clear that not all students struggle in the transition to university, our poor pass rates indicate a widespread problem and it is possible that the NCEA system is not adequately preparing potential tertiary students for the level of motivation for academic success or independent learning style, presumed by the manner of teaching at VUW.

University engineering, mathematics and physics (all core first year BE) courses at VUW predominantly revolve around students attending lectures taking notes and then attending labs or tutorials where the emphasis is often on completing assignments and going over lecture material. The teaching component of these classes as it relates to personalizing the learning environment is low and in many cases non-existent. Motivation is also generally left to the student with the assumption similar to that mentioned above: '…high achieving students would work hard no matter what' [3].

Our 'teaching' and learning environment/culture does not always help. It is designed for our perception of teaching that fits into one of Ramsden's pervasive tertiary teaching myths that: '[teaching] consists in presenting or transmitting information from teacher to student, or demonstrating the application of a skill in practice; and that students in higher education must not be too closely supervised, lest the bad habits of dependent learning they are supposed to have acquired at school are reinforced' [4]. Ramsden makes the further salient point that: 'It is said in support of this myth that able students understand and apply the skills and information they have been exposed to. If the rest don't learn, they have a difficulty that the teaching cannot be blamed for; after all, they are in higher education now' [4]. Statements of similar content can be heard throughout meetings of academic staff at VUW.

Zepke's research into student perceptions revealed that out of the three factors affecting students' success; 'teaching, motivation and external influences, teaching is the most important'[5]. Yet Zepke, argues that while teaching was the most significant factor, that understanding student engagement was not that simple and was always a complex interplay between teaching, motivation and external influences and as such it is difficult to point to only one factor as the pre-eminent causation of poor student academic performance. Zepke describes the findings of the research in an interesting manner:

- 'Student engagement is complex. It comprises nodes (e.g. teaching, motivation, external influences) clustered into larger nodes (e.g. student engagement) clustered yet into larger nodes (e.g. research orientations). Each node is understood as a network in its own right linked to other node networks. This means that teaching, motivation and external influences each form a complex network connected with every other node in the system. Simultaneous connection and distinction is a feature of this network.
- Since teaching, motivation and external circumstances are distinct, these nodes can be investigated separately and compared. But researchers need to be aware that by doing so, they are not taking into account the simultaneous connections between these nodes and therefore they are oversimplifying the results.
- The finding that teaching is more important than motivation, then, cannot be taken at face value. While useful, it neglects the complexity that underpins the relationships between these terms' [5].

Importantly this leads to the conclusion by Zepke that there are many nodes or node networks beyond those listed above affecting student engagement. The pastoral care interviews point to NCEA as a node potentially affecting student performance. Another significant node was a lack of understanding about what it was they were going to study in engineering at VUW. This confirmed much of the work done by the Engineering Pathways Project at VUW [6].

The more we investigated retention issues the more it became apparent that the complex interplay of factors, or as Zepke describes it nodes, makes any single solution problematic in terms of effectiveness across the whole student cohort, which in turn increased the importance of targeted individual pastoral care. For example, an interesting finding of the interviews was the unwillingness to access help or support services when students found themselves in a difficulty node. This node then has a network of related causes. Students expressed a general reluctance to access help stating comments such as, 'I thought I could catch up', or 'I didn't think I needed any help'. Other student comments included a general acknowledgement of fear in accessing help. This was related to a general perception of help indicating that they were academically inferior to their peers and also fear of being part of a ‘help group’, preferring anonymity. Awhina support was largely rejected by our predominantly male students of European descent who felt put off by the Maori and Pasifika face presented by Awhina.

The interviews and the intervention of the pastoral care provides access to the complex node networks allowing for immediate connection with the individual student regarding their difficulties and also allows for some broader understanding of common barriers across the main student cohort.

V. OUTCOMES

While it is difficult to directly attribute the pastoral care interviews with student improvement we believe these interviews resulted in some positive outcomes for student engagement in the core engineering paper Engineering Fundamentals (ENGR101). Feedback was given to the course coordinator throughout the process of the interviews and subsequent changes were made in the structure and teaching of the course [7]. Many students who had attended interviews showed a grade improvement in the weeks following the interviews. Overall, the results were that the pass rates significantly improved from 52% of the students gaining a B or greater in 2011 to 63% in 2012.

At least 20 students changed their major or degree as a result of the pastoral care interviews to better suited educational pathways.

In addition, there was a significant increase in the uptake on accessing ‘help’ in the Peer Assisted Student Support (PASS) Scheme. PASS groups are study groups run by a good student who did the course the previous trimester. These have been run successfully by the Student Learning Support Service at VUW for many years in several faculties. In 2011 Engineering set up a PASS group for Math 151 (an introduction to linear algebra) and had a poor uptake, with only 2 students out of the 58 enrolled in MATH151 attending PASS. This suggested that students were poor at accessing help and reluctant to take independent responsibility for their own learning.

With the advent of a Pastoral Care staff member in 2012 we saw an increase in the uptake of students attending PASS groups for MATH151, with 28 students out of 64 attending. The academic results of PASS were however disappointing with only 6 out of 28 students (21%) receiving a B or better grade for Math151.

Feedback from students attending the PASS group indicated that it was not assisting in developing increased mathematical ability in the attendees and focused on solving tutorial or assignment questions. PASS groups are led by a student who has done the course within the previous couple of years. As such, we had great difficulty in obtaining PASS leaders who had sufficient knowledge of math to answer difficult questions of the material and who also understood good teaching practice. PASS group leaders do undergo training and also have access to mentoring but we feel that a more experienced tutor would yield better results.

The 2012 end of year grades have been received and the results have improved. Table I below details the data collected on first year students’ progress with Part One of the BE over its first six years. The numbers represent actual first year students in calendar years so all students starting in trimester two will show up as an earlier student when they complete. In 2012 the number of new entrants completing Part One in their first year is up 46% on the best previous year and a corresponding increase in grade average performance with 40 students achieving an A- average. There is also a substantial trend of students now completing in their second year.

Table I. Student Performance in Part One of the BE
2007-2012

	2007	2008	2009	2010	2011	2012
Students completing at least one Part One course	104	92	111	120	108	172
Students completing all required courses for their Part One major.	40	40	54	48	42	72
Students passing all required courses for their Part One major	23	22	31	36	26	54
Students achieving a GPA ≥ 4.5 in their Part One courses	38	46	46	54	42	77
Students achieving a GPA ≥ 6.5 in their Part One courses	18	20	18	33	13	40
Students passing Part One	22	21	31	35	25	51
Earlier students completing Part One.		9	18	14	21	23
Total students completing Part One	22	30	49	49	46	74

In addition, we have made steps to disseminate our findings and actively involve lecturers and support staff in the challenges we face. This has led to a gradual interest across the faculty. The interview findings have also been the subject of several seminars at VUW.

One of the major outcomes of the Pastoral care interviews and Big Sister programme has been an informed motivation to revamp first year engineering, mathematics and physics papers to meet student expectations and academic ability. Suggested changes include the complete overhaul of the core mathematics courses currently taught by the mathematics department. The proposed change aims to introduce three papers that have as their principal concept the belief that the course must be interesting and show engineering relevance to students through project based learning.

Alongside the proposed changes to first year papers already mentioned, the School of Engineering and Computer Science has recently (at the time of writing) received approval to appoint an additional academic staff member to assist directly in the teaching of first year papers and a tutor to assist in developing 'new' tutorials in support of difficult first year courses. It is also planned that this tutor will run one-on-one and group sessions for students identified through the pastoral care. Discussion has been active on whether these tutorials should or could be compulsory.

While we are confident in the success of the intervention of Pastoral Care and analysis provided by Big Sister we realize that we have a long way to go. Many questions remain:

- How do we educate the students in what is required at university in first year without using the sink or swim approach?
- How do we increase the pass rate without decreasing the quality of students progressing?
- How do we 'more' get students to attend currently available help?
- How do we get students to take responsibility for their own learning?
- How do we get 'all' lecturers and courses engaged in pedagogy and improving the teaching and learning experience?

It is hoped that in the future we will have the answers to some of these questions and be able to report further on developments made. We also look forward to any feedback from the conference participants on how we might continue to improve our support.

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Student Perceptions of Cheating in Online and Traditional Classes

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***Abstract*—With classroom instruction undergoing a massive transformation to incorporate online learning techniques at unprecedented levels, technological advances have facilitated a range of mechanisms that improve teaching and learning. At the same time, these technological advances have also facilitated different forms of cheating in classes.**

Although the impact and implications of cheating have often been studied, we feel that this problem experiences constant evolution, and the dynamics of cheating, especially in online courses, needs more examination to be fully grasped. The study presented here surveyed computer science, computer information systems, and engineering college students, with the goal of gaining a greater understanding of their perceptions, beliefs, and attitudes about the many dimensions of academic integrity violations. Results of this survey, coupled with statistical analysis and some conclusions, are presented.

The impact of our popular Virtual Lab (VLAB) facility is also examined in this context, and it is found to make a positive difference in student attitudes about cheating in classes.

I. Introduction

Technological advances open up many new directions, opportunities and paradigms to augment and improve the learning experience. In particular, classroom instruction is now undergoing a massive transformation, with the increased adoption of research-driven instruction methods, experiential learning, and online learning. With a bona fide approach by both instructors and students, there is no doubt that all will benefit. At the same time, many of the technological advances that help to improve pedagogy have also facilitated different forms of cheating in classes. Like never before, cheating has become easier and ubiquitous. In this Internet age, it has become almost too tempting for students to examine and experience behavior that can easily fall under the category of academic integrity policy violations.

Educators, university administrators, parents, and the general public are getting more concerned about the impact and implications of students cheating while earning college degrees. In this study, we have surveyed college students with the goal of gaining greater understanding of the many different dimensions of academic integrity violations. Another goal is to reveal some preliminary delineation of gray and white zones from among generally agreed-upon clear academic integrity violations. As part of the study, we have sought students' anonymous and candid responses related to the acceptability of cheating in different life and social settings, as well as in the classroom, together with their awareness and perception of such behavior. We believe that our study is a contribution toward understanding the extent of today's students' exposure, awareness, and perception of academic integrity violations.

We surveyed students who had participated in a variety of different computer science and engineering classes on our campus, with a secondary goal of examining the impact of our popular Virtual Lab (VLAB) environment's effects on our students' tendency toward cheating. We present VLAB as a concrete example to examine possible correlations between technological change in delivery (or online teaching in general) and any manifestations of integrity violations by students.

The rest of the paper is organized as follows: Section II presents background and related work. The details of the survey with question categories are provided in Section III. An assessment and analysis of the the survey results are given in Section IV. Section V contains a summary of the conclusions and future work.

II. Related Work, Background

The definition of cheating in online or traditional (in-person) classes may be interpreted imprecisely by students and instructors. Instructors will have different definitions/interpretations of what constitutes cheating, and in the absence of a clear definition, students are free to draw their own conclusions. In this age of instant Internet access, many have grown accustomed to various types of dishonesty without considering their moral or legal ramifications. For example, consider the situation of a person who is otherwise honest but who downloads copyrighted content from the Internet without paying for it. It seems reasonable to imagine that, due to the lack of a clear framework or definition of "right and wrong" on the Internet, such a person might make a relatively short moral leap into cheating in online classes.

In society, there are various potential definitions of cheating: in most sports, cheating is considered to be part of the game and acceptable behavior - as long as the player is not caught. For example, one might consider stealing a base in baseball to be a form of cheating, except that it is allowable within the rules. A better example might be that of committing a minor violation, such as holding, in American rules football, without getting caught by the referee. Most sports typically write off instances such as this; the game moves on and the incident is usually forgotten. Additionally, penalties for such behavior (when caught) are swift and well-defined, but they are also relatively minor in most cases.

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Other forms of cheating also have varying levels of punishment and societal views on how bad they are. It may be informative to consider whether it is acceptable to cheat on taxes, on a spouse, or in an online video game. In fact, a quick survey of literature finds considerable work examining cheating in online video games, for example [1], [2], [3]. The precise definition of cheating is often contextual. Even in academic activities, its definition may depend completely on an explicit agreement between student and instructor. Other work also supports the notion that the context of cheating is related to how it is perceived in society. Bowyer [4] argues that in war, politics, and espionage, cheating is pervasive and expected.

There have been numerous studies related to the concept of academic cheating, whether online or not. We primarily focus here on work related to cheating in online mode classes, in terms of the approaches to take to deal with it in prevention and/or detection. These can be roughly classified into several different approaches: cultural/social/attitudinal; embedding structural mechanisms into courses; educational approaches; and technical approaches. Additionally, there is considerable literature studying the precise forms of cheating and student motivations to cheat.

A comprehensive set of definitions of cheating behavior, for traditional classes, is presented in [5]. This presents various forms, in which students cheat on homework assignments, as well as in online, in-person and take-home exams. Other definitions include *e-cheating* techniques, such as accessing websites, instant messaging, email, seeding test computers with answers, and using non-exam disks containing exam answers [6]. Ramim [7] provides an overview of the common aspects of academic misconduct and proposes a standard definition based on the findings of a study, for online learning environments.

Motivations for cheating are explored by several authors [8], [9], [10]. In particular, Harding et al. [9] present a fairly comprehensive survey of past research on student motivations. The work of Carpenter et al. [10] also identifies implementations of student-suggested techniques to deal with it. In general, the research shows that extrinsic motivations, such as pressure to succeed academically from various sources, are among the more commonly cited reasons for cheating. The research highlighted by Novotney in [8] also shows that students who cheat tend to adjust their morality to fit their circumstances. In other words, behaviors that may have formerly been incorrect are later justified, once they have been done.

Cultural mechanisms are also presented by Novotney in [8]. These include facilitating community feelings of disgust at cheating behavior, greater education in the classroom about academic integrity, and more student engagement. Other means of improving culture are studied by Broeckelman-Post in [11], in which it is reported that effective engagement with students, as well as more in-depth discussion of cheating behaviors and expectations, can have a significant effect on deterring cheating. An approach to defining cheating that also uses cultural/attitudinal factors is presented by Stepp and Simon in [12]. The authors asked students to define the act of cheating as it related to their own course assignments. Having the students take ownership in this fashion helped to facilitate a culture against cheating. Another study [13] presents an argument for education of faculty members, as it discusses approaches to educate new faculty members on establishing cultures discouraging cheating.

Other studies [14], [15] examined student and instructor beliefs on cheating and explored techniques to curtail it. Some effective techniques cited include improved learning objectives, group work, review sessions before exams, and building a good rapport with students.

There are many studies examining technical approaches. Webley [16] presents a discussion of the potential for cheating in Massively Open Online Courses (MOOCs), discussing approaches to deal with it, including the use of honor codes, high-tech remote proctoring, and giving unique exams, with a focus on the exams themselves as potential solutions. The study focused on the use of the course's exams, coupled with anti-cheating measures, to determine whether a student receives credit. Various authors present technical approaches that focus on exams themselves, whether they are online or in-person [17], [18], [19], [20]. These may include problem randomization, encryption of questions/answers, imposing time limits, the use of laptop-installable exam software such as Secure Exam Environment (SEE) [19], and even mobile technologies for smart phones [20]. Others [21], [22] present work on remote proctoring mechanisms (aka remote invigilation), in which networks of computers connected via web cam are used, as well as the possibility of image processing. Frank [23] also presents a framework and a risk analysis of *dependable distributed testing* with a classification of seven types of risks encountered in taking exams in online classes.

Some other technical mechanisms, such as identity verification, IP address verification, and pedagogical methods (e.g. video interactions with the instructor) are highlighted by Lepi in [24]. Others include anti-cheating software, such as Moss, TurnItIn, WCopyfind [25], [26], NetSupport [6], and Quenlig [27], which is a generic questionnaire assessment tool with built-in cheating detection mechanisms. Some solutions simply involve denial of access to the Internet [28], although this solution primarily applies to in-person and not online classes. Burlak et al. [29] proposed the use of data mining techniques for detection of cheating in online student assessment.

Other approaches include mechanisms for automated assignment individualization [30], with the goal of encouraging peer teaching rather than cheating behavior. The use of steganography has also been proposed [31], in which voice samples are embedded into an exam paper at regular intervals, to ensure safe and correct authentication of exam participants.

Structural mechanisms can also be effective deterrents to cheating. For example, McCloud [25] describes a class in which, aside from a mid-term exam administered in a monitored situation (i.e., proctored), cheating was essentially impossible because there were no other summative assessments, and all students had access to the same online files. Other mechanisms, such as centralized testing locations, strict timing of online exams, and using course management software to set up password-protected areas for each student, are cited as not working well [26]. For example, requiring online students to take exams at centralized locations is difficult to implement for all online students. In contrast, Richardson and North [32] argue in favor of exam proctoring, citing it as an effective means for improving trust in online courses. They also argue that some technical mechanisms may be easily circumvented by simply having other students login for the ones supposed to be doing the work.

To examine the issue of trust further, many researchers argue that less technological solutions are the only effective means to deal with the issue of cheating in online courses. Trust and honor codes are one approach [26], [32], [33]. Simply making the courses more interesting and engaging has also been found to be an effective mechanism to reduce, if not completely eliminate, online cheating. Harding et al. [34] also highlight honor codes, as well as pressure to succeed, as strong factors influencing cheating behavior.

Other structural mechanisms appear to be enacted not specifically to discourage cheating, but the effect worked this way. In a paper on student peer reviews in an online class [35], Wolfe cites the student community as an effective countermeasure against cheating. Collaboration was acceptable, as long as the students gave due credit to the source. Wolfe observed that instances of outright plagiarism were detected and reported by the online student community, partly due to the structure of the assignments requiring students to examine each others' work.

Hanfer et al [36] argue that a systems approach, in which many different techniques are employed to create a unified "system against cheating" may be the most effective means of combating cheating. This may be the ultimate point of the ongoing research into countermeasures against cheating. Ultimately, the best deterrents involve using multiple approaches, ideally using all of the categories highlighted earlier.

We consider our approach to be a combination of several mechanisms: technical, structural, and cultural. Its technical aspects involve the use of our *Virtual Laboratory (VLAB)* facility to accomplish laboratory exercises in systems and networking-oriented courses in a fully online fashion. These are performed by using virtual machines provided on a server that is accessible over the Internet. Further details of this approach are provided in [37], [38], [39]. The structural and cultural aspects of our approach involve our attempts to make our exercises highly engaging and interesting for the students, in such a way as to discourage cheating and to foster a culture of collaborative learning without cheating.

III. SURVEY

The survey was distributed online to a total of 756 graduate and undergraduate students in computer science (CS), computer information systems (CIS), and engineering. The total number of completed surveys was 88, including 66 from CS/CIS and 22 from engineering. Graduate students who responded to the survey attend a hybrid in-person/online Master's program in computer science and information systems, and they represented 34% of the respondents. Seniors represented 33% of the respondents, with the remainder of the responses evenly distributed among freshmen and sophomores. The number of female respondents was 20, with a similar distribution (freshman through graduate) as that of the overall population. Racial demographic information was not collected.

A. Categorization of Questions

We attempted to probe student views on a number of different categories of information with some embedded control questions at various points in the survey. The categories of questions asked included:

1) Notion of cheating in "every day life" situations: students were asked whether they felt cheating was acceptable in various "real-life" and academic situations; the questions attempted to probe their awareness of cheating by asking whether it was ever acceptable, as well as how often they felt it occurred.
2) Awareness and perception of cheating: students were asked a series of questions gaging their awareness of the university's academic integrity policy, as well as awareness/identification of cheating websites.
3) Definition of cheating in classes: students were asked whether various actions (e.g. copying work, getting information online, etc.) conformed to their definition of cheating. They were also asked whether and how they differentiated between cheating in traditional and online classes.
4) External motivations toward cheating: students were asked whether outside influences might affect their likelihood of cheating. These included the level of commitment to a class (whether it cost money, whether it meant something in terms of a degree or professional certification), as well as more commonly cited influences, such as lack of interest in the class, pressure to succeed, etc.
5) Instances of cheating: students were asked whether they had cheated, and how often. This was followed-up with similar questions specifically oriented toward the cheating in various categories of instruction: online classes, traditional classes, online exams/quizzes, and take-home exams/quizzes. In all cases, students were given the option of selecting "I haven't cheated" as an exclusive answer.
6) Motivations for cheating: as a follow-up to the prior categories of questions, students were asked why they had cheated in various situations, with the option of selecting "I haven't cheated" as an exclusive answer.
7) Moral views on cheating: students were asked a series of questions on how to deal with those caught cheating. Additionally, they were asked whether certain extrinsic factors would make them less likely to cheat.
8) Questions related to classes at the university: students were asked whether they had taken courses that use our virtual laboratory (VLAB) facility, including whether they felt the VLAB had been a factor in behavior that has been found by other researchers to discourage cheating activity.

9) Additional thoughts: students were invited to share any additional thoughts in an open-ended format.

The survey was implemented online, and many of the questions were dependent on others. For example, we only asked questions regarding online cheating if the students verified that they had completed online classes. This is similar for taking online exams, taking take-home exams, and the use of our VLAB facility. Consequently, the value of N varies in different categories of questions. The total number of survey respondents was 88, with varying response rates.

IV. Assessment of Survey Results

A. Survey Results

Figure 1 presents the results of the question in which students were asked whether the listed behavior constituted cheating, showing the percentage of students who agree. Several control questions were included to validate the data - i.e. to ensure the students were not confused about the definitions. The "non-cheating" activities primarily related to solution strategies or other activities that were not restricted in a class. Although all of the categories that represent cheating in some form had a large majority of students in agreement, there were some behaviors in which significant numbers of students did not perceive the activity as cheating, including: posting questions at web sites, reading instructor's manuals, watching videos that show answers, and sharing of answers with fellow students.

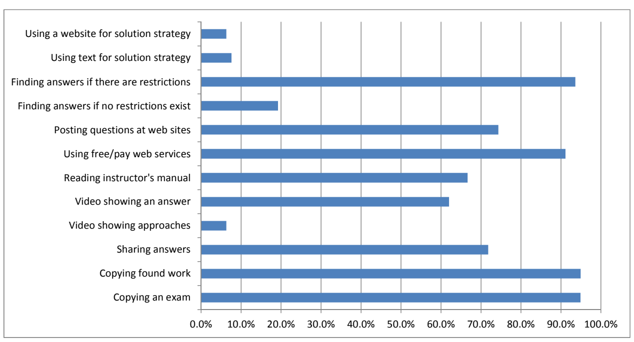

Fig. 1. Percentage of students who would consider cheating, given these factors.

Figure 2 shows the results of one question in which the students were asked whether cheating is acceptable in various social and academic situations (for $N = 64$). In all cases, the majority of students believe none of these are acceptable activities, but a significant minority responded in the affirmative as it concerns cheating in sports. That is, the question of whether some form of skirting the rules is acceptable. It is also notable that a relatively large percentage (24%) felt that downloading of copyrighted material off the Internet is also acceptable, at least occasionally.

As for comparison with student responses on their likelihood of actually cheating in an online class, we found no correlation for $r(60) = 0.211$, $p < 0.05$ (one-tailed). That is, although a significant percentage of the students felt that downloading copyrighted Internet content was acceptable, there was no correlation with attitudes on acceptable online cheating (responses illustrated in Figure 4). This lack of correlation does not apparently support the contention that students who do something viewed as illegal in one context will be more likely to cheat in class.

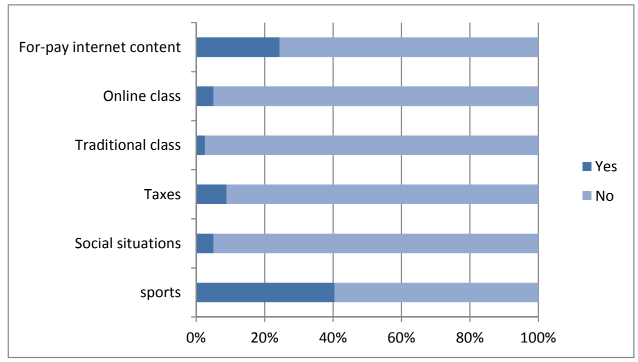

Fig. 2. Percentage of respondents believe cheating is OK in various situations.

Students were asked about their perceptions of the prevalence of cheating using a 5-point Likert scale (never, rarely, sometimes, often, always). Figure 3 shows the percentage of students who believed cheating occurs at least some of the time (i.e. rarely or higher on the response scale). The primary conclusion drawn here is that there appears to be a common belief among students that cheating is prevalent in many aspects of life and learning.

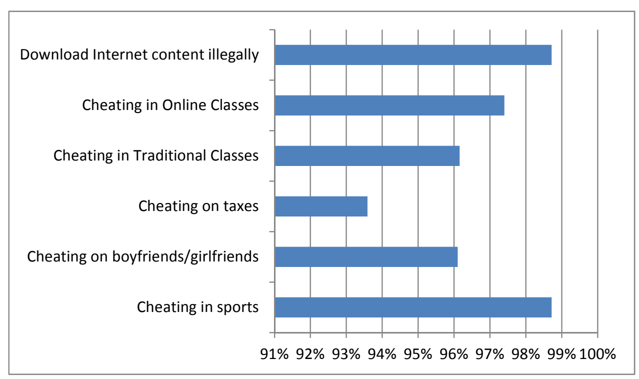

Fig. 3. Percentage of students who believe cheating occurs, at least sometimes.

As it concerns external factors that might lead them to cheat, we asked the students two categories of questions: whether the level of financial or professional commitment made them more likely to cheat, and whether various external factors made them more likely to cheat. In the case of professional commitment, the levels of commitment were defined to include free classes, inexpensive classes, typical college classes (costing hundreds of dollars to more than a thousand dollars), free professional certification classes, and paid-for professional certification classes. The level of commitment seems to present unremarkable information; between 43% and 54% of respondents felt that varying monetary and/or professional commitments would make them more likely to cheat.

Of more interest were the responses to the questions that asked them about external factors. Students were asked to rate their likelihood of cheating on a 5-point Likert scale (not at all, occasionally, sometimes, much of the time, always) based on various external motivating factors. Figure 4 shows the percentage of students who responded with a rating of at least occasionally, indicating they would be influenced to cheat at least some of the time, given these factors.

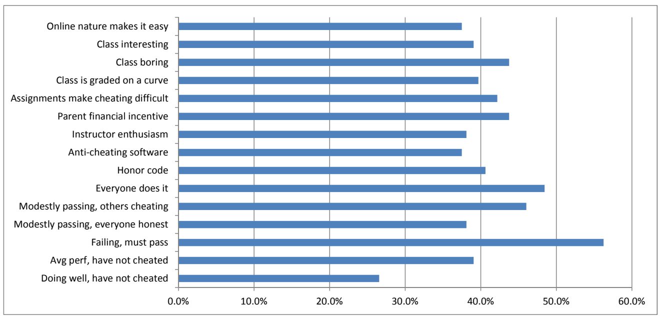

Fig. 4. Percentage of students who would consider cheating, given the listed factors.

The student responses to this question agree with results reported in prior research, which have found that certain external factors tend to encourage or facilitate cheating behaviors [26], [32], [33], [34] As they pertain to our survey, these especially include non-engaging (boring) subject matter, external pressures such as curved grading, pressure to succeed, and the idea that "everyone else is doing it". Additionally, the responses agree with assertions about the opposing behaviors, which contend that students are less likely to cheat with interesting class material, good instructor interaction, a social/cultural feeling that everyone is honest, and the simple possibility that the student is already doing well without having cheated.

Figure 5 presents results from a question in which we asked students about various cheating activities they had participated in, without having differentiated among class type (online or traditional) or course activity type (homework and exams). This question also was phrased using a 5-point Likert scale (not at all, occasionally, sometimes, much of the time, always), and the figure shows the percentage of students (for $N = 64$) who admitted to having done these activities at least occasionally. Most of the activities shown in the graph conform to the definition of cheating, although "watching videos - strategies" was included as a control question in the survey (we do not view it as cheating). It was included to verify that students recognize that watching of solution strategies is not cheating. The figure illustrates that certain activities are practiced by students in significant numbers. In particular, finding solutions via web search and sharing of solutions were both reported to be practiced by more than 50% of respondents. Additionally, 37.5% of students reported having downloaded/used instructor's manuals.

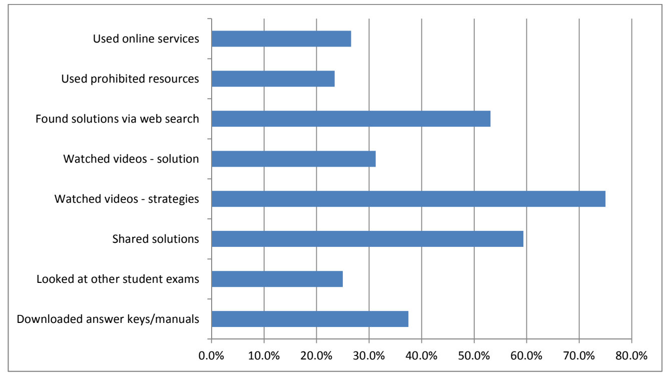

Fig. 5. Percentage of students reporting "cheating" activities.

We also found some correlation ($r(60) = 0.211$, $p < 0.05$ one-tailed) in students who admit to having cheated (i.e. participated in some of the activities listed in Figure 5) and those who felt likely to cheat, given various external motivating factors, as illustrated in Figure 4. This is not surprising, and it agrees with earlier conclusions indicating that if the factors are removed, the students will be less likely to cheat.

Student response rates to questions related to motivations for cheating are shown in Figure 6. The figure shows the underlying reasons that students cheated, when they did. Responses were not mutually exclusive, and the figure shows that typically, a lack of information on how to approach problems, as well as external factors that included stress, outside commitments, etc., were among the most commonly-cited reasons for cheating.

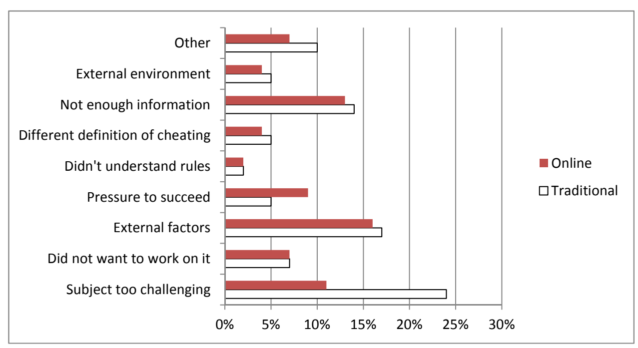

Fig. 6. Self reporting: why they cheated in classes.

The numbers here are mostly highly correlated, indicating support for the contention that the motivating factors for cheating in online and traditional classes are not significantly different, except possibly in one category. When presented with the option concerning the difficulty of the class ("subject too challenging"), student reporting of their experiences in traditional classes cited this much more often as a reason for having cheated (24% of the time vs. 11%). We believe this may be due to two possible factors: first, students working in online classes are already online and material relevant to the class is already at their fingertips through web search; second, the more traditional classes may indeed simply be more challenging to the students.

Figure 7 presents survey responses as they relate to the VLAB facility. Here, 30 respondents had experience with classes using our VLAB facility. In most cases, the student responses indicated the majority of them agreed with the statements posed in the questions. We are especially encouraged by the responses related to student completion of the activities by themselves. Students generally reported believing that the level of detail and ease of completion encouraged them to complete the assignments on their own. They also felt the assignments were engaging and interesting.

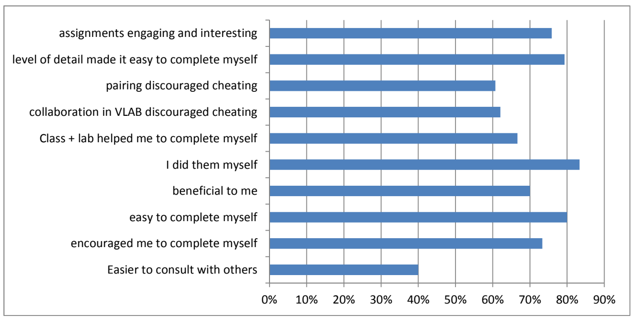

Fig. 7. Student Perceptions of VLAB Benefits.

These results agree with prior research, which concluded that engaging and interesting class activities make students more likely to work on the assignments themselves [8], [11]. Results shown in Figure 8 also appear to support this. The figure presents the results of a question in which students were asked what factors would make them less likely to cheat. The largest factor was reported to be a high interest in the assignments. Categories that also had high ratings included having their identity verified and the use of anti-cheating software.

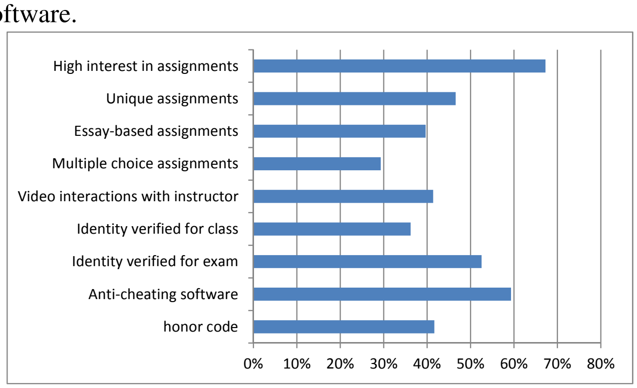

Fig. 8. Factors making students less likely to cheat

B. Student Comments

The last question in the survey requested comments, inviting students to share any thoughts they had related to the issue of cheating, whether they happened to be inspired by the survey, or otherwise. We feel that these responses were very valuable, in terms of pointing us toward further investigations. Although there is no statistical correlation to be found within, many of the responses showed considerable insight.

Some of the comments focused on the precise definition of cheating and/or the teaching itself. For example, one student stated "I think the teacher of any class has a responsibility to clearly state their policy about what is and isn't cheating. After that, they can leave it to the student's integrity. But if they haven't even done that much then what can they expect from their students?"

Some evidence of a lack of understanding of the precise nature of cheating is illustrated by another student comment: "My only instances of 'cheating' have been the sharing of answers as a group in an attempt to collaborate and better understand homework. I have never given or received answers just to get the points. Whether this is truly 'cheating' is up for debate".

It is also interesting to note that some of the comments echoed what has been revealed in the literature, specifically that teacher interaction can improve student learning and also help to curb cheating: "Teacher interaction is key to students learning. Just assigning due dates and exams does nothing to teach."

V. Conclusions, Recommendations, and Future Work

This paper presented results of a survey examining current student attitudes, knowledge, and practice related to cheating. The reported results agree with some of the prior results related to student attitudes about cheating, and they also found a positive effect from student use of our VLAB facility.

The study also represents the beginning step of a longer-term, and wider in scope, study of the same topic. As part of our future work, we will try to examine in greater detail the above VLAB approach, and we intend to expand this study to other colleges across the US, as well as in international universities.

We have also found that results of this study will allow us to refine the studies we conduct in the future. Additional studies will delve into greater detail on precise methods of cheating employed by the students, as well as an examination of more questions related to societal/cultural issues, which we did not consider in great detail within this survey.

Some of the student comments in the end-of-survey question also indicated that there is a disconnect between the instructor definition of cheating and that perceived by the student. Thus, another thrust of future work will be to delve into the definition of cheating, to differentiate among student perceptions of what is acceptable and what the instructor considers to be cheating. We also intend to examine alternative class instruction methodologies that accommodate a broader definition of what may be acceptable in the class setting. These may include employment of additional mechanisms to make the course both more interesting and engaging, as well as structurally less possible to engage in academic misconduct. We feel that going too far into technological solutions may be missing the point.

Ultimately, we feel that the results we observed point to the implementation of an overall systemic approach to improve teaching and learning, while simultaneously addressing the cheating problem. Several actions, including developing more engaging classes and assignments, fostering a culture against cheating, being absolutely clear with students about the definition of cheating, and implementing some effective deterrents, are all supported.

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Perceptions and Influencers Affecting Engineering and Computer Science Student Persistence

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***Abstract*—In the 2012-2013 academic year, a survey to investigate why engineering and computer science students persist in their major was conducted at Michigan Technological University. This paper discusses the results of the survey and ties the findings to the literature. It focuses on: (1) who influenced students' decisions on picking a major or on changing a major (for example, friends, family, academic advisors, faculty, upper-division or graduate students, co-workers, and supervisors), and how did they affect students' persistence and (2) what is the impact of role models on student persistence. The analysis compares students who reported not having considered changing majors to students who considered switching to another major. The findings show that the students who did not consider changing majors reported having a stronger support system including faculty, academic advisors, and engineers who serve as role models. The data suggest that university faculty and staff need to reach out to the students who are deliberating about their initial choice of major and support the decision making process.**

Keywords—Engineering education; computer science education; persistence; retention; attrition; survey; role models

I. Introduction

The US as well as the global economy is increasingly relying on a highly educated workforce in engineering and computer science. Careers in these disciplines usually promise a job well-respected by society and one with a good salary. However, approximately 55% of the students across the US who enter engineering and computer science programs leave these fields within 6 years, either switching to a non-STEM field or leaving higher education altogether [1]. Therefore, a detailed investigation of persistence of students in engineering and computer science disciplines is of widespread interest to educators.

Student persistence in any university discipline is a complex issue. Starting in grades K-12, the decisions of students are affected by a multitude of individuals, groups, and communities, i.e., stakeholders. All of these stakeholders strive to help students so that they can make career decisions that are best for them, and consequently complete their degree. While the role of stakeholders is important, it is hard to determine how students perceive the degree of their influence.

Studies pertaining to influencers of student persistence are commonly organized with respect to two stages that correspond to well-defined transition points. During high school years, the major stakeholders are family members, high school teachers, counselors, university outreach staff, and role models who share the goal of helping with the transition to college. During college, family members, university faculty and staff, support groups, and mentors help students with the goal of having the student graduate and transition to being a professional. However, there is an additional phase where a student considers if their current major is right for him or her, and deliberates about whether to change majors. This is a critical but not well-studied phase, which may include a transition from one major to another.

The purpose of this study is to analyze the influence of stakeholders in students' decisions about whether to change majors. This approach aligns with recent research that shifts away from viewing persistence as an issue of prior knowledge or personal traits. Instead, persistence is viewed as an issue of being integrated into the culture of a discipline, or ``identity,'' and is seen as being affected by the communities surrounding the students [2]. In this study, communities of stakeholders are divided into two as internal to the institution, such as university faculty, staff, and peers; and external to the institution, such as family and external role models.

The analysis relies on survey data collected in the 2012-2013 academic year at Michigan Technological University (Michigan Tech). This analysis focused on students who were at some point engineering or computer science majors, dividing their responses in two groups. The first group is the students who reported not having considered changing majors (*resolute* about continuing in their current major). The second group is the students who considered changing their current major (*deliberated* about changing their major) regardless of whether they switched as a result of their deliberation.

In the remainder of this paper, a brief overview of the literature on influencers who affect student persistence is presented. Next, the methodology is explained, followed by a discussion of the findings. The paper concludes with a summary and recommendations.

II. Background

The behavioral choices made by individuals are driven by self perceptions related to skills, characteristics, competencies, personal values, and goals [3]. During the pre-college years, these perceptions are potentially influenced by the individuals

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that students interact with [2], namely teachers, counselors, family, peers, and other significant adults.

In 2010, Aschbacher et al. looked at how relationships and interactions with family, teachers and other important socializers in students' different communities of practice influence identity in SEM (Science, Engineering, Medicine) fields [4]. This was a longitudinal study of 33 students with diverse ethnic and economic backgrounds. Overall, family encouragement was reported as the reason for the initial interest in science. However, less than half of the high school students reported that family members were still encouraging. Most of the students who expressed continued interest in SEM majors described family members in SEM fields who served as role models. There were gender and ethnic differences where fewer girls felt parental encouragement towards ambitious careers, while parents of minority boys strongly advised them to go to college.

Another 2010 article described a gender-based study of the predictors of high schools students' choice of physics as a career [5]. They found that both female and male high school teachers can positively affect physics identity by focusing on conceptual understanding, making real-world connections, and countering stereotypes, and by exhibiting care, engagement, and passion.

A survey of 280 secondary school students was conducted in 2004 [6]. The response to "my science teachers make me more interested in science" was very positive for 49% of the 11 year old students but dropped significantly to 31% for 14-16 year old students. The responses to questions about science as presented in the media were not very positive, with up to two-thirds of students declaring that they would not watch a TV program about science or did not read news items about science.

Media, in particular television programming, is known to widely affect career perceptions of students. In 2008, 86 women in the United Kingdom who had earned degrees in science, engineering and technology were interviewed to determine the impact of media on their career choices, along with their perceptions about how the media portrays women in technical careers [7]. In general, these women felt that the media did a poor job overall portraying women in technical fields in programming targeting both children and adults. However, science fiction programming for movies and television, along with books, did provide women with positive role models. Many women stated that news events such as the launch of the space shuttle had a significant impact on their career decision. On television programs, the women stated that the female characters who were technically oriented were portrayed negatively as incompetent, victims, de-feminized, or supporting a strong, male character. When discussing the negative impact of the media, many women stated that they received positive support from other sources such as family members, teachers, and other mentors in their decision to pursue a technical degree.

Studies show that there are many students who are not aware of the career options in engineering and computer science. In a survey of 431 New Jersey junior and senior high school students, participants responded with "I don't know" or "No Opinion" to a surprisingly high number of items regarding technical fields [8]. For example, 41% of the students did not know whether they would have a problem finding a job if they had an engineering degree; 44% did not know whether engineers get involved in business decisions; and 50% did not know whether engineers spend most of their time working in laboratories. These results showed that these students would benefit highly from outreach programs.

Many people look to others to see how they handle different situations and then "model" that behavior. The phrase "role model" is based on "the concept of role and the tendency of individuals to identify with other people occupying important social roles" and "the psychological matching of cognitive skills and patterns of behavior between a person and the observing individual" [9].

The efficacy of computer science (CS) role models was studied with respect to gender in 2011. The study participants were women non-CS students. They interacted with role models who were either stereotypical or non-stereotypical CS undergraduates. Stereotypical CS students were ones who wore unfashionable clothes and/or glasses, played video games or programmed in their free time and other characteristics associated with this group. The non-stereotypical CS undergraduates wore "cool" clothing, played sports or hung out with friends and did other "fun" activities. Prior to the meeting, the participants were asked if they thought they could succeed in CS. The participants were asked the same question at the end of the meetings. It was found that participants who interacted with a non-stereotypical CS student reported that they had similar beliefs in CS success as prior to the interaction. The opposite occurred for those participants who interacted with stereotypical CS undergraduates where the success belief of the participants was much lower than the baseline [10].

Faculty take a key role in not only teaching the discipline but also shaping students' attitudes toward careers in STEM fields. An interesting study looked at the attributes of faculty role models in medical schools [11]. The attending physicians who were identified as role models differed from their colleagues in a multitude of ways. In particular, they spent additional time with students beyond their teaching responsibilities, had formal training in teaching, and demonstrated a comprehensive approach to patient care. This led to the conclusion that excellence in role modeling is a skill that can be acquired through training and advice. Other literature pertaining to the role of faculty in student persistence exhibits similar findings. Barker et al.'s study shows that when faculty incorporate peer interaction as a mainstream activity in their courses, students' intention to persist increases [12]. Lewis et al.'s research compares the attitudes and beliefs of students in the introductory CS courses and senior students to the expectations of faculty. Their findings suggest that faculty can develop more effective curricula by closely studying attitude shifts of students as they progress in their studies [13]. A report by Brown et al. includes several strategies for faculty to support student retention [14]. One recommendation is to explain to students how the course content develops the skills required for careers in the field. A recent article in the Chronicle of Higher Education explores student motivation as a predictor of retention, and suggests that faculty, rather than the institution as a whole, are the key players [15].

III. SURVEY METHODS

In Spring 2013, a survey was completed at Michigan Tech. The survey was anonymous and conducted online. The survey questions were designed by extending questions developed for a previous survey completed in Spring 2011 [16, 17] and using additional questions from other related projects [5, 18]. The prototype survey was given to five students outside of Michigan Tech for review, and the questions were modified according to their feedback. Upon completion, an e-mail message containing the objectives of the survey along with the web link was sent to all program advisors who in turn sent it to the students in their program. All undergraduate students were invited to participate in the survey. Follow-up e-mails and reminders were forwarded by faculty in the departments and student organizations, e.g., Society of Women Engineers (SWE), Women in Computing Sciences (WiCS).

This analysis concerns only those students who have reported working towards degrees in engineering or computer science at some time in their university career; referred to as ENG&CS students for this analysis. The survey response rate was 12%. The current major reported by the ENG&CS students and the university enrollment figures (preliminary numbers for Spring 2013) are shown in Table I. Majors were grouped into a single item when the underlying departments incorporate multiple majors. The "Other Engr." category includes general engineering, engineering undeclared, geological engineering, material science and engineering, and those who have changed to current majors outside of ENG&CS. Within the ENG&CS population, the proportion of female students responding to the survey was greater then the university enrollment (see Table II) with a response rate of 24% among female students and 9% among male students. The higher response rate is expected from the directed invitations to participate sent to members of student organizations.

The ENG&CS population had less than one percent of respondents identifying themselves as Hispanic or Latino/a (*n*=8). The race of the respondents was predominantly Caucasian (*n*=374), with students also reporting American Indian or Alaskan Native (*n*=3), African American (*n*=4), and Asian (*n*=48); students were asked to select all that apply.

TABLE I. SURVEY PARTICIPANTS & ENROLLMENT BY MAJOR

	Survey Participants		University Enrollment	
Major	**Num.**	**Perc.**	**Num.**	**Perc.**
Biomed. Engr.	15	3.8	246	7.4
Chem. Engr.	46	11.6	405	12.2
Civil & Env. Engr.	85	21.5	511	15.4
Comp. Sci.	37	9.4	294	8.9
Elec. & Comp. Engr.	62	15.7	505	15.2
Mech. Engr.	103	26.1	1041	31.4
Other Engr.	47	11.9	313	9.4
ENG&CS	395	100.0	3315	100.0

TABLE II. SURVEY PARTICIPANTS & ENROLLMENT BY GENDER

	Survey Participants		University Enrollment	
Factor	**Num.**	**Perc.**	**Num.**	**Perc.**
Female	149	37.7	627	18.9
Male	246	62.3	2688	81.1
Total	395		3315	

The overall structure of the survey is depicted in Fig. 1 (the full survey structure is available at [19]). All survey participants completed the first two sections about pre-college experiences and who was an inspiration. Then students were asked if they had thought about switching majors or had switched majors. The students who had not thought about switching were grouped as *resolute*, while the students who had thought about switching or switched were in the *deliberated* group. Both groups were asked similar questions regarding who influences their decisions and whether or not these people or groups were supportive. The students in the *deliberated* group were asked about their decision on switching. The last section of the survey involved questions regarding the student's career plans and demographics. The following sections describe the survey components that were analyzed in greater detail.

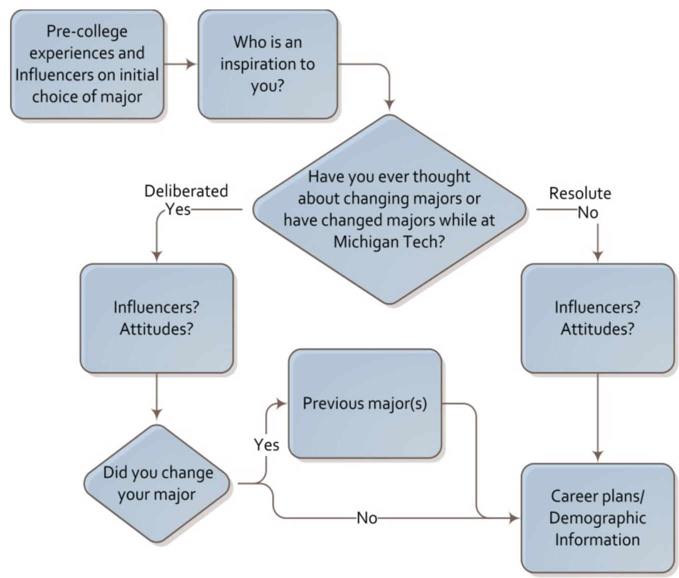

Fig. 1. Survey Structure.

A factor of particular interest within the survey is respondents' answer to the question, "have you ever thought of changing majors or have changed majors?" Students who responded negatively to this question are labeled *resolute*, that is, they are convinced about continuing in their current major. Students who responded positively to the query are labeled *deliberated*, that is, they are or have at some point considered switching majors. Of the ENG&CS respondents, 50.6% (*n*=200) are *resolute* while 49.4% (*n*=195) *deliberated*.

The survey respondents were asked about the interactions they had with others regarding their majors. The *deliberated* students, those who thought about or did change their major, were asked a series of questions regarding the role others had in their deliberations. The population of *resolute* students, those who had not thought about changing, were asked a parallel series of questions regarding the role the same set of people had in their continuing in their major. The structure of the survey (Fig. 1) shows where the split occurred in the survey questions.

IV. RESULTS

The results focus on four questions, with whom do students discuss their progress, who influences a student's decision to persist or change majors, what were these peoples' attitudes (positive/negative), and who were the students' role models.

A. With Whom do Students Discuss their Scholastic Progress

The students were asked with whom and how often they discussed progress in their major. The people or groups of people they were asked about included their family, friends, and significant others. From within their peer or near-peer groups, they were asked about their roommates and hallmates, resident assistants, more senior students, teaching assistants and learning center coaches, and fellow members of student organizations. They were asked about faculty, academic advisors, career services, and counseling services as well as work colleagues and supervisors. The respondents were given the choice of "NA", "never", "one time", "once a semester", once a month", "every week", and "every day".

There was no statistically significant difference between the *resolute* and the *deliberated* students in their answers to questions about with whom and how often they discussed progress in their major. The groups students talked about progress in their major most often with were "Family", "Friends", "Roommates, Hallmates", "Significant Other", and "Academic Advisors", in that order. Over 48% of the students talked to their families about their progress at least once a week. They talked to their friends and roommates at about the same frequency. Approximately 44% of the students talked to them at least once a week. The question regarding "Significant Other" had the highest response for discussing progress every day at 22%, with 42% of the students saying they discussed progress with their significant other at least once a week. An additional 42% of the students marked the "Significant Other" questions as not applicable. Students typically discussed progress in their major with "Academic Advisors" once a semester (61%). A small number reported these discussions once a month (14%), one time (11%), and never (8%).

B. Who Influences Decision of Persisting or Changing Major

This portion of the analysis focused on several different groups of people to determine who impacted student decisions regarding remaining within their chosen field and contemplating changing to a different major. The people or groups considered were the student themselves, plus those considered in the previous section on discussions about progress in the major.

TABLE III. WHO INFLUENCED DELIBERATION ON STAYING / SWITCHING MAJOR: SURVEY RESPONSES ON DEGREE OF INFLUENCE FOR RESOLUTE AND DELIBERATED STUDENTS

		% (*n*)								
		NA/no		small/some		large/v. large		Mean		
Statement	**Choice**	**1-2**		**3-4**		**5-6**		**Choice**	**Total**	***p*-value†**
Self	resolute	2.0	(4)	2.5	(5)	95.5	(190)	5.73	5.71	0.948
	deliberated	1.6	(3)	2.6	(5)	95.8	(182)	5.68		
Family	resolute	17.6	(35)	36.7	(73)	45.7	(91)	4.06	3.69	0.000
	deliberated	37.6	(71)	39.7	(75)	22.8	(43)	3.29		
Significant Other	resolute	62.9	(124)	17.3	(34)	19.8	(39)	2.45	2.29	0.004
	deliberated	76.5	(143)	15.0	(28)	8.6	(16)	2.12		
Friends	resolute	41.6	(82)	40.6	(80)	17.8	(35)	3.13	2.90	0.004
	deliberated	57.1	(108)	33.3	(63)	9.5	(18)	2.67		
Roommates, Hallmates	resolute	63.5	(125)	24.4	(48)	12.2	(24)	2.62	2.41	0.001
	deliberated	76.2	(144)	21.2	(40)	2.6	(5)	2.18		
RAs (Resident Assistants)	resolute	82.7	(163)	15.7	(31)	1.5	(3)	1.98	1.92	0.059
	deliberated	90.9	(170)	8.0	(15)	1.1	(2)	1.86		
Academic Advisor	resolute	49.5	(98)	37.4	(74)	13.1	(26)	2.91	2.88	0.717
	deliberated	53.2	(100)	33.5	(63)	13.3	(25)	2.85		
Faculty	resolute	46.2	(91)	35.5	(70)	18.3	(36)	3.03	2.79	0.001
	deliberated	63.8	(120)	26.6	(50)	9.6	(18)	2.55		
More Senior Students	resolute	53.6	(105)	38.3	(75)	8.2	(16)	2.73	2.53	0.000
	deliberated	76.5	(143)	15.5	(29)	8.0	(15)	2.32		
TAs, Learning Center Coaches	resolute	79.7	(157)	18.3	(36)	2.0	(4)	2.15	2.00	0.000
	deliberated	93.6	(175)	5.9	(11)	0.5	(1)	1.84		
Work Colleague and Supervisors	resolute	75.8	(150)	18.2	(36)	6.1	(12)	2.21	2.12	0.010
	deliberated	87.2	(163)	8.0	(15)	4.8	(9)	2.02		
Career Services	resolute	86.4	(171)	13.1	(26)	0.5	(1)	1.96	1.97	0.218
	deliberated	88.2	(165)	9.6	(18)	2.1	(4)	1.97		
Counseling Services	resolute	93.9	(184)	5.1	(10)	1.0	(2)	1.83	1.81	0.806
	deliberated	95.2	(179)	3.7	(7)	1.1	(2)	1.79		
Members of Student Organizations	resolute	71.1	(140)	22.8	(45)	6.1	(12)	2.37	2.23	0.009
that you are Affiliated With	deliberated	84.0	(158)	12.2	(23)	3.7	(7)	2.08		

† *p*-values were calculated using a chi-squared test, with a null hypothesis of independence of choice

The question asked students who had a role in their deliberation on changing majors or continuing in a major. For each group, students had a choice of six answers, "NA", "no role", "small role", "some role", "large role" and "very large role". The results are shown in Table III with the students' responses condensed into three categories.

There are many similarities. Looking at who had the largest role, as measured by the largest percentage of responses in the "large/very large" category, the top six are very similar for *resolute* and *deliberated* students. For both groups of students (*resolute* and *deliberated*), "Self" had the largest role, followed by "Family". Both student groups ranked "Faculty" fourth and "Friends" the fifth highest. The third and sixth highest items are switched for the two groups. "Significant Other" is the third highest among *resolute* students and sixth amongst *deliberated* students. "Academic Advisors" is the third highest among *deliberated* students and sixth among *resolute* students.

It is noteworthy that there are only two groups of people which more than 1 in 5 students weigh as having a "large" or "very large" role in continuing their major or in deliberation of changing, "Self" and "Family". Also, for *deliberated* students, over 50% say that "Academic Advisors" and "Faculty" have no role in the deliberations. Over 85% of students reported that "Career Services" had no role, although career services offers an on-line career planning tool that many of the students have completed.

Eight of the questions have responses that are statistically significantly different with respect to whether the student is *deliberated* or *resolute*. Chi-square tests, with the null hypothesis that *deliberated* and *resolute* groups were independent, were performed on the data in Table III. From these tests, the p-values are reported. The statistical tests were also run on the original data without condensing the categories. The same eight people or groups are statistically significantly different in either case. The groups where differences exist are "Family", "Significant Other", "Friends", "Roommates, Hallmates", "Faculty", "More Senior Students", "TAs, Learning Center Coaches", and "Work Colleagues and Supervisors". Each of these items had a larger role in the *resolute* students than in the *deliberated* students. This can be seen by comparing the means for the two groups of students and by looking at the percentage of the responses in the "large/very large" category.

C. *Attitude of Influencers of Deliberation*

The students were asked about the attitude each of the people/groups took toward their possible change in major or their continuing in a major. The choices were "NA", "Negative", or "Positive". These results are shown in Table IV. For all items, the response was overwhelmingly more positive than negative. The primary differences were between positive and not applicable (NA). Both the *resolute* and *deliberated* students reported that very few people had negative attitudes toward what they wanted to do. Note,

TABLE IV. ORIENTATION OF INFLUENCERS' ATTITUDE ON DELIBERATION: SURVEY RESPONSES FOR RESOLUTE AND DELIBERATED STUDENTS

		% (*n*)						
Statement	**Choice**	**NA**		**Negative**		**Positive**		***p*-value†**
Self	resolute	1.5	(3)	2.0	(4)	96.5	(192)	0.000
	deliberated	10.6	(20)	13.8	(26)	75.7	(143)	
Family	resolute	3.5	(7)	0.5	(1)	96.0	(191)	0.000
	deliberated	22.3	(42)	16.0	(30)	61.7	(116)	
Significant Other	resolute	43.7	(86)	2.0	(1.0)	55.3	(109)	0.000
	deliberated	60.4	(113)	4.8	(9)	34.8	(65)	
Friends	resolute	8.6	(17)	0.5	(1)	90.9	(179)	0.000
	deliberated	40.5	(75)	6.5	(12)	53.0	(98)	
Roommates, Hallmates	resolute	26.0	(51)	0.5	(1)	73.5	(144)	0.000
	deliberated	55.6	(104)	3.2	(6)	41.2	(77)	
RAs (Resident Assistants)	resolute	53.8	(106)	0.5	(1)	45.7	(90)	0.000
	deliberated	76.5	(143)	1.6	(3)	21.9	(41)	
Academic Advisor	resolute	22.2	(44)	0.5	(1)	77.3	(153)	0.000
	deliberated	46.5	(87)	6.4	(12)	47.1	(88)	
Faculty	resolute	27.4	(54)	1.0	(2)	71.6	(141)	0.000
	deliberated	65.1	(121)	5.4	(10)	29.6	(55)	
More Senior Students	resolute	33.0	(65)	1.0	(2)	66.0	(130)	0.000
	deliberated	71.1	(133)	3.2	(6)	25.7	(48)	
TAs, Learning Center Coaches	resolute	56.9	(112)	0.5	(1)	42.6	(84)	0.000
	deliberated	85.6	(160)	1.6	(3)	12.8	(24)	
Work Colleague and Supervisors	resolute	46.2	(91)	0.5	(1)	53.3	(105)	0.000
	deliberated	76.3	(142)	2.7	(5)	21.0	(39)	
Career Services	resolute	59.4	(117)	1.0	(2)	39.6	(78)	0.000
	deliberated	82.4	(154)	1.6	(3)	16.0	(30)	
Counseling Services	resolute	68.0	(134)	1.0	(2)	31.0	(61)	0.000
	deliberated	85.0	(159)	2.7	(5)	12.3	(23)	
Members of Student Organizations that you are Affiliated With	resolute	44.4	(87)	1.0	(2)	54.6	(107)	0.000
	deliberated	75.3	(140)	1.6	(3)	23.1	(43)	

† *p*-values were calculated using a chi-squared test, with a null hypothesis of independence of choice

student's perceptions of others' attitudes are subjective and not independent of their own attitudes and interactions.

For both groups of students, the first five questions with the largest percentage with a positive attitude are the same. In order they are "Self", "Family", "Friends", "Academic Advisors", and "Roommates, Hallmates".

It is notable that all of the questions have responses that are statistically significantly different with respect to whether the student is *deliberated* or *resolute*. Chi-square tests, with the null hypothesis that *deliberated* and *resolute* groups were independent, were performed on the data in Table IV. From these tests, the p-values are reported and they all were very small (p-value<0.000). For each question the positive attitude percentages are higher for *resolute* students than for *deliberated* students. In fact, the average of the difference between the two percentages is almost 30%.

There is also a marked difference in the proportion of each question that was marked not applicable (NA). The *deliberated* students had on average a little over 25% greater marked NA than *resolute* students. This may indicate that the *deliberated* students' support system was not as strong as those who were continuing their major. Their consideration of changing majors, instead of being a result of negative attitudes from the people around them, could be a result of not having strong influencers that are either positive or negative.

D. Role Models (Inspirations)

The survey had a series of questions where the students focused on "one person who inspired you in what you want to be." The intent of this series of questions was to explore the people who were an inspiration to students, in other words, role models. Approximately 10% of each student group did not answer these questions, meaning they did not have a "role model" or could not select one to be the focus of their responses.

The first question asked "how do you know this person," or what is their relationship to you? Fig. 2 shows the responses of the two groups of students to this question. No statistical significant differences between the two groups were found (p-value 0.447).

Next, the respondents reported the career or profession of the person who inspired them. The categories were drawn from occupations tracked by the Bureau of Labor Statistics. The 7 most frequently reported occupations are shown in Fig. 3 with the remaining selections grouped into STEM and non-STEM related fields. There is a statistically significant difference between the responses of *resolute* and *deliberated* students (p-value 0.022). Those who are convinced of their major are more likely to have an engineer as an inspiration than those debating their major.

Another aspect of this person of interest is how long the person selected had been an inspiration to the student. The distribution of responses is illustrated in Fig. 4. There is not a statistically significant difference between the responses of the two groups (p-value 0.274).

Finally, the ways in which students interact with the person

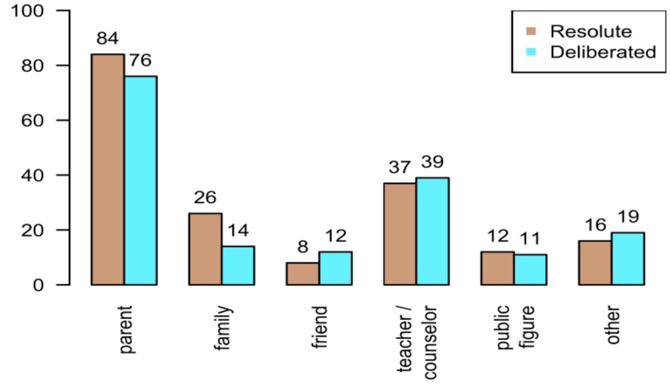

Fig. 2. Responses to "Who is an inspiration to you?"

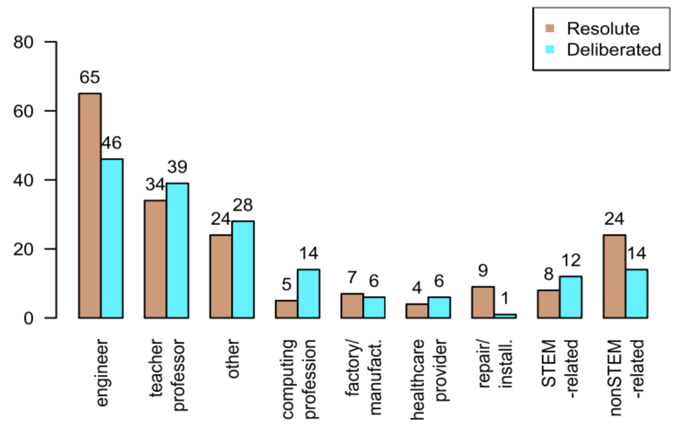

Fig. 3. Responses to "Career or profession of who is an inspiration to you?"

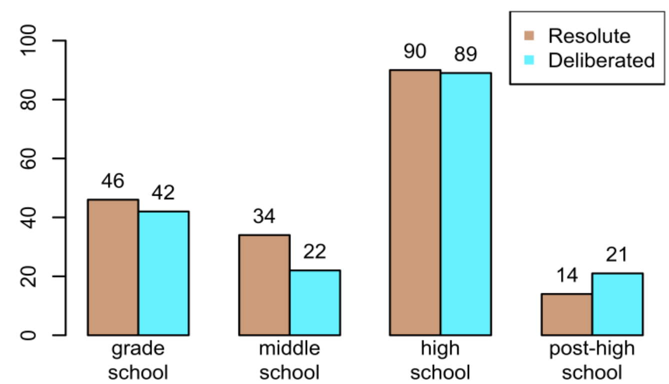

Fig. 4. Responses to "When did this person become an inspiration to you?"

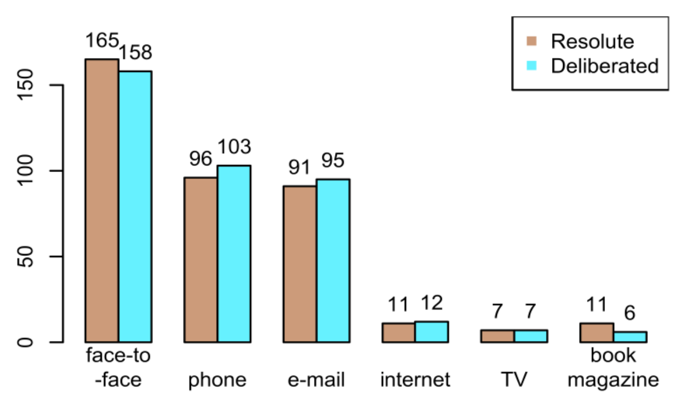

Fig. 5. Responses to "How have you interacted with this person?"

who inspires them are reported in Fig. 5. The interaction method was not restricted to one response. There is no statistically different response based on whether the student is *resolute* or *deliberated* (p-value =0.849).

V. Conclusion

As students progress through their degree program, there are times when many of them debate their choice of major, while others are resolute in their decision. All students had a group of supporters. The people who had the greatest influence on the students' decisions were similar between the *resolute* and *deliberated* groups. On the other hand, these people had higher influence on the *resolute* students versus the *deliberated* students. The findings show that the students who did not consider changing majors reported having a stronger support system including faculty, academic advisors, and engineers who serve as role models. These data suggest that university faculty and staff need to make a larger effort to reach out to all students, so that students, especially those deliberating, will view faculty and staff as resources in their decision making process.

Of the students who indicated they had a role model, there were few differences between the two groups. One difference was that many more of the *resolute* engineering and computer science students reported that an engineer was inspirational to them than the other group. For the students reporting a role model, the person most frequently became an inspiration during high school. Most students reported having personal interaction with their role model. These results confirm other research with respect to role models. Therefore, efforts should be made at the high school level for students to have meaningful contact with engineering and computer science professionals. In addition, faculty need to be aware that a student's personal interaction with role models is still very important during college. Faculty serve as role models themselves and should also facilitate role model connections between students and engineering and computer science professionals.

In future analyses, differences between female and male students, STEM and non-STEM majors, and various STEM majors will be explored. Questions related to future career plans, perseverance, perceptions of gender composition within majors, and anecdotal evidence of the persistence of other students will be examined. Additionally, it will be interesting to compare the data from this survey to other national surveys, such as PACE and NSSE [18, 20]. One of the future goals of this research is to have focus groups to explore some of the more qualitative differences between deliberated and resolute groups that quantitative (survey) data cannot address.

VI. Acknowledgements

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The Dynamic Image of the Engineer

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Abstract **– In this work, engineering students are asked what engineering is and what it means to be an engineer. Their responses suggest that there may be an inconsistent development of the image of an engineer as the student progresses within their engineering program, and a lack of philosophical discussion that leads to a deeper understanding of their field. Additionally, non-engineering students are given the same questions, providing an interesting perspective. The survey questions are presented and an analysis of the results is provided with suggested approaches to improve the observed issues.**

Keywords – Engineering Education, Engineering Identity, Engineering Society, Engineering Culture

I. Introduction

More than ten years ago, common perceptions of engineering and its stereotypes had been based on years of development of the fields and the culture, their academic tracks, professional and amateur accomplishments, average salaries, etc. Through the many facts and fictions provided by books and media engineering was a well-developed image in the minds of the public. There are numerous studies about the effect of new media and communication possibilities that have been creating and transforming the image of professionals and, in particular, engineers [1-2].

There may be no unique or generally acceptable image for what an engineer is, but the fact that this image has the ability to transform more rapidly now than ever before cannot be ignored. Research shows that the freshman engineering classes are among the most transformational experience of most students [3-4]. There have also been several studies on the mutual effects, expectations, and communication venues that separate or unify the student's and instructor's perspective in these first year courses [5-6]. What may be a most probing issue is the difference in expectations and interdependencies between teacher and student beliefs of what engineering and the image of the engineer is.

It is safe to assume that an engineering instructor has a matured expectation of what an engineer is and what they expect students to become. Students in engineering, on the other hand, have very malleable definitions of their engineering degree. In many cases, students' defining image of a professional in their field does not mature until late in their academic career. Additionally, the engineering curriculum has great influence in how this image matures, and may or may not be helping. A consequence of this delayed image maturity may lead to fulfillment (because students have found that their chosen field is what they thought it was), dissatisfaction or depression (because they have found that it is opposite, but it is too late to switch or quit), or switching fields (which takes more time and money).

In this work we analyze the image of the engineer from the perspective of freshman and senior students in electrical and computer engineering as well as non-engineering students taking engineering studies courses. The goal is to help engineering students develop their unique identity, gain a better understanding of student image progression, and possibly capture a glimpse of the current and future trends that could be transforming the engineering field.

II. Experimental Setup

In this experiment, 32 engineering students from a freshman class in electrical engineering (EE), 71 from a senior class in electrical and computer engineering (ECpE), and 33 non-engineering students from a sophomore class in engineering studies (EngSt) at Iowa State University were asked the following:

> *"Imagine that you are at a party, and a person with no particular background in engineering asks you, "What is engineering, and what does it mean to be an engineer?" In your own words, please describe your reply. What is your belief of what engineering is and what it means to be an engineer?"*

From the replies, 11 characteristics or descriptive phrases were extracted that may or may not have been common among each answer. The number of times a criterion had been made reference was then tabulated, and a ratio (in percent) of the number of references to the respective population was reported. Finally, the top five referenced criteria were chosen to represent the image of the engineer.

In the tabulation process, each characteristic could only be tabulated once per respondent, however multiple characteristics could be tabulated from one description. The 11 criteria are the following:

1. Technical problem solving, design, and innovation
2. Ethical behavior
3. Advance society
4. Develop products
5. Apply use of math, science, and physics
6. Apply leadership and communication
7. Apply critical thinking and creativity
8. Make the world a better place
9. Gain and apply knowledge
10. Lifelong learning
11. Lack social and communication skills

III. Results and Discussion

The tabulated results are provided (Table I). Common among all groups is the characteristic of engineering being a field that practices technical problem solving, design, and innovation.

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TABLE I. PERCENT OF STUDENTS REFERENCING CRITERIA

Freshman in EE		Seniors in ECpE		Sophomores in EngSt	
Criteria	*Percent*	*Criteria*	*Percent*	*Criteria*	*Percent*
1	91%	*1*	66%	*1*	67%
8	28%	*5*	32%	*5*	55%
5	25%	*4*	25%	*9*	24%
4	22%	*9*	20%	*4*	15%
9	22%	*7*	18%	*11*	15%
-	-	-	-	-	-
7	16%	*3*	15%	*8*	9%
3	9%	*2*	10%	*7*	6%
6	6%	*6*	7%	*2*	0%
2	3%	*10*	6%	*3*	0%
10	0%	*8*	4%	*6*	0%
11	0%	*11*	0%	*10*	0%

TABLE II. DEFINITIONS OF AN ENGINEER

Source	First Definition of "Engineer" or "Engineering"
Oxford English Dictionary	Engineer: A person who makes engines, structures or systems.
Merriam-Webster Dictionary	Engineer: A member of a military group devoted to engineering work.
Encyclopedia Britannica	Engineering: the application of science to the optimum conversion of the resources of nature to the uses of humankind.
Dictionary.com	Engineer: A person trained and skilled in the design, construction, and use of engines or machines, or in any of various branches of engineering.
Wikipedia	Engineer: An engineer is a professional practitioner of engineering, concerned with applying scientific knowledge, mathematics, and ingenuity to develop solutions for technical problems.

Maybe the most noticeable difference in perspective between freshman students and seniors is the placement of criterion #8: "Make the world a better place." These results suggest that as one learns and grows in the program, students lose sight of the purpose and mission of engineering, which is to benefit humanity. This difference also may suggest a dilution of the essence of engineering ideals.

Another interesting point to note is the close alignment between the image of an engineer in the eyes of senior engineers in ECpE and sophomore non-engineers in EngSt. Only one criterion is different, not considering order of importance, between the two: #7 for the engineers and #11 for the non-engineers. Additionally, criterion #11 was not mentioned at all by the engineering students (for an understandable reason). It seems that in the eyes of non-engineers, engineering students lack social skills and abilities to communicate well. Terms and phrases were used to describe engineers such as "geek," "nerd," "know-it-alls," and "superiority complex." Although these are purely subjective opinions which may have derived from single, defining events, the fact that there may be merit to this on a broadened scale cannot be ignored [7].

Finally, one should notice the qualities of engineers that did not make it to the top 5 in any of the student sample sets: Criterion #2, #3, #6, and #10. It appears that although some agree these are important, the collective student sample population does not. The application of leadership and communication can directly affect social skills. This may be a reason why non-engineering students feel criterion #11 was worth mentioning. Lifelong learning was within the bottom three criteria of all sample sets, if mentioned at all. This suggests a lack of inspiration to pursue higher education or other academic endeavors.

To serve as a reference, first definitions from the Oxford English Dictionary, Merriam-Webster Dictionary, Encyclopedia Britannica, Dictionary.com, and Wikipedia are stated (Table II). It is arguable that the definition of an engineer from these five external sources fit criteria #1, #5, and #9 posed by students. In addition, these criteria are all in the top five mentioned for each of the three student groups. Thus, one may conclude that the majority of the respondents have a relatively accurate technical definition of what an engineer is.

Overall, it seems that as students progress throughout their education program they begin to place more emphasis on technical-oriented activities and understandings and less emphasis on the philosophical questions that define how they fit in the world and what their contribution to society is (other than technical problem-solving). Based on these results, it is possible that increasing efforts to include more activities that practice ethical behavior, leadership, communication, and lifelong learning in the engineering curriculum may broaden students' understanding of engineering and its cultural bearing. Much effort has been taken by educators to help with this and similar issues [8]. However, it is clear that further efforts may be needed.

This study posed one question from a single perspective to draw conclusions about the image of an engineer. In addition, the respondents represent less than 3% of the total enrolled engineering students at Iowa State University. The authors plan to expand this study using a similar methodology but involving more questions, students, and external sources to enhance and refine the results. Therefore, this study serves as a work in progress.

IV. CONCLUSION

In this work, it has been found that the image of an engineer has the ability to change drastically throughout an engineering education curriculum. Analysis shows that students and external sources agree that an engineer practices technical problem solving, design, and innovation. However, there appears to be inconsistencies on the philosophy of engineering and its non-technical role in the world as students progress in their program. To improve this, it is suggested that topics relating to the philosophy of engineering be brought to the curriculum, in addition to activities that practice ethical behavior, leadership and communication, and lifelong learning.

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Comparing the Attitudes towards Engineering of Honors Students and Engineering Students at a Liberal Arts University

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***Abstract*—In Fall 2012, 53 honors students and 53 engineering students (including seven students in both honors and engineering) completed a survey designed to examine their attitudes towards engineering and their ability to succeed in engineering. Preliminary analysis of five factors shows that the attitudes of engineers and honors students were similar in many respects. The main areas of difference were that honors liberal arts students had lower confidence in their ability to succeed in science and math and all non-engineers showed lower aptitude for engineering. Non-engineering women showed slightly less affinity for solving open-ended problems. All students expressed similar attitudes about the creativity of engineers and their contributions to solving society's problems.**

Keywords— Attitudes; Factor Analysis; First-year; PFEAS

I. INTRODUCTION

In this work, the attitudes towards engineering of 99 University of San Diego (USD) students who were studying engineering and/or participating in the Honors Program are analyzed to identify differences and commonalities. Understanding these attitudes may help engineering programs to identify students who have the potential to succeed as engineers, but who might need encouragement, or who might have impressions of engineering that can be changed through intervention prior to, or shortly after arrival on campus.

The next section presents a brief survey of the literature related to student attitudes towards engineering, followed by a description of USD's engineering and honors programs. In Section III, the survey is described. Section IV presents preliminary analysis of the survey results.

II. BACKGROUND

A. *Prior Research on Engineering Attitudes*

Several studies have assessed how student attitudes or motivations affect their pursuit of engineering degrees. The Pittsburgh Freshman Engineering Attitude Survey (PFEAS) [1, 2, 3] identified 13 distinct attitudes of students towards engineering, and was used to explain persistence and differences in attitudes across gender and race. Discriminant analysis was applied to PFEAS results to predict persistence in engineering [4]. The Persistence in Engineering survey was used [5] to assess 20 factors related to student attitudes towards engineering among 8,000 students at 29 schools. Factor analysis has been used to compare the attitudes of engineering and non-engineering students [6, 7].

Overall, the prior work showed that confidence in the ability to perform college-level math and science, and a belief that engineering degrees improve job security were important predictors of persistence in engineering. Women generally conveyed less confidence in the basic engineering skills and abilities, and a lower perception of how engineers contribute to society than the men. Engineering students' opinions of engineering's contribution to society was significantly higher than the opinions of non-engineers.

B. *Engineering and Honors Students at USD*

USD is a private, faith-based, national liberal arts university. Students applying for admission do not apply to specific majors, and there are no enrollment caps on any major. The engineering programs require 4.5 years to complete and students receive a dual B.S./B.A. in their engineering field, electrical, industrial and systems, or mechanical engineering. Because of the core requirements, it is believed that USD tends to attract fewer engineering students who have narrow, technical interests, and more students who are interested in a broad, liberal arts education. Thus, the attitudes of these engineering students may not reflect those of students at large public universities, or institutions with an emphasis on engineering or science.

Incoming students who have demonstrated unusual accomplishments in leadership, community involvement and academic excellence may be invited to participate in the Honors Program. Selection is based on admission scores used to award scholarships and a separate application to the Honors Program. Students in the Honors Program typically take one honors class each semester towards fulfilling USD's core curriculum and complete an Honors Thesis. Each year approximately 120 first-year students out of an incoming class of 1100 are invited to join the Honors Program.

During their first semester at USD, incoming first-time in college (FTIC) students are placed in one *preceptorial* class

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according to their expressed academic interests. Honors students are placed in honors preceptorial classes. In Fall 2012, there was one honors section of ENGR 101, the introductory class taken by all engineering students. Because there were not enough engineering students to fill a complete honors section, some high achieving engineers who were not in the Honors Program were added to this section. All other students expressing interest in studying engineering were enrolled in regular sections of ENGR 101.

III. USD Attitude Study

In Fall 2012, FTIC students were surveyed to assess their attitudes towards engineering. The purpose of the survey was to explore differences in the attitudes of students across many disciplines at a predominantly liberal arts university. The 30-question survey was based on the PFEAS and a revised version of the PFEAS [7]. Each question was phrased so that students could state the degree of agreement or disagreement with a statement such as, "*I have strong problem solving skills.*" A 5-level Likert scale was used ranging from *Strongly Disagree* to *Strongly Agree.* The complete survey appears in [8].

The survey was completed by 272 students in 28 classes. Factor analysis was performed on the results, and five significant factors based on 16 questions were identified [8]. The remaining questions were not used. These factors were: APP (mechanical, technical, and computer aptitude), CONF (confidence and enjoyment of Science, Technology, Engineering and Math), CREATE (creativity of engineers), PROB (student affinity for solving open-ended problems), and SOC (engineering contributions to society). Factor loadings were between 0.44 and 0.92 and no questions were associated with more than one factor. Oblimin rotation was applied to account for correlation between factors.

In this work, a subset of the survey responses is examined more closely. The attitudes of engineering students are compared to the attitudes of honors students. Because honors students have demonstrated high levels of academic success, it is hypothesized that many of them may be able to succeed in engineering, but have chosen different fields because of different attitudes towards engineering.

The survey was completed by 99 students who were in ENGR 101, a course in the Honors Program, or the honors section of ENGR 101. Table I gives a summary of the respondents. Science, math and computer science students are identified as SMCS, and all other students are considered liberal arts students. SAT scores were not available for all students. The averages of the available scores are presented. High school grade point averages were available for all students.

Table I contains some evidence that most honors students are academically qualified to pursue engineering. Their SAT-Math scores were on par with those of the engineers and their critical reading scores and GPAs were much higher.

TABLE I. Characteristics of Students Who Completed Attitude Survey in Fall 2012

		# of Students	**SAT-CR**	**SAT-M**	**HSGPA**
ENGR Non-Honors	Men	34	598	668	3.81
	Women	12	578	668	3.98
Honors ENGR	Men	5	660	668	4.06
	Women	2	N/A	N/A	4.31
Honors Liberal Arts	Men	10	640	652	4.25
	Women	10	705	672	4.28
Honors SMCS	Men	8	658	688	4.37
	Women	18	649	688	4.37

IV. Preliminary Analysis of Survey Results

The Likert responses' values for each question are summarized here. Questions were reverse coded where necessary so that a "positive attitude" to engineering would be scored as a five regardless of the wording of the original question. All questions related to a factor were averaged to yield an overall response from the student. (A more comprehensive analysis that considers the factor scores is beyond the scope of this preliminary investigation).

Figures 1-4 present box plots of the most interesting results. In each plot, the thick horizontal line represents the median response, and the box represents the limits of the first (Q1) and third quartile (Q3) of the responses. The dashed whiskers denote observed responses within 1.5*(Q3-Q1) of the box. Circles represent outliers.

Figs. 1-3 all reflect a student's perception of their ability to succeed in STEM (science, technology, math and engineering) classes, or affinity for solving the types of open-ended problems that engineers encounter. Although rigorous statistical tests have not been conducted, Fig. 1 suggests that all STEM majors felt confident in their science and math capabilities, and are much more confident than liberal arts students are. The relatively narrow height of the boxes suggests uniformity in these attitudes. On the other hand, Fig. 2 shows that students' perception of their mechanical, technical, and computer aptitude is much less consistent, that men are more confident than women, and that SMCS students are more similar to liberal arts students than to engineers despite their strong math and science confidence. Fig. 3 suggests that, regardless of the discipline, women generally enjoy open-ended problems less than men do, or have less confidence in their problem solving skills, even though they enjoy, or are confident in their math and science abilities.

Fig. 4 shows that all USD students had similar attitudes towards the ability of engineers to address societal problems. These results do not reflect the gender differences that were observed in other published studies [3]. The results for attitudes regarding the creativity of engineers were similar to the SOC responses.

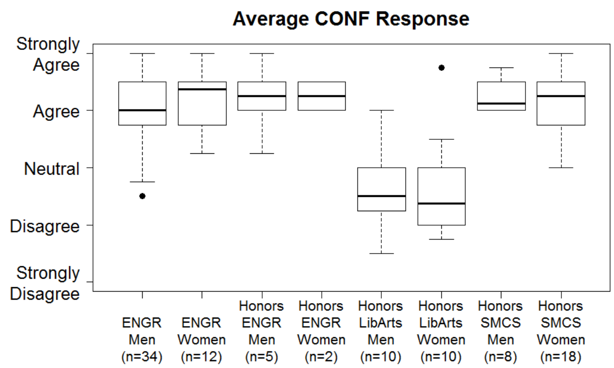

Fig. 1. Average response to questions probing subject's confidence and enjoyment of STEM classes.

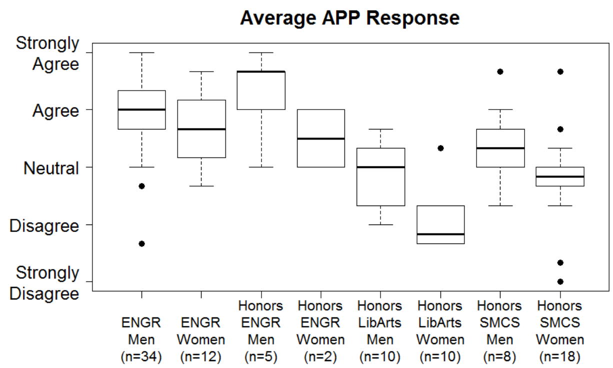

Fig. 2. Average response to questions probing subject's mechanical, technical and computer aptitude.

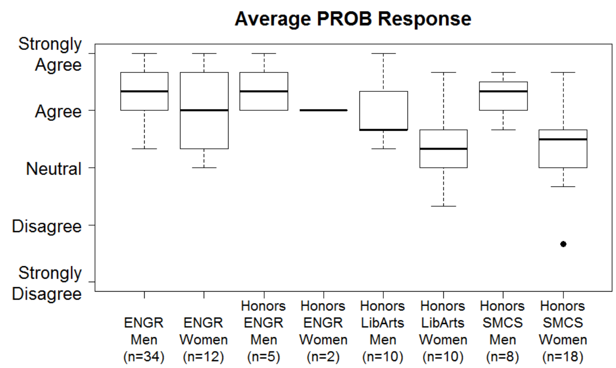

Fig. 3. Average response to questions probing subject's affinity for working on open-ended problems.

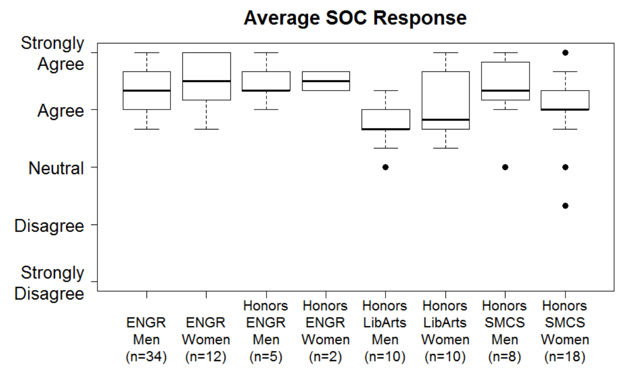

Fig. 4. Average response to questions probing subject's perception of engineering contributions to society.

V. Conclusions

These preliminary results support earlier work that shows that students who pursue engineering have strongly positive attitudes towards factors related to engineering success. However, they also show that many SMCS students have similar attitudes to many of the factors with the most notable exception being mechanical, technical, or computer aptitude. This observation suggests that these students may be more attracted to engineering if they can be encouraged to believe in their abilities, or if they can be made aware of a broader understanding of engineering including that many fields of engineering solve important problems that are not "mechanical" in nature and that their math and science skill will help them succeed in engineering.

Acknowledgment

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Carry-on Effect in Extreme Apprenticeship

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***Abstract*—We argue that the first undergraduate courses are the most important ones on the student's path towards becoming a computer scientist. Therefore, during 2010-2012, we have exercised extensive effort in order to improve the first-semester Computer Science (CS) courses. We have been able to use a learning-by-doing approach called the Extreme Apprenticeship (XA) method accompanied by personal advising even for courses with hundreds of students. We claim that when high demands are met with sufficient support, students learn valuable programming skills that become a foundation that carries them in their further CS courses. In this paper, we analyze how the effects of a three-year effort of renovating our introductory programming courses propagate to further studies. Compared to the control cohorts of 2007-2009, we observe a carry-on-effect caused by the XA method in student success that is visible in the per-student average accumulation of credits after 7 and 13 months after the start of studies. In addition, we can see the effect propagating to mandatory subsequent courses, even without the XA method.**

I. Introduction

It is well known that learning to program is hard [1]. As computer science is typically not taught in high schools, first-year Computer Science (CS) students experience difficulties that are manifested in high failure and drop-out rates in the first programming courses (often referred to as CS1). Improving the operation of the first programming course has been a popular topic for years in the CS education community.

A challenge in examining the improvements in education is that the examination is oftentimes either too broad or too narrow. The administrative view to teaching development emphasizes the student throughput and number of degrees, cost-effectiveness [2], faculty readiness to adopt new teaching methods (see e.g. [3], [4]) but does not elicit the true effect of the improvements in the learning within the CS1 course. On the other hand, a teacher's view and reports thereof emphasize the uniqueness of the course without inspecting the effect on the subsequent courses [5], [6]. Extending the view from a single course is important as the expertise accumulates throughout the degree.

At our department, we have exercised extensive effort on improving the first-semester Computer Science courses that our university students encounter. Due to the teaching improvements and efforts, our department has been awarded various national teaching prizes during the last decade. During the last three years, we have made effort to investigate and apply a learning-by-doing approach accompanied by personal advising even for courses with hundreds of students. The application of the method to our introductory programming courses has both increased students success rates as well as actual learning. The results are significant, as the improvements have been made in a context, where the teaching has already been praised both by the students and the nation.

We purposefully and openly press our students to immerse themselves into a mode of building a strong programming routine by deliberate practise from day one of their studies. Contrary to many other approaches, we do not seek a silver bullet that would allow our students to spend fewer hours on learning. Instead, we want our students to really put the effort into purposefully guided learning-oriented activities. We claim that when high demands are met with sufficient support, students learn valuable hidden skills that become a foundation that carries them during their further studies.

Now, after three years of applying the method to our first semester, we are ready to examine the long-term effect of the *learning* in the students' first CS1 course. It is known that "teacher-induced learning has low persistence, with three-quarters or more fading out within one year" [7]. However, we have observed a rise in the skills of the students that suggests there is a carry-on effect from the first course to subsequent courses.

In this paper, we present the data that shows that the increase in programming skills in the first course enables more students to continue on a path to become a computer scientist. We observe an effect on the success of the studies 7 and 13 months after the initial programming course, as well as the courses immediately after the first programming course.

II. Background and Context

In Finland, there are no tuition fees for anyone in studies in higher education. There are more study positions in STEM (science, technology, engineering, and mathematics) subjects in higher education than there are high school students with a suitable high school course selection, and naturally, every institution wants to recruit good students. Unfortunately Computer Science is not among the most desirable study subjects, therefore, it is not very difficult to secure a study right in CS. The entrance exam for CS studies is based on logical and analytical skills and does not require programming knowledge. The studies start with no expectation of previous knowledge on the subject.

The Department of Computer Science at the University of Helsinki has been selected as a national Centre of Excellence (CoE) in higher education twice in a row, 3 years at a time. This is a remarkable achievement for the department, since in the last round of CoE, the status was awarded only to 10 units in the whole country. The CoE status was received based on ten years of well-documented department-wide teaching improvements, such as formalized study circles, detailed and explicit

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learning outcome rubrics for all mandatory and steadily recurring courses, and arranging the study environment according to the so-called *constructive alignment* [8]. Thus, it is safe to say that the education and teaching provided by the department has been highly valued and in a solid form already before the advent of the latest development that is in the focus of this paper.

Contrary to the common attitude, where faculty draws away from undergraduate education in order to teach graduate courses and fulfill research demands [9], we have exercised extensive effort to improve the undergraduate education starting from the very first courses. The most recent work in this area has been an improvement to both teaching arrangements and the content of our software engineering-related courses [10].

During the improvement, we have created and started applying a pedagogical method that we call the Extreme Apprenticeship (XA) method. As the first undergraduate courses are important on a student's path towards becoming an expert computer scientist, meaningful support activities must be organized for early courses. Approaching the early student population with too much distance can be detrimental to the learning community, students and teachers alike. Therefore, one important aspect of XA is to reduce the distance between the students and the teachers. In practice, this means constant emphasis on two-way feedback (interaction) between the teachers and the students.

A. The Extreme Apprenticeship method

Extreme Apprenticeship (XA) [11] is a method of organizing programming instruction in an effective and scalable manner [12]. It is not only about *learning about expertise* but *becoming an expert* in the practiced skill, e.g. programming. XA is influenced by Extreme Programming [13], where software development best practices such as code reviews are taken to the extreme, and Cognitive Apprenticeship [14], where emphasis is put on making tacit processes visible for the students via modeling, after which the students are scaffolded as they work on the task at hand themselves.

Exercises play a crucial role in XA education. Our courses are carefully structured around collaboratively produced learning objectives and assessment criteria that are visible to the students and teachers alike. Each learning objective is covered using several of exercises, that build on top of each other in a stepwise fashion. The stepwise increment is an adaptation of test-driven development [15] and the Spiral approach in education, where students deepen their knowledge on the topic step-by-step validating their work during each step.

Exercises are designed to help students start easy and deepen their knowledge in an iterative manner. An easy start provides feelings of success and helps students achieve their comfort level. Feelings of success feed the motivation that is known to be fluctuating strongly even within a course [16]. As the students work through the easier exercises, they practice skills that have been relevant in the earlier parts in the course, as well as are introduced to new topics in a gentle fashion. As students proceed within a course, the learning objectives of the exercises start overlapping each other, and more focus is put on facilitating deliberate practise [17].

As students start their work on a task, they first build a mental model of the problem at hand e.g. via well-structured exercise design, process recordings, or during lectures. Once the modeling phase has been continued to a state, where the student feels that she is confident about working on the task, she works on the task under guidance of a more experienced instructor, e.g. a teaching assistant. The teaching assistant scaffolds the student if she needs support, and even in such cases the student is only nudged towards a direction, where she can again proceed on her own.

In our context, the students are constantly helped in computer labs by course instructors, who actively engage the students that work on the exercises; students typically receive help within minutes, depending on the time of day, and the amount of students in the labs. Scaffolding provided by the instructors and learning material are designed to help the students to reach their zone of proximal development [18]. There are tens of weekly exercises, some of which provide step-by-step guidance for completing them, mimicking the solution process that a master can utilize while solving them, while other exercises are open-ended and allow students a larger degree of freedom for designing and programming a solution for them. While the students receive support and guidance in the labs, we also provide (semi-)weekly code reviews for some of the open-ended exercises.

Although there is no limit on the amount of guidance that a student can receive, or on the amount of times that the exercises can be returned, it is of utmost importance that as soon as the student does not require scaffolding and can proceed on their own, the scaffolding is faded, i.e. the support is reduced. The cycle of modeling, scaffolding, and fading takes place several times each week as each week typically contains several learning objectives and tens of exercises; the exercise sets for each week also have a strict deadline, after which they cannot be returned. Even if a solution that the student ends up with is correct, it may still require refinement. Depending on the quality of the solution, the student may be directed to further improve her work in the lab and apply practices such as clean code [19].

In practice, the most significant differences between XA and the traditional operation from the organizational perspective are: 1) there are no lectures in XA (or if there is, the lectures serve the exercises); 2) students are encouraged and expected to use as much time as needed to master the skills (thereby different students use very varying amounts of time in the XA lab during the week). Students are free to come and go as they wish to the XA labs. With careful allocation of resources, XA does not cost more than the traditional way of organizing lecture-based education [12].

So far the results in our XA-based programming education within the programming courses have been impressive. The change from traditional (lecture-based with take-home assignments) has resulted in a statistically significant change in acceptance rates of our programming courses; the average rates of our introductory programming course and advanced programming course have increased by 32% and 37% respectively (see [20] for further details). This is a noteworthy improvement as a lot of effort was already put into the improvement for the introductory programming course.

B. Students as voluntary TAs

In XA-based programming courses, most of the work is typically done in computer labs, where the teaching personnel scaffolds the students that work on the exercises. Since starting to apply XA, we have observed a substantial increase in students that are willing to help others in the labs, even on a voluntary basis. As a response to the increase, we have welcomed the student teaching assistants; many of them are in a very early phase of their studies, and are participating in the teaching community even as early as during their second semester [21].

The students that participate as teachers become legitimate peripheral participants [22] of the teaching community. Having young student members as part of the teaching community is beneficial for all parties, as it may increase the retention rate [23] and create a more enjoyable learning context [24]. Between fall 2010 and spring 2013, in addition to the course faculty, we have had 93 junior teaching assistants participating in making the XA experience as positive as possible to the students in the classes. Contrary to some other laudable efforts in using students as agents of educational reform [25], we aim to have some 20% of our students involved in XA labs as TAs.

III. Study Setting

The carry-on-effect of XA-based education is studied using three different measures: (1) grade distribution in the first mandatory programming course; (2) credit accumulation per average student 7 and 13 months after the start of their studies, and (3) success in the expected study path during the first semester by examining the success in two of the subsequent courses right after the first programming course. In all of these examinations, the point of introduction of XA-based education is the year 2010.

The data used in this study is extracted from the official study records of the University of Helsinki, and contains records for students that have enrolled at the university with CS as their major subject since 2007. In total, the database extract has information on 895 students. The yearly intake of students has been aimed at 130 (except 2007 when it was 150). In practice, there is year-by-year fluctuation since a part of the accepted students do not register for CS (as they probably have succeeded in landing a more preferable study place somewhere else). "Overbooking" in the student intake is typically something around 35% but fairly difficult to predict. This is the reason for normalizing the numbers year-by-year so that we can compare the relative, not absolute changes in the results.

The application of Extreme Apprenticeship method for the first courses was started in 2010. Hence, years 2010-2012 are post-XA years, and 2007-2009 are pre-XA years in the data. Pre-XA years means a more traditional way of organizing education around a fixed number of weekly lectures, exercise sessions, and study groups. The teacher responsible for the courses Introduction to Programming and Advanced Programming has been the same during 2007-2011, while a different teacher was assigned to the courses during 2012.

A. Grade Distribution

Even though the first programming course has been completely revamped with the advent of XA, the paper-based final exam has been deliberately kept mandatory and as closely corresponding to the exams during the pre-XA era as possible. Therefore, the grade distribution of the course Introduction to Programming is comparable on a yearly basis. It is important to note that the grade distribution at our university is completely decidable by the teacher responsible for the course. In other words, the grades do not need to be forced into a bell curve. Changes in grade distribution can therefore truthfully reflect the changes in student skills and knowledge.

We acknowledge the fact that since XA is about heavy practice, students are likely to accumulate a stronger programming routine and other desirable qualities that are not captured by the traditional final exam. In order to emphasize the thinking and not just the doing – as Allendoerfer et al. [26] aptly put it – a paper-based final exam that requires higher-order thinking skills is a valid addition to the educational arrangements, even when XA is employed.

B. Credit Accumulation

Possible differences in credit accumulation were analyzed by extracting the number of computer science credits that each student had gathered in 7 and 13 months since the start of their studies. As there is always a handful of students that do not start their studies during the same year they enroll, we removed the students that had not attempted to take any courses from the analysis.

As the number of students starting their studies each year differs, the credit accumulations have been normalized based on the number of active students, i.e. students, that have at least attempted a single course. After normalization, the results are directly comparable. As the students start their studies on August 1st, the 13 month accumulation for year 2012 is not available during the time of writing this article.

C. Early Study Path Success

In addition to the credit accumulation for each student group, we analyze if there is any difference in study path success between students. The student cohorts are built based on the year when they took their first introductory programming course, which is considered as the first step in computer science studies, as it is mandatory for every student.

We analyze two different course pairs for each student cohort: (1) Introduction to Programming and Advanced Programming (both changed to XA after 2010), and (2) Introduction to Programming and Software Modeling (the latter has not been changed to XA). The courses are organized right after the course on Introduction to Programming in the same semester.

The method employed here resembles the research conducted by Carrell and West [27]. However, as the organization of courses and allocation of teachers is not so structured at our department and administratively collected student feedback infrequent, we cannot examine the effects of XA in such a comprehensive fashion.

IV. Data and Results

In this section, we show the data and the results extracted from the study registry. First, we discuss how the grade distribution has changed within our introductory programming course. Then, we focus on the overall credit accumulation between students that have started during different years, and finally, we consider students' early study path success.

It should be noted that there have not been other significant organizational arrangements that can interfere with the results. The required study path for BSc students has been the same from 2007 to 2012. The number of teachers has remained the same, and no differences in student intake can be evoked. However, as the yearly intake in 2007 was 150 and only 130 from 2008 to 2012, we use the year 2008 as a baseline, as one could argue that the student cohort of the year 2007 was somehow inferior to the subsequent years.

Another worthy detail is that all teachers responsible for these courses are tenured teachers, not adjunct or contingent. All of the courses have had several students as paid TAs; the number and the "quality" of TAs is comparable year-by-year.

A. Grade Distribution

The grade distribution in the introductory programming courses from 2007 to 2012 is visible in Figure 1. The areas in dark color, i.e. grade 0, depict the number of students that have failed the course, while the areas in brighter color indicate students that have passed the course. In the XA-based courses, 38.5% of the students have received the highest grade available, i.e. 5, which is indicated by the brightest color. The grade 5 has been awarded to 22.6% of the students in traditional courses. During 2007-2009, 42.3% of the students failed the course Introduction to Programming on the first try, while during 2010-2012, 28.2% of the students failed the course on the first try.

It is clearly visible that the grade distribution and pass rate has been improving. However, as we do not employ tests similar to ACT/SAT, we are not able to directly compare e.g. grade inflation [28], as is possible in several other countries. However, in our context, there are no direct or hidden incentives tied to the grade distribution, and the teacher responsible for every course instance has been a tenured teacher who also teaches many of the subsequent courses to the very same students; "letting the students off easy" would be harmful for the teacher herself.

Successful start on the study path is a valuable first step, as it is a clear signal for a student that she is doing a good job and is appropriately rewarded. A successful first step can start a virtuous cycle for the student but only if the student truly has learned the required skills. Grade inflation would be counterproductive in XA-based education.

B. Credit Accumulation

Credit accumulation describes the number of credits that students have received during an observed interval. The students are grouped based on the year when they enroll at the university and start their studies. The number of credits has been aggregated from the student groups. Table I shows number of students, sum of credits after 7 months of studying

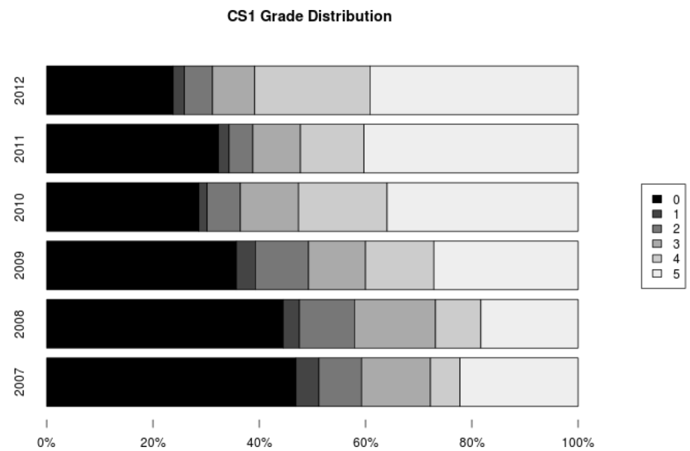

Fig. 1. Grade distribution for the course Introduction to Programming between 2007 and 2012

and credits after 13 months of studying for each student group. In addition to the sum of credits, normalized credit counts and comparison to year 2008 are also shown. The normalization is done based on the student population size, and year 2008 was chosen as a baseline as the student intake was decreased from 2007 by 20 students. Note that the data only contains students that have started their studies, i.e. at least attempted a single course.

TABLE I. Credit accumulation for student groups from different yearly intakes

Year	Students	Credits 7 (norm, scaled %)	Credits 13 (norm, scaled %)
2007	136	1681 (2237, **91.6**)	2558 (3404, **95.2**)
2008	119	1605 (2441, **100**)	2352 (3577, **100**)
2009	120	1616 (2437, **99.9**)	2686 (4051, **113.3**)
2010	136	2030 (2701, **110.7**)	3418 (4549, **127.2**)
2011	140	2287 (2957, **121.1**)	3352 (4334, **121.1**)
2012	168	3042 (3277, **134.3**)	n/a

When looking at the years 2010-2012, we observe a clear increase in the number of credits that students gain during their early studies when compared to the years 2007-2009. The higher number of freshmen in 2012 is explained by an experiment, where we utilized a massive open online course (MOOC) in programming as an entrance exam to CS studies [29]. The number of students that received a study place through "the normal way" was not influenced by the experiment.

To compare whether there is a difference between the 2007-2009 and 2010-2012 cohorts, analysis of variance (ANOVA) was conducted on the credit gains after 7 and 13 months. With three samples in both groups, there is a statistically significant difference between the groups ($p < 0.05$). In the 13 month groups, where the numbers from 2012 is missing, there is no statistically significant difference ($p = 0.062$).

This may be partially explained by the number of samples, and partially by the introduction of XA. XA was introduced during spring 2010, and some of the students that failed first programming courses during fall 2009 retook their programming courses during spring 2010. Typically, spring versions of the programming courses are populated by CS minor students, whereas fall versions are for CS major students.

In addition, we analyze the credit gains of students that attempted their studies, i.e. enrolled to at least a single class, and students that passed courses.

When analyzing the students that attempted their studies, the students in the pre-XA group gained 13.1 credits during the first 7 months (n=375, σ=11.6), while the students in the post-XA group gained 16.6 credits (n=444, σ=11.1). The two groups were also compared using an ANOVA test, which indicated that there is a statistically significant difference for the pre-XA and post-XA groups after 7 months of studies ($p < 0.01$).

When considering the credit gains after 13 months, where year 2012 has been excluded due to currently unavailable data, the pre-XA group gained 20.3 credits on average (n=375, σ=18.6), while the post-XA group gained 24.5 credits on average (n=276, σ=19.0). A statistically significant difference was observed using an ANOVA test ($p < 0.01$).

When considering students that passed courses, i.e. they have passed at least a single course, the students in the pre-XA group gained 17.0 credits during the first 7 months (n=289, σ=10.4), while the students in the post-XA group gained 19.6 credits (n=376, σ=9.3). An ANOVA test indicated that there is a statistically significant difference for the pre-XA and post-XA groups after 7 months of studies ($p < 0.01$).

When considering the credit gains after 13 months, where year 2012 has been excluded due to currently unavailable data, the pre-XA group gained 25.6 credits on average (n=297, σ=17.4), while the post-XA group gained 29.3 credits on average (n=231, σ=17.1). A statistically significant difference was observed using an ANOVA test ($p < 0.05$).

C. Early Study Path Success

In order to validate the effect of XA, we want to examine the mandatory first course (Introduction to Programming) and see whether the success in two mandatory subsequent courses (Advanced Programming and Software Modeling) benefits from the fact that the first course is based on XA or not. To validate the effect even further, one of the subsequent courses (Advanced Programming) is also XA-based, but the other one (Software Modeling) is not. All of these three courses are mandatory courses for every BSc student in CS, and all of the three courses are scheduled to be taken during the first semester.

In the following examination, study path success describes the student percentage that has succeeded in a specific course pair on the first attempt. The percentage for yearly course pairs is shown in Table II.

TABLE II. STUDY PATH SUCCESS WHEN MOVING FROM INTRODUCTION TO PROGRAMMING TO ADVANCED PROGRAMMING AND INTRODUCTION TO PROGRAMMING TO SOFTWARE MODELING

Year	Intr. Prg. & Adv. Prg	Intr. Prg. & SW. Modeling
2007	45.1	41.5
2008	39.2	48.8
2009	50	54.2
2010	68.5	63
2011	71.1	74.4
2012	70.3	72.2

Before XA, the year with the best success was 2009, where 50% of the students that enrolled in both Introduction to Programming and Advanced Programming passed both courses on their first attempt. A similar result is visible in the course pair Introduction to Programming and Software Modeling; 54.2% of the students that started both courses passed both on their first attempt.

The lowest scores after the introduction of XA are from the year 2010. Here 68.5% of the students passed both programming courses on their first attempt, and 63% of the students passed both Introduction to Programming and Software Modeling. However, a clear difference can be observed between the pre-XA and post-XA courses. An interesting issue is that the effect of the first course using XA appears to carry over to the subsequent course, irrespective of the use of XA in the subsequent course.

When conducting an ANOVA test for the course pair Introduction to Programming and Advanced Programming, there is a statistically significant difference ($p < 0.01$) between the pre-XA and post-XA groups. Statistically significant difference is observed also for the course pair Introduction to Programming and Software Modeling ($p < 0.05$).

V. DISCUSSION

We have described results from a long-term study of student performance before and after applying a method called XA in our early programming courses. Our results indicate that the grade distribution, pass-rate, overall credit accumulation, and student success in staying on the desired study path have all improved after applying XA, when looking at students' performance after 7 months and 13 months of studying.

At our university, the teachers are not rewarded for performing well, nor are they punished for performing poorly. As a matter of fact, it is very difficult for a teacher to even know how they are performing, as there are no formal measures other than student grades that the teacher herself decides. The administration oversees the study progress on a larger scale but has no measures to evaluate *learning*. Many times even the formal course feedback received from the students has little impact as the teacher herself is the main actor in processing the feedback. Fortunately, in our context where teaching is valued and teachers want to be good teachers rather than bad teachers, our introductory programming courses have always received excellent feedback and been held in high esteem. Therefore, the improvements described in this paper are valuable, as they extend beyond a single course and improve an already well-functional educational arrangement.

The results and XA that are described in this paper are a part of a larger change, which was started in late 2009. Every change requires people willing to change; we have been lucky to have teachers eager to deliberately practice and hone both their skills and knowledge, and apply their knowledge fully into teaching. Communication and bi-directional feedback valued by XA requires that the teachers are on the same level as the students, as students work on their exercises: both receive feedback on what they are doing well, and what could be improved, which allows a cycle, where the courses can be aligned to match the needs of individual learners.

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A Successful Graduate Cloud Computing Class with Hands-on Labs

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***Abstract*—Modern web-based services increasingly have a cloud-based component, which only in recent years has been studied in an academic manner. Many cloud-computing courses focus on fundamental concepts that, while universal to cloud computing understanding, may not provide students with enough background to actually deploy an application to the cloud. To that end we present a cloud computing class that through the use of labs, presentations, and research projects, integrates practical hands-on experiences with academic research. The labs not only deploy to multiple public cloud environments, but also walk students through the process of creating, configuring, and maintaining their own private clouds. We maintain that this juxtaposition of practice and theory leads to not only better learning outcomes in the classroom in the form of refereed publications and further study, but also leads to practical skills which better prepare students for joining the workforce.**

Keywords – cloud computing; graduate teaching; hands-on laboratories.

I. INTRODUCTION

The rising use of cloud computing in industry has led to a shift in the way modern web services are architected and deployed. With the previous paradigm of purchasing and racking servers to create a website slowly going away, the new generation of programmers is faced with a unique dilemma.

Traditional development assumes a dedicated server farm in a well-maintained data center with an army of system administrators available 24 hours a day. Each server is reliable, closely monitored, and treated as a business critical asset. With cloud computing this paradigm is no longer valid. A server is now a virtual entity competing for resources with other entities on shared hardware in a common network. Depending on what applications are being run on neighboring computing instances, this can result in wildly different performance and usage patterns for the cloud as whole.

In the current computing landscape it is possible to create a fully functional, virtual computing environment with scaling, configuration, and redundancy built in. Replacing the traditional model of dedicated hardware in a private data center for a shared computing environment in a public cloud however requires a different way of thinking about how to create and maintain a modern online web-based service.

Much like the shift from declarative to object-oriented programming, cloud-based programming requires a new way of thinking. While a virtual machine (VM) in a cloud environment is generally abstracted as a fully functional (albeit amorphous) computer on the Internet, it is in actuality an entity that is fundamentally different when compared to a similar physical server housed in a dedicated data center. Differences in performance and reliability must be accounted for in a cloud-based architecture, as they can make the difference between a successful deployment or a complete failure. It is this difference that makes the study of cloud computing of paramount importance in a modern engineering curriculum.

This paper describes a graduate level cloud-computing course that was first taught at San José State University in San José, California, USA in the fall semester of 2012. Because of the proximity of San José to Silicon Valley, it was decided to incorporate a variety of cutting-edge cloud computing technologies with the traditional curriculum to better prepare students for local positions in industry as well as for further Ph. D. study. The success of this teaching method is the focus of the remainder of this paper.

The paper is organized as follows: the second section describes the course content in-depth. The third section focuses on the hands-on lab assignments, including lessons learned designing the labs. The fourth section presents the results of the course in the form of student feedback, success stories, and the results of one particular project. The fifth section details goals for future classes, and finally the last section concludes the paper.

II. COURSE DESCRIPTION

A. Overview

The course used a traditional curriculum including lectures, student presentations, and group research projects, supplemented with eight hands-on labs intended to introduce various aspects of cloud computing. The overarching goal of the labs was to provide the students with practical experience building and deploying a cloud infrastructure from the ground up.

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B. Student Background

Most of the students in the class had graduate standing either in Computer Science or Electrical Engineering with several additional non-regular students who were working professionals. Roughly half of the students attended school part-time while working full-time in some capacity in the IT field. Several of the students were also in the process of pursuing their second (and in one case third) graduate degree. For the majority of the students, this class was their first exposure to cloud computing.

C. Lectures

For the first part of the semester traditional lectures from the primary textbook were presented which introduced cloud computing from an academic perspective [1]. The focus of the lectures was on fundamental concepts common to cloud computing including: distributed system models, virtual machines (VM), virtualization, cloud platforms and architectures, service-oriented architectures, cloud programming and software environments.

In addition at the beginning of each class session students took turns presenting a chapter from a secondary textbook on cloud computing [2]. Unlike the primary textbook, which approached cloud computing from an academic viewpoint, this textbook was written primarily for professionals currently employed in industry with a desire to learn more about cloud computing. As a result, the emphasis was more on real world examples that focused less on theory and more on practice.

This was the first student activity that required demonstrable mastery of the practical application of cloud theory and its importance in industry. The second was the use of the hands-on labs that students worked on for the duration of the class.

D. Laboratories

The labs were divided into three general groups, each of which emphasized a different student-learning outcome. The labs start with a description of the VM as the fundamental unit of the cloud with each subsequent section showcasing its use in both the private and public cloud.

1) Introduction to VM – The first group of labs describes the VM as the fundamental unit of a cloud and leads the student through the automated creation and configuration of a VM through the use of specialized software tools.

2) Private IaaS (Infrastructure-as-a-Service) - The next group introduces the concept of a private cloud infrastructure and walks the student through the steps required to programmatically create, configure, and use a private cloud using the OpenStack IaaS open-source software application [5].

3) Group 3: Public Clouds – The next group introduces public clouds which are used to repeat the application deployment done previously in the private cloud. In this way students gain an appreciation for the benefits (and drawbacks) of using a public versus a public cloud computing environment.

4) Group 4: Advanced Topics - The final group introduced advanced cloud computing concepts deemed to be topical to the class. In our class students were introduced to advanced configuration management using heterogeneous public clouds by having the students create a cloud based configuration server on one public cloud and use it to manage cloud instances on a different public cloud provider. This allowed students to see how subtle differences in public cloud providers can result in additional effort on the part of the programmer to ensure cloud interoperability.

Additionally students also configured a private Storage-as-a-Service cloud using the OpenStack cloud created previously. This allowed the students the ability to see how a cloud-based storage system could be implemented using open source software in a private cloud.

E. Research Projects

After gaining hands-on experiences from the labs, the students then worked on two advanced cloud computing research projects. The first focused on research survey while the second required programming and a project demonstration.

1) Project 1

The first project is a literature review whereby each student team selects an advanced research topic relevant to cloud computing. One such topic was *"Workflow algorithms for scheduling in cloud computing"*. Each team then researches their topic by reading available journal articles and conference proceedings related to the selected topic. Once their research is done, the student team writes a paper summarizing their findings, which is presented in class. Completion of this project segues into the second project. The list of project topics for this term is given in Section IV.

2) Project 2

In the second project the student teams come up with an original idea based on their work on the previous project. Student teams are given wide latitude for their topics and are encouraged to find something they are interested in learning more about. If necessary, the student will confer with the instructor for ideas, but the students are ultimately responsible for the final proposal, which must be novel, quantifiable, and practical to test and/or implement. As an example for Fall 2012 the group that chose the following topic for Project 1: *"Workflow algorithms for scheduling in cloud computing"*, worked on the following topic for Project 2: *"A tunable Workflow Scheduling Algorithm Based on Particle Swarm Optimization for Cloud Computing"*.

Once the ideas have been formally approved the student teams will then begin work immediately. The project involves original work with regular check-ins with the instructor for the remainder of the semester and culminates at the end of the term when every team presents their work to the class, submits a paper, and does a live demonstration of their work. The students are then evaluated by their peers, who provide feedback to the instructor who assigns the final grades.

III. HANDS-ON LABORATORIES

In the following section we first present the eight lab sessions, followed by a discussion of these labs. Finally, we discuss the lessons learned from designing these labs.

A. The Laboratories

There are a total of eight labs, organized into four groups. Each of the lab assignments focuses on a specific aspect of cloud computing and are meant to build on the work and ideas introduced in prior assignments. They are deliberately broad in scope so that students may become familiar with major cloud computing paradigms.

1) Lab 1: Introduction to VM

The first lab in the series walks the students through the installation and configuration of VirtualBox, the Virtual Machine Manager (VMM) software application used for the remainder of the semester [3]. The student is evaluated on whether they are able to successfully create and use a VM.

2) Lab 2: VM Configuration

This lab introduces the concept of the programmatic configuration of a VM using Puppet, a widely used automated configuration tool [4]. The student is evaluated on their successful creation of multiple customized VMs programmatically via configuration files.

3) Lab 3: Private IaaS configuration

In this lab the student creates a private IaaS cloud using the VMM they installed and used in the previous two labs. The student is evaluated on the successful creation of a standard VM running OpenStack that is functionally equivalent to the Amazon EC2 service [6].

4) Lab 4: Advanced IaaS

This lab introduces the configuration of external cloud images as well as the creation and use of virtual storage. The student is evaluated on the successful import of third-party disk images and their ability to successfully use virtualized storage with virtual instances created using the aforementioned images.

For the next three labs, students used cloud-computing resources available on the Internet, which they programmatically controlled and configured. In the interest of minimizing the cost, only cloud entities that had a free tier of computing service that was deemed sufficient for successful completion of the remainder of the labs were used.

5) Lab 5 – Public IaaS

This lab walks the students through creating and customizing a VM using the Amazon EC2 platform. It additionally introduces the students to the programmatic creation of a public cloud infrastructure via application program interface (API) calls [7]. Students were evaluated on their ability to successfully write software to programmatically create and configure VMs in a public cloud.

6) Lab 6 – Platform-as-a-Service (PaaS)

An alternative PaaS cloud is introduced using the Google App Engine (GAE) platform [8]. Students were evaluated on their ability to create a website using the GAE Java software development kit (SDK) [9].

7) Lab 7: Inter-Cloud Configuration Management

With a sponsorship provided by GoGrid, students worked to integrate two different public clouds, Amazon EC2 and GoGrid [10]. The students built a VM with the Puppet configuration server using GoGrid which they used to create and provision a cloud web service in the Amazon EC2 cloud. Students were evaluated on their ability to manage multiple VMs in heterogeneous clouds.

8) Lab 8: Storage-as-a-Service

Originally, only seven labs were designed. As students asked for extra credit opportunities, one extra lab was then added. This lab may be seen as an extension to Lab 4 (advanced IaaS). It details the addition and use of the Storage-as-a-Service functionality to the installation of OpenStack in Lab 3 and to the generation and use of virtual storage in Lab 4. Students were evaluated on their ability to create a functional equivalent of the Amazon Simple Storage Service (S3).

B. Lab Discussions

In this section we discuss some major decisions made while designing these labs.

1) Private Cloud vs. Public Cloud

It may be easier (and sometimes more economical) to do everything in the public cloud over the Internet. However we decided to include both private and public clouds in these lab sessions since both are vital and have their own advantages.

Working to build and configure private clouds forces students to learn a great deal of technical details of cloud computing. One thing that the cloud purposefully does is obfuscate the myriad of details that go into creating a fully functional VM. These are details that, while deploying to the cloud (which is essentially a third party), an engineer should carefully consider. Below are some examples:

- What happens behind the scenes when a new image is imported?
- When a VM instance is launched but there are not enough resources, what does that look like from the VM perspective? What about from the hardware perspective?
- If I run x number of VM instances on a dedicated hardware, what is an optimal load on the host operating system (OS)?

In an ideal world a developer not only has experience using the cloud, but also running it. By having students build their own cloud they are able to use and evaluate the cloud as both consumers and producers.

2) OpenStack vs. Eucalyptus

The original version of the class was planned using the Eucalyptus IaaS platform [12]. One attractive feature of Eucalyptus is that it offers API compatability with Amazon's EC2, thus enabling the creation of AWS-compatible private and hybrid clouds. Its steep hardware requirements however, led us to look for other alternatives.

After careful evaluation of competing IaaS platforms, we decided to use OpenStack [5] instead. OpenStack is another open-source project that is also API-compatible with Amazon EC2, S3, etc. It offers another advantage in that it has been adopted by several major Linux distributions (Ubuntu, Red Hat) and companies (Hewlett Packard). It also boasted a community-supported, VM-based install which allowed students to create their own self-contained cloud-computing environment.

3) Amazon EC2 vs. GoGrid

Initially the labs were designed to use only the cloud-computing resources freely available in the Internet (in addition to students' own computers). Thus, all but the last lab sessions were based on Amazon EC2, Google GAE, etc.

GoGrid is a local company based in San Francisco, CA, USA [10]. It reached out to us shortly after the class began and generously offered cloud computing resources for our students. The availability of GoGrid offered a unique teaching opportunity for students to create multi-vendor cloud-based web services (Lab 7).

4) Online Documentation

To help students quickly and confidently master the labs, a detailed lab menu was created. Most of the documentation for the labs was adapted from online sources. This is especially true in the labs using the public clouds, which by and large referred students to the vendor's "Getting Started" guides.

5) Teaching Assistant

There is usually no teaching assistant (TA) available for graduate courses at San Jose State University. The first author, then a graduate student at SJSU and having many years as a system administrator and program manager, volunteered himself as the TA for the course. The TA helped create, administer, and grade the lab assignments. He was familiar with cloud computing concepts and had hands-on experience creating and deploying private clouds using both Eucalyptus and OpenStack. Furthermore, the TA had held regular office hours specific to the labs in addition to the professor's normal office hours.

C. Lessons Learned

1) Assumptions about students' Linux background

As this class was focused on cloud computing in general, we tried as much as possible to be platform-agnostic. This however did become an issue as there were a small number of students who had no previous experience working in a Unix command-line environment, which presented a problem when using VMs based on Linux.

A detailed lab menu and documentation were created partly to deal with this issue and to help these students. This is essential especially for the first three labs, so that students' lack of Unix experience did not become a negative factor for their success. Additionally, the TA had held extra office hours for students who needed more help in the first several weeks. In practice we found that students who made it past the second week did not have problems completing the remainder of the labs regardless of their experience using Unix.

2) Open-Source Software

One informal goal was to teach cloud computing in a way that was as platform-agnostic as possible. To that end it was decided to use open-source software as much as possible that was not tied in to a particular OS or hardware platform. This goal was achieved as students successfully completed the labs using recent versions of Windows, Linux, and Macintosh operating systems. However it was decided to have a standard platform that would be supported for the class. We went with the 64-bit version of Microsoft Windows running on a recent (within the last two years) PC to minimize potential pitfalls involved in running multi-platform software.

3) Software Versions

To avoid additional problems regarding incompatible versions the software was "frozen" during the class session so that the software versions available on the first day of class were the only versions that were guaranteed to work.

This decision became important later in the course as the version of the OpenStack IaaS platform used by the class is a development version that is continuously updated. With this in mind the TA would do a fresh installation of OpenStack once a day to ensure that the latest version used by the students was functional.

4) Liability

Another concern when using the public cloud was the possibility of the student being charged for using up the "free" tier of computing service and being charged. This was not a problem with GAE. Amazon however, did require a valid credit card prior to allowing the use of their free tier. As a precaution a warning was placed in every lab that utilized the public cloud reminding students that they are responsible for any and all charges.

D. Overall Feedback

The feedback from the students after the end of the lab sessions was overall very positive. Students especially enjoyed the "hands on" nature and in particular said they enjoyed the opportunity to create their own private clouds. For the students who had some exposure to cloud computing all of them said that they learned something new while doing the labs that they had not known was possible previously.

IV. Research Results

In this section we focus on the results of research projects (Projects 2 and 3). The list of research projects is first presented. Next, one particular research result is described. This is followed by an overview of student feedback.

A. Research Projects

Among 17 students, seven teams were formed. These student teams chose their project topics based on their own interest and their assessment of importance/usefulness of various topics. The following is the list of projects:

1. Workflow scheduling algorithms for cloud computing
2. The issue of energy efficiency on mobile cloud computing
3. Water-marking for Hadoop security

4. Quantitative and analytical comparison of cluster and cloud computing
5. Parallel Java for cloud computing
6. Improving cloud computing privacy using smart phones
7. Two-party auditing for cloud computing privacy

B. Example: Workflow Algorithm for Cloud Computing

In this section, we present a particularly successful example, in which the research project led to a refereed publication [13]. In this project, the team of four members started a literature survey, and decided to work on workflow scheduling for cloud computing. Its major results are described below.

1) Introduction

Cloud computing uses a great amount of heterogeneous resources to deliver countless different services to users of distinctive quality of services (QoS) requirements. Numerous diverse tasks need to be carried out to meet the vastly different QoS and budget requirements. Workflow scheduling is therefore critical for the success of large-scale cloud computing.

A workflow is formed by a logical sequence of interdependent tasks decomposed from applications. The scheduler decides which resources will be used, as well as which tasks will be executed on each of these resources while satisfying the QoS constraints set by users, such as execution time and cost. The workflow scheduling problem, like general scheduling problems, is NP-complete. Workflow scheduling algorithms therefore often utilize heuristics to obtain approximated solutions.

This research project adopts a workflow scheduling strategy using Particle Swarm Optimization (PSO). PSO, developed by Kennedy and Eberhart [14], is one of the latest evolutionary algorithms inspired by nature. PSO approximates an optimal solution by iteratively improving a swarm of candidate solutions, called particles. Each particle is modified iteratively by the best information from both the individual and the entire swarm. PSO works well on most global optimal problems.

Makespan and cost are two main performance measurement criteria specified by cloud users and considered by workflow schedulers. Makespan is the time from the beginning till the completion of the sequence of tasks in a workflow. Some algorithms are designed to achieve minimum cost [15][16]while others strives for minimum makespan [17] or for load balance [16].

In this project, a workflow scheduling strategy to attain a combined minimal cost and minimal makespan is introduced. The main contributions are:

1. *A model for a mapping between tasks and resources is formulated, achieving a tunable objective between cost and makespan.*
2. *A PSO-based heuristics is presented to realize the optimal mapping for the tunable objective.*
3. *The heuristics is further improved by addressing bottleneck tasks and thus reduces the makespan even more.*
4. *While most PSO papers simply use a fixed particle number in their experiments, the effect of the number of particles in the PSO performance is studied.*

2) Scheduling Problem Formulation

Several optimization objectives are formulated as follows. Let $Makespan_{total}(M)$ denote the makespan of the workflow with respect to the mapping M:

$$Makespan_{total}(M) = finish\ time\ of\ the\ last\ task - start\ time\ of\ the\ first\ task\ . \quad (1)$$

The makespan of a workflow is the time duration from the beginning of the first task till the end of the last task. Since a workflow consists of interdependent tasks, both execution time and transfer time need to be considered.

Next, let $Cost_{exec}(R_i)$ and $Cost_{trans}(R_i)$ be the execution and transfer costs of resource R_i, respectively. $Cost_{total}(R_i)$ denotes the total cost of resource R_i:

$$Cost_{total}(R_i) = Cost_{exec}(R_i) + Cost_{trans}(R_i)\ \ 1 \le i \le m\ . \quad (2)$$

Let $Cost_{total}(M)$ be the total cost of the workflow *w.r.t* the mapping M:

$$Cost_{total}(M) = \sum_{i=1}^{m} Cost_{total}(R_i)\ . \quad (3)$$

For the objective of minimizing the cost while balancing the load [16], the fitness function is given as:

$$Fitnessfunction_1 = Max(Cost_{total}(R_i)),\ 1 \le i \le m\ . \quad (4)$$

The objective is to minimize $Fitness\ function_1$. The reason for not using the total cost of all the resources is to prevent from mapping all the tasks to a single, least-cost resource.

For the objective of optimizing makespan (such as the work by Zhang et al [17]), the fitness function can be defined as:

$$Fitnessfunction_2 = Makespan_{total}(M)\ . \quad (5)$$

The objective is to minimize $Fitness\ function_2$.

In this paper we propose an objective of minimizing the *weighted* sum of total cost and makespan; the fitness function can then be defined as:

$$Fitness function_3 = \alpha\, Cost_{total}(M) + (1-\alpha)\, Makespan_{total}(M), \quad 0 \le \alpha \le 1, \quad (6)$$

where α is the weight given to the total cost and $1-\alpha$ is the weight given to makespan. This fitness function can be easily tuned by changing the value α to satisfy the various QoS requirements including budget constraints. Again the objective is to minimize $Fitness\ function_3$.

3) The PSO Algorithm

The evaluation of each particle is performed by the fitness function, defined according to the optimization objective, as described above. The high-level structure of a PSO algorithm is given in Table I

.

TABLE I. The PSO Algorithm

1: Initialize particles' position and velocity randomly.
2: ***While*** *stopping criterion is not satisfied* ***do***
3: ***For*** *each particle* ***do***
4: Calculate its fitness value using the fitness function.
5: Update its local best position.
6: ***End For***
7: Update the global best position.
8: ***For*** *each particle* ***do***
9: Update its velocity and position.
10: ***End For***
11: ***End While***
12: Return the global best position.

Next, we present a heuristics to further reduce the makespan, as illustrated in Table II. Since all the ready tasks assigned to a specific resource are independent, it will speed up the workflow by scheduling first the "bottleneck" task; i.e., the task having most descendants.

TABLE II. Improvement: Bottleneck Reduction Algorithm

1: ***For*** *each resource* ***do***
2: ***For*** *all the ready tasks in the resource* ***do***
3: Sort tasks in descending order of the number of descendants.
4: ***For*** *ready tasks having the same number of descendants* ***do***
5: Sort tasks in ascending order of execution time.

4) Performance Evaluation

In this section, we first describe the four PSO algorithms and the cloud experiment setup. Next, a subset of performance results are presented.

a) PSO Algorithms

The JSwarm package is extended for conducting the PSO experiments [18]. The number of iterations in the PSO algorithm is set to be 100. Four algorithms are evaluated, as summarized in Table III.

TABLE III. Four PSO Algorithms

Algorithm	Objective	Fitness Function	Strength
1 [20]	Minimize the maximal cost	(4)	Load balance
2	Minimize the makespan	(5)	Low makespan
3 (Proposed)	Minimize the weighted sum of total cost and makespan	(6)	*Tunable*
4 (Proposed)	Minimize the weighted sum of total cost and makespan, with *bottleneck reduction*	(6)	*Tunable*, with Bottleneck-reduction, minimal cost & min. makespan

b) Cloud Experiment Setup and Results

CloudSim 3.0 is used to configure cloud environment and simulate the execution of workflow [19]. A data center consisting of one switch and four hosts each having two VM (Virtual Machines) is configured in CloudSim. The millions of instructions per second (MIPS) and execution cost of each VM, and the data transfer cost between different VMs are set as the experiment input. The prices are by referring to the pricing policy of Amazon EC2's pricing policy.

We vary the tasks' MI (Millios of Instruction) by multiplying different proportion values. Fig. 1 shows the total cost of the four algorithms. The cost of Algorithms 3 and 4 are lower than Algorithms 1 and 2, while the cost of Algorithm 2 is the highest. This is reasonable since Algorithm 1 minimizes the maximal of the individual costs rather than the total cost (to prevent all the tasks executing on a single resource), while Algorithm 2 minimizes the makespan. Algorithms 3 and 4 aim to minimize the sum of total cost and makespan, both achieves the lowest cost.

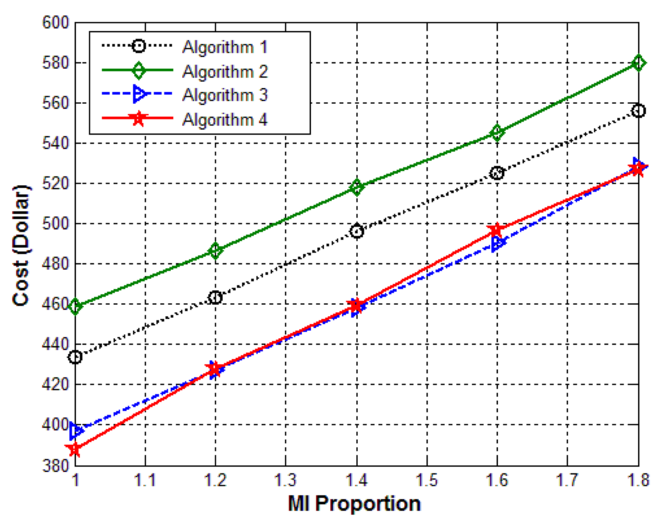

Fig. 1. Cost vs. MI (Millions of Instructions).

The makespan of the four algorithms is shown in Fig. 2. It is clear, and with obvious reason, that Algorithms 1 and 2 have the highest and the lowest makespan, respectively. Note that Algorithm 4 attains a makespan that is very close to Algorithm 2, and is even lower than Algorithm 2 with MI proportion = 1.8. *This demonstrates that Algorithm 4 has achieved concurrently both minimal total cost and minimal makespan.*

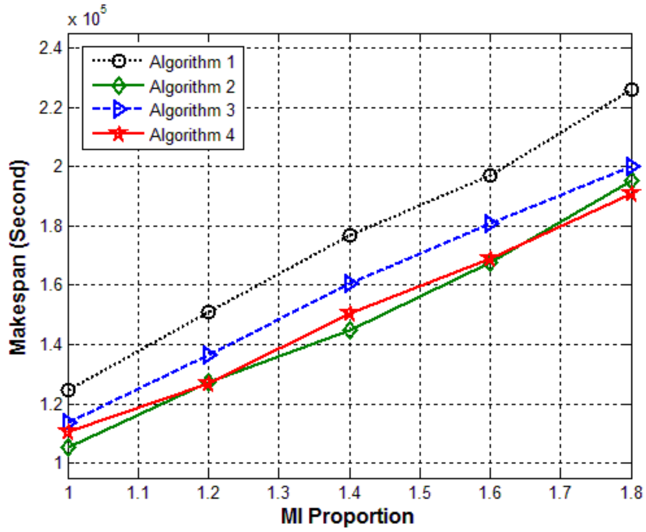

Fig. 2. Makespan vs. MI (Millions of Instructions).

C. *The Next Step: Master Thesis*

In our experience a large number of these research projects have led to Masters thesis as well as publications in various conferences and academic journals [21].

V. FUTURE COURSES

Based on the success of the first course as of Fall 2013 the class is now a part of the San José State Computer Science curriculum. There will be a newer updated set of labs provided by the instructor and TA that we hope will continue to explore new and novel uses of the cloud.

Some ideas include having one student group build a private cloud while another group uses their cloud for deployment. After which they would then evaluate each other and present their findings to the class detailing why their peers are (or are not) a good cloud provider. This would be interesting in that it would allow students to see what makes an optimal cloud user as well as provider.

With the rise of big data processing the automated on-demand creation of a virtual Hadoop cluster within a private OpenStack cloud would also be an interesting project as the same processes and methodology could be applied to a public cloud.

VI. SUMMARY

This paper has presented our experiences integrating practical hands-on lab assignments with a traditional classroom setting. Cloud computing is a broad topic that is constantly evolving. To that end we feel this class does an excellent job introducing key cloud concepts such as VM configuration and maintenance while also exposing the students to real world cloud environments that they are most likely to be using in their careers after college. In addition, students are also involved with advanced research survey and projects. The results include refereed publications, advancement to master theses and advanced Ph. D. studies.

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Brain-based Programming

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Abstract**—***Learning languages can be hard. As the yearly results of the course "Introduction to structured and object-based programming" at our university show, learning the first programming language might be even harder. Many students complain about the difficulty of the course and fail in the exam. With the desire to support the students and enhance the learning outcomes we initiated the project "Brain-based Programming". The basic question is: "How can learning to program be made easier?" The answer may come from the interdisciplinary field of neurodidactics that offers many general suggestions for improving teaching and designing teaching material. But concrete examples for computer science education are scarce, and empirical research is still missing. This was the impetus for the project "Brain-based Programming" that aims at (1) creating and evaluating a brain-based script for beginners in Java programming and at (2) implementing and evaluating brain-based teaching methods in the programming course. In the pilot phase we conducted a didactic experiment in one of seven parallel groups and combined brain-based teaching methods and exercises. The results demonstrate the success of the experiment and support the hypothesis that learning is more effective when it considers how the brain learns and follows neurodidactical principles.*

Keywords—brain-based learning; neurodidactics; cooperative learning; programming;

I. Introduction

Learning languages can be hard. As the yearly results at the University show, learning the first programming language might be even harder. Many students taking the course "Introduction to structured and object-based programming", shortly "ESOP", complain about the difficulty of the course. But more important and alarming, many students fail at completing the course. With the desire to support the students and enhance the learning outcomes of this course, the idea for the project "Brain-based Programming" was born.

The basic question is: "How can learning a programming language be made easier?" Answers may come from two directions: Firstly, in the literature about introductory programming learning different approaches can be found, e.g. the use of a three dimensional animation software [1] or interactive learning objects [2]. Furthermore, all attempts to increase motivation may be helpful as described e.g. in [3].

Other answers can be found in the field of neurodidactics and educational neuroscience that offers mainly general suggestions for improving teaching and designing teaching material by considering the functioning of the brain [4], [5]. But concrete examples for the field of computer science education are scarce [6], [7] and empirical research is still missing. This was the impetus for the project "Brain-based Programming" that wants to build a first bridge between theory and practice - between neurodidactical research and its application in computer science education.

The aims of the project are:

(1) Developing, testing and evaluating a "brain-based" self-learning script for beginners in Java programming and

(2) Implementing and evaluating brain-based teaching methods in an university course for beginners in Java programming.

This paper first describes the basis of the project "Brain-based Programming", the neurodidactical principles behind the concept, and reports on the pilot test: a didactic experiment in the programming course, its evaluation by the students and the learning results in comparison with the other parallel courses. These results demonstrate the success of the experiment and moreover the principles behind it. The paper will close with the discussion of the results and an outlook on future work in this field.

II. Neurodidactics – The Basis of Brain-based Programming

A. The Basis: Neurodidactics – A New Way for Teaching?

Neurodidactics is an interdisciplinary research field that combines findings of brain and memory research, psychology, pedagogy and didactics that shall help to improve teaching and learning. The term neurodidactics, a combination of neuroscience and didactics, was proposed by a German mathematician in order to emphasize the interdisciplinarity of the field. In the English-speaking world two other terms for similar research have become widespread: Educational Neuroscience and Brain-based Learning. All three have the same goal: the improvement of teaching and learning by considering how the brain works. The contributions come from three directions:

1. *Neuroscientists* inform about structure and functions of the brain that might be useful for teachers. They also give suggestions for the improvement of pedagogy and didactics, but sometimes without considering that the everyday life in schools and university courses often deviate from the experimental settings of their research. [8]

2. Contributions from authors of different disciplines (not neuroscience), criticize the current pedagogy and offer more or less useful guidebooks for brain-based learning. Unfortunately, in the booming business of brain-based learning some neuro-

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myths like the left brain/right brain oversimplification or the use of only 10 % of our brains persist. [8], [9]

3. Educators and didactics experts who work out neuropedagogical or neurodidactical concepts based on brain and memory research offer the third approach. Their point of view can be important when they consider the real conditions in the classroom. But often the suggestions are too vague and general like "Learning should be fun". [8]

Neuroscience can do much for education but only when neuroscientists work together with didactic experts and teachers and when neurodidactical concepts are investigated empirically [8]. The project "Brain-based Programming" and the planned follow-up project "Teaching informatics with the brain in mind" shall be a step in this direction.

B. Neurodidactical Principles for Brain-based Programming

The most important principles that were considered in the project "Brain-based Programming" are the following:

1. Knowledge cannot be transferred. It has to be generated in each student's brain [10].

Learning contents can be provided to students in different ways; but storage in the long-term memory is only possible when the input is actively processed in the brain of each student. Students should be active instead of only listening to a lecture and they should be supported to discover structures and rules themselves. This works best in open lessons where they can follow their own learning rhythm. [11]

2. Learning through imitating

Mirror neurons enable us to understand, interpret and imitate observed actions and to predict their results. They are responsible for learning through mirroring respectively imitating [4]. Students need models that they can imitate (e.g. role models, step-by-step instructions, solution-based learning). This activates also the brain mechanism of pattern recognition.

3. The brain recognizes and produces patterns, categories and rules itself [12].

Pattern recognition or patterning is a basic function of the brain. It helps us to extract rules and structures from available examples. So students do not need declarations and rules, but good and meaningful examples (e.g. correct program code, role models, step-by-step instructions, etc.) to understand the structure and extract the essential rules [12]. Using the function of patterning e.g. in discovery learning leads to a more active and therefore deeper processing and retention of information whereas lecture usually results in the lowest degree of retention (see fig. 1). [4]

4. New content is always built on existing knowledge and learning occurs through associating.

In this context knowledge is not only subject-specific but means also experience as well as knowledge from all living areas and from the world of the students. The physiological basis for this principle is that learning occurs through creating new or strengthening existing synapses (connections between neurons). This previous knowledge is individually different, which means that students should have the possibility and time to ask their individual questions to the teacher and/or peers respectively peer-tutors. [4, 12]

5. Learning is more effective when it makes sense and has meaning [4].

This criterion should be considered where possible in the selection of topics, tasks and products to be developed by the learners. The students should have the possibility of choice between different competence-oriented exercises and different topics. This increases motivation and, hence, may increase the learning outcomes, too. [4]

6. The brain needs time for consolidation.

The brain needs time (short breaks) to consolidate new information. Only then it can be permanently stored in the long-term memory. This should be considered in the structure and organization of the lessons. If the brain does not get time for consolidation (e.g. in usual lectures of 90 minutes) new information can overlay earlier content and/or information heard before can inhibit the processing and memorizing of new input. [4, 11]

7. The instruction method has impact on the retention of new information [4].

Besides practice by doing cooperative learning settings like group discussion and peer tutoring (teaching others) seem to be the most effective methods concerning retention as shown in fig. 1.

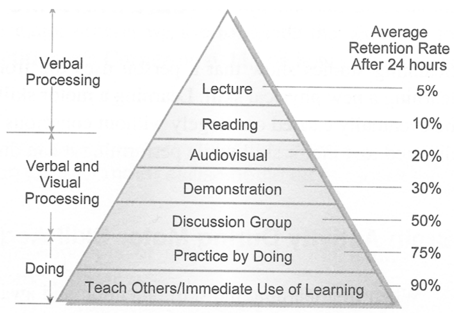

Fig. 1. Average percentage of retention of material after 24 hours [4]

An evaluation of more than 800 meta-analyses considering millions of students confirms the effectiveness of cooperative learning environment and shows an overall effect size of d= 0.41 [13]. The success of cooperative learning can be explained by the fact that it supports the memory process: cooperation and communication always require a recall from the memory and each recall or retrieval always causes a restart of the whole memory process. It leads to new processing, new storing and also new and stronger anchoring of the information in the long-term memory. Cooperative methods can therefore support the learning and memory process and are an essential part of the new brain-based programming concept. [4, 11]

III. The Project "Brain-based Programming"

A. About the Project

"Brain-based Programming" is the pilot project for a larger empirical study about "Teaching Informatics with the brain in mind". It is based on the hypothesis that teaching and learning can be more effective when neurodidactical principles are considered in the design of tasks and exercises as well as in the lesson structure and the teaching methods. The phases of the project are the following:

1. The development of tasks and worksheets under consideration of neurodidactical principles as well as their first evaluation in the university course "Introduction to structured and object-based programming" (2012).

2. A didactic experiment: Application and evaluation of "brain-based" teaching methods of the developed worksheets in one of seven parallel practical courses "Introduction to structured and object-based Programming" (winter term 2012/13).

3. Evaluation and adaptation of the worksheets, aiming to develop a self-learning script for beginners in Java programming based on neurodidactical principles (2013).

The project is currently in phase three, where the results of the brain-based course are taken into account and the student feedback is used to redesign the worksheets for the following self-learning script.

Before describing the didactical experiment the following section gives a detailed description of the developed worksheets and the different types of "brain-based" tasks, always referring to the related neurodidactical principles. After that we present the course organization in the experimental group, the applied teaching methods and the form of assessment.

B. Brain-based Tasks

Usually, all students of the parallel courses get the same worksheets. The experimental group got them, too, but only for voluntary work and in order to provide a broader variety of exercises. Additionally, they got the new "brain-based" worksheets because one reason for the difficulties in the course may lie in complex contents (e.g. mathematical problems) or too complicated instructions of the existing worksheets that are often incomprehensible for beginners.

Every worksheet is divided into three parts and contains the following types of exercises:

1. Reading exercises

The first part of the worksheet shall foster discovery learning and take advantage of the automatic brain function of patterning. It contains the following types of tasks:

- Reading corners with a simple and small, but complete piece of Java program code, which is accompanied by some questions that should lead the learners and help them to discover the structures and rules behind.
- Puzzles of jumbled program code or cloze-tests where small parts of the code are missing.
- Step-by-step instructions including also the whole sample solution, which help to comprehend and reproduce a task by taking one step after another.
- Mini exercises or short tasks including a sample solution that the students can use immediately in the sense of discovery learning or after having resolved the task for verifying their own solutions.

2. Competence-oriented tasks

This part provides short and rather easy competence-oriented tasks covering different contents and topics that may have sense and meaning for the students, e.g. programming a course schedule or a vocabulary trainer. Following the principle "practice makes perfect", the students get a big variety of tasks that they can choose according to their individual interests, competences and needs. This may increase motivation, occupy all students with useful tasks and may therefore support the memory process and enhance the learning outcomes, too.

3. Programming tasks

The last part of the worksheet provides different tasks for small, complete programs or some subprograms as parts of a complex semester topic that have to be assembled to complex Java project at the end of the course. This considers a neurodidactical principle already postulated by Aristotle "The whole is more than the sum of its parts" or, as defined in neurodidactical literature, "Learning is more effective when it considers the whole AND the details" [14]

C. Brain-based Lessons: A Didactic Experiment

Usually in the practical programming courses only two settings are used in turns – *laboratory* in one week, where the students had to do a part of the exercises that they continue at home, and *presentation* in the following week, where one student presents his/her solution and the others are passive. In the experimental group we tried to offer more possibilities and to keep all students active according to their individual capabilities. This satisfies the neurodidactical principle that learning has to be active.

In the very first lesson of the experimental group the students had to do a self-evaluation of their programming skills by means of a competence grid that should help them categorize their capabilities and competencies. Based on this self-evaluation, three groups were formed:

1. Professionals: students with solid knowledge about the topics in the course and the ability to help their colleagues as peer-tutors or peer-teachers.

2. Amateurs: students with some experience in programming, but who did not feel able to assist their colleagues.

3. Beginners: students without any programming experiences.

These groups were formed because we tried to take into account, as much as possible, the individual experiences, talents and needs of each student. The neurodidactical principles "New content is always built on previous knowledge" and "Learning is more effective when it makes sense and has meaning" were considered, as the students could choose between different types of tasks, topics and collaboration in the course. Whereas the advanced students solved more complex projects and/or acted as peer-tutors and peer-teachers the beginners got more short competence-oriented exercises and could benefit from the peer-tutors.

The weekly lessons of 90 minutes each were characterized by an open learning setting considering the individual learning rhythm that allowed time and room for individual interests and needs. In general the lessons were divided into the following three phases and, when required, supplemented by a short lecture of the teacher or a peer-teacher: Asking questions, discovering and laboratory with pair programming.

1. Asking Questions

In the first phase (ten to fifteen minutes) the students worked together in small groups with one peer-teacher or peer-tutor (one "professional" or "amateur" student). In this time, the students got the chance to ask any question they had in mind. The idea behind was to encourage them to ask also questions that they would have never asked in the whole group, perhaps because they considered them too trivial or too stupid. But sometimes these questions and certainly the corresponding answers can help to understand a concept because they build up on the previous knowledge of the students…

2. Discovering

In the second phase (ten to twenty minutes) the students worked in small groups, too, each of them guided by a peer-tutor. On the base of the different reading exercises, already described in section A *Worksheets and Tasks*, as well as short video clips they tried to discover new topics or re-discover topics they had already learned before. This active way of processing input takes advantage of the brain's automatic pattern recognition and rule extraction, which may lead to a better and stronger storage in the long-term memory [12]. The video clips of some minutes offer a further advantage: the multimedia or modality effect, investigated by [15]. When information is double coded, e.g. text combined with corresponding pictures or animations, it can be remembered better.

3. Laboratory: Pair Programming

The third and last phase in the course was the laboratory. The students were ought to solve the tasks of the given worksheets by collaborating in pairs according to a well known and effective software engineering method: pair programming. This setting allows cooperation and communication, which may enhance learning because, as mentioned above, each recall from the memory (which is necessary when discussing the problem of the task and the way to solve it) restarts the whole memory process.

Depending on the topic and the needs of the students, these three phases could differ from time to time. Worth to mention is that all students were active in all phases. Due to the open learning setting the lecturer had enough time to visit the small groups, one after another, to ask questions for checking participation and comprehension as well as to help them with upcoming difficulties. At the second half of the lesson, a student tutor of a master course assisted the teacher in answering questions and helping the students solving the exercises.

The open learning setting allowed the students to follow their own learning rhythm, and hence consider the individual consolidation phase of the brain. Sometimes a supplementary phase of lecture was necessary where the lecturer or a peer-teacher explained a topic or concept for all students in a maximum of twenty minutes. More is not useful because we know from neurodidactics that the attention decreases approximately after this period. The following "down-time" with a low attention level shall be used for consolidation and revision. Fig. 2 visualizes a possible segmentation of a learning episode. After presenting new information in the first prime-time and some practice in the following down-time a phase of closure or summary of the new information is offered.

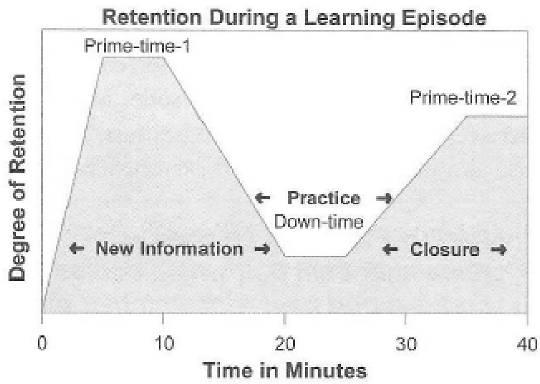

Fig. 2. Retention during a learning episode [4]

D. *The assessment*

The standard assessment criteria of all parallel courses of the "Introduction to structured and object-based programming" were valid for the experimental group, too, but were slightly adapted as follows:

- The course grade consists of 50% written exams a mid term and a final exam, each graded with max. 25 points and 50% participation in the course (number of correctly solved exercises, presentations, active participation in the lessons).

To get a positive grade, the students had to fulfill the following requirements:

- Compulsory attendance is required in at least 85% of the lessons.
- At least 50% of the tasks of each worksheet must be completed and the program code must be executable. As the students in the experimental group got the double number of worksheets and tasks, they had more choice. To offer a fair grading method, each task of the worksheets (the regular ones for all students as well as the "brain-based" tasks for the experimental group) was evaluated with points. Whereas usually only completely executable solutions are counted, the experimental group had a graduated assessment. The number of points depended on the percentage of the available correct program code. To give fair points, four categories were introduced: (1) complete and executable, (2) complete, but not executable (with slight errors), (3) program code mostly complete and (4) less than 50%. This concept of evaluation was introduced to motivate the students to do their own work, to avoid copying and to value mistakes, as we learn from them.
- A minimum of 50% of the written exams the same for all parallel groups must be achieved, that means 12.5 points for each, in total at least 25 points. Students who

don´ t reach half of the points in the mid term exam usually have to terminate the course. This was slightly adapted in the experimental group. The students had to achieve the total minimum of 25 points, too. But if one reached less than 12.5 points in the mid term exam s/he could compensate that in the final exam. This opportunity should motivate the students to remain in the course, to work more and to catch up on the missed topics. Whereas many students of the parallel courses had to terminate after their negative mid term exam two of three students in the experimental group actually could benefit from this criterion and terminate the course with a positive grade.

IV. Evaluation and Results

Brain-based programming was implemented as a didactical experiment in one of seven parallel groups with 21 of 126 students. Due to this small group and a certain teacher bias the positive results of this pilot project are not statistically relevant, but seem to support the hypothesis that learning can be more effective when brain and memory functions are considered in lesson and task design. This will be verified in a larger follow-up study at university and secondary school level.

To measure the acceptance and benefit of the brain-based methods and tasks, the students of the experimental group were given surveys at the beginning, the middle and the end of the semester. Furthermore, the university's official student feedback, completed by 15 of 21 students, has been considered.

Taking a closer look at this official feedback with grades from on a scale from 1 (best) to 5 (worst), it can be said that the experiment was successful. The "brain-based" course was graded with 1.1, whereas the average grading of all equivalent courses in the last three years lies at 2.1. Moreover, the students were very satisfied with the concepts used in this course. According to the students' verbal feedback, most notably and helpful are the concepts of peer-tutoring and peer-teaching, reading exercises discovery learning, mini exercises including solutions, step-by-step instructions, and the revision worksheet at the end of the course.

This confirmed the mid term feedback where 19 of 21 students graded the methods and tasks from 1 = very useful to 4 = not so useful (fig. 3).

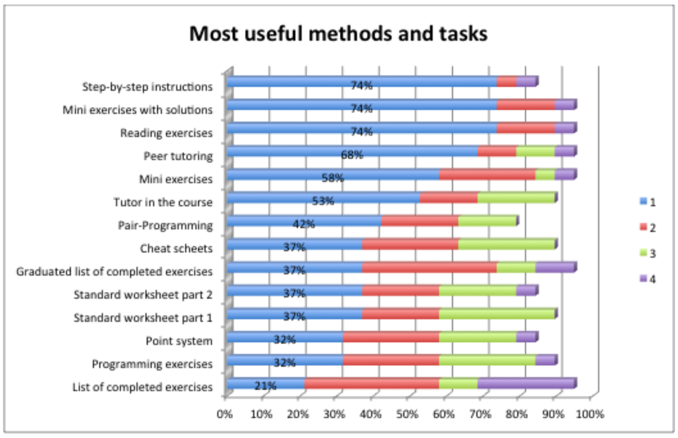

Fig. 3 Mid term evaluation of methods and tasks

Step-by-step instructions, mini exercises with solutions and reading exercises were considered as most useful tasks by 74% of the students. Concerning the teaching methods mainly peer tutoring (68%), the tutor from a master course (53%) and pair programming (42%) were considered very useful. Compared to the standard worksheets part 1 and 2 distributed in all parallel courses all new "brain-based" tasks (except programming exercises) and methods scored better.

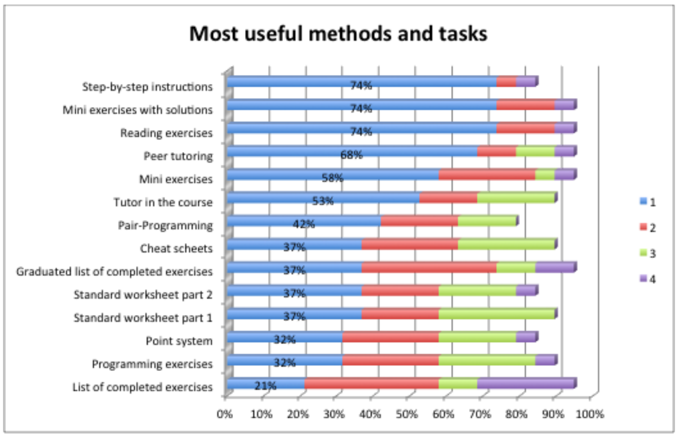

Fig. 4 Mid term evaluation of methods and tasks

The evaluation of the last survey (fig. 4), completed after the course only by 11 of 21 students, shows similar results.

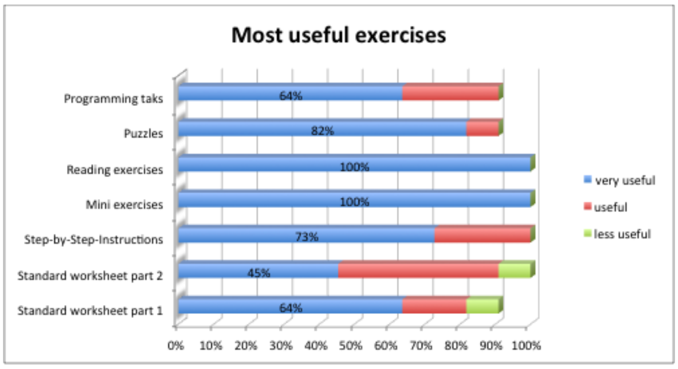

Fig. 5: Evaluation of the different exercise types

The students appreciated all forms of material for discovery learning, mainly the mini exercises including solutions and reading exercises (100% considered them very useful). They are followed by puzzles (82%) and step-by-step instructions (73%), which are other types of reading exercises. This shows that learning from worked-out examples, and benefiting from the automatic brain function of pattern recognition can be very useful.

The final evaluation of the methods shows the following results: All students found that the sample exams offered in the unit before the mid term and the final exam were very useful. Peer tutoring and pair programming where the most helpful methods (both indicated by 91% of the students) followed by the tutor (82%), discovery learning (73%) and asking questions (64%). the methods used in the parallel courses – laboratory programming and presentation of one student's solution – were considered very useful only by 45% of the students.

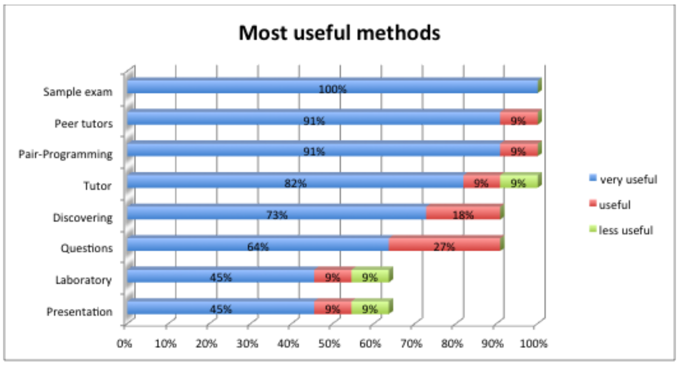

Fig. 6 Most useful methods, results of the final survey

In order to verify if brain-based methods and tasks can enhance the learning outcomes the results of two courses shall be compared: the practical courses as well as the corresponding lecture on “Introduction to structured and object-oriented programming”. Unfortunately, the results of the lecture exams are still not available, hence we can only describe the outcomes of the practical courses.

As all students of the parallel practical courses got the same exams, a mid term and a final exam, that are evaluated using the Austrian grading system from 1 = excellent to 5 = failed. It has to be mentioned that there is still a teacher bias in this evaluation although all lecturers tried to assess the exams in the same way. The results of the lecture will be more relevant. The average of the grades in the experimental group was 2.19 whereas the average of the seven parallel courses was 2.94. Fig. 5 shows the average grades for all groups. The numbers in brackets indicate the final number of students in the respective courses.

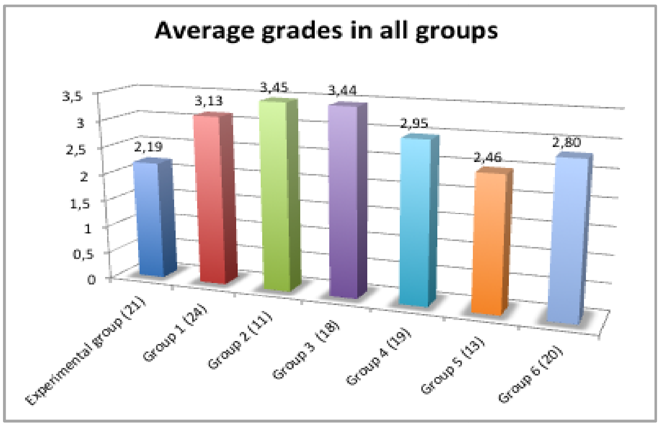

Fig. 7 Average grades in all parallel courses

This clearly shows a tendency of enhancement, although comparing the grading is, of course, only a week indicator. There are many factors involved in learning that can influence the outcomes. So the better score of the students in the experimental group could have different reasons; perhaps it is due to single methods, but the combination of different methods and exercise types. Maybe it is simply a consequence of higher motivation and more practice. This is to be verified in the larger follow-up study next year that will focus on the effects of cooperative learning (peer tutoring and pair programming) as well as on discovery learning (reading exercises and step-by-step instructions), which benefits from the functions of pattern recognition and rule extraction.

V. CONCLUSION AND OUTLOOK

The evaluation of the didactical experiment shows, that tasks and concepts based on neurodidactical principles are positively mentioned and preferred by the students. All in all the results of the pilot test "Brain-based Programming" are satisfying and show an overall improvement for the students as well as an above-average evaluation of the course. This supports the hypothesis that learning is more effective when the functioning of brain and memory is considered. As learning is a very complex process it cannot be said that the success of the pilot project is due to certain methods or the appropriate material. We suppose that the combination of both “brain-based” teaching material and “brain-based” methods, above all cooperative and discovery learning was the key to success. Should there really be single neurodidactical factors that lead to better learning, this has to be verified in further studies.

Therefore the concept of “Brain-based Programming” will be continued in a larger follow-up project “Teaching Informatics with the brain in mind”. It is now extended to other courses of our department (Introduction to Computer Science and Software Engineering) and will be then adapted for testing and evaluation at schools, too.

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Multiple Intelligence approach and Competencies applied to Computer Science 1

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***Abstract*— In order to contribute to the improvement of Computer Science 1 (CS1) course's results we designed a set of activities based on competencies and multiple intelligence approach. Hypothetically, we propose that including this kind of activities helps to obtain better results in the course. A preliminary experimentation was done in 2012. This year, the course included a low number of freshmen students. The initial results show a positive difference in student's results, particularly in freshmen students and no differences in students who are taking the course for the second or third time.**

Keywords— competencies; computer science 1; multiple intelligences.

I. Introduction

Introductory programming courses usually have high drop out rates and failure [1,2,3,4]. Our goal is to contribute to the improvement of Computer Science 1 (CS1) course's results by the incorporation of activities based on multiple intelligences and generic competencies. In this paper we include definitions of "competence" and possible classifications. We include also concepts related to multiple intelligences. After that, we detail our CS1 course, the activities proposed; the experimentation, results, conclusions and future work.

II. Competencies

Competencies represent a dynamic combination of knowledge, understanding, skills and abilities [5]. A competence is defined as the capacity of a person to use knowledge and skills in different situations either personal or professional [6]. Tovar [7] defines competence as the ability shown by the use of knowledge, technical, personal, social and methodological skills that can lead to success in professional and academic environments.

Competencies are distinguished in subject specific and generic ones. The generic competencies are also distinguished in three types: instrumental, interpersonal and systemic [5]. Transversal or generic competencies have acquired a special relevance in last years [7]. Generic competencies play a key role in the teaching and learning process [8]. Higher education must provide advance knowledge, skills and competencies that students need for their professional life [9]. The development of competencies in educational programs can significantly contribute to join reflection and work at university level [5].

Tovar and Soto found that reading, analytical comprehension and mathematical skills are part of the core competencies required to succeed in computer engineering studies, also suggests that universities must decide whether to take a comprehensive set of skills (such as the Tuning or extended version of it) [7,10].

Tuning Latin America Project [11] refers to 27 generic competencies. From this list, we select those that apply in the context of our CS1 course: capacity for abstraction, analysis, and synthesis (C1), ability to apply knowledge in practice (C2), ability to organize and plan time (C3), capacity for oral and written communication (C4), ability to use information and communication technology (C5), ability to learn and update learning (C6), ability to identify, pose, and solve problems (C7), ability to work as part of a team (C8), interpersonal skills (C9) and ethical commitment (C10). Most of these competencies are skills that software engineering graduates must possess [9].

III. Multiple intelligences

The theory of multiple intelligences (MI) was proposed by Gardner [12,13,14,15]. Gardner [16] argues that traditional ideas about intelligence must be reformed, so he proposes a new approach. Gardner defined intelligence as: "the ability to solve problems or to create products that are valued within one or more cultural settings". In this context, enumerates the intelligences: linguistic (MI1), logical mathematical (MI2), spatial (MI3), bodily-kinesthetic (MI4), musical (MI5), interpersonal (MI6), intrapersonal (MI7) and naturalist (MI8). Armstrong [17] refers two key points of MI: each person possesses all eight intelligences and most people can develop each intelligence to an adequate level of competency.

According to Gardner [16], the purpose of education should be to develop intelligence and to help people reach vocational and avocational goals that are appropriate to their particular spectrum of intelligence. In this context, Gardner [15] argues that MI theory is certainly relevant, to education, but not in itself an educational rationale or goal. Gardner 's notion of multiple intelligences shows that competencies are neither innate nor predetermined. People, with their intelligence are capable of preparing constructions based on the demands from their surroundings and they can develop specific capacities [18]. Research studies related to multiple intelligences in engineering education [19,20] suggest that students benefit from learning materials adapted to suit their intelligences.

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IV. CS1 COURSE

Introductory programming courses have generally high failure and high drop out rates [1,2,3,4]. Research studies have been proposed to face the problem with different approaches: for example: games [21,22], robots [23], pair programming [24].

The course of CS1 at Universidad ORT Uruguay makes emphasis on teaching using problem-solving methodology and enables the student to analyze, design and implement simple object oriented language applications. It involves programming assignments, problem sets and a project. The duration is 15 weeks, 4 hours of lectures and 2 hours for lab session per week. The programming language used is Java for all this assignments. The main topics are: pseudo code, variables and control structures (weeks 1-3), objects and classes (week 4), association (weeks 5-7), inheritance (week 8), aggregation and collections (weeks 9-10), enumeration (week 11), sorting and searching (week 12) and advanced use of collections (weeks 13-15). Our teaching strategy is based on design activities that motivate and engage students in order to achieve lower dropout rates.

V. ACTIVITIES PROPOSED

In order to improve the results of the course, we present a set of activities designed using MI1-MI7 and C1-C10 approach:

1) Scratch (week 1): The use of Scratch in CS1 course promoted a high level of motivation, thus a positive perception of learning programming [25]. Students solve practical programming games that include sound and images.

2) Infographics (week 4): This is a graphic visual representation of information combined with words to help students explore and conceptualize Java. In this activity each student creates an infographic of Java technology (i.e. What is Java? , Who developed it?).

3) Kinesthetic (week 4): To become familiar with the concept of identifying objects, aliasing and message passing we propose a kinesthetic learning activity modeling clay [26] promoting comprehension of object oriented concepts.

4) Minute Test (week 4): Student reflects on what the main concepts of objects shown in the lecture are, answering in one minute several questions: for instance: "What do you want to find out about the theme?", "Which concepts are important?".

5) Wordle (week 5): Wordle [27] generates "word clouds" from a provided Java source. Students generate a cloud of words and analyze the most frequent reserved words of the language (public, private, int, …).

6) UML Modeling Game (week 6): We bring to class some child games. This activity aims to develop a simple design model of those games. Students use top down criteria identifying attributes and represent the model in UML.

7) Rubric (week 7): To improve students own learning and communication expectations, we propose and discuss a rubric and students must evaluate sample works using it.

8) Pair Programming videos (week 8): The activity is oriented to discuss the benefits of using pair programming methods analyzing some related videos.

9) Inheritance (week 8): Group of students read in class material related to a new topic (inheritance). They read chapters of several books of the course and complete a questionnaire.

10) Concept Test (week 10): Peer Instruction (PI) [28] engages students during class through activities that require each student to apply the core concepts being presented, and then to explain those concepts to their fellow students. A class taught with PI is divided into a series of short presentations, each focused on a central point and followed by a related conceptual question. We apply this activity to introduce foundational topics of arrays.

Each activity refers to some competences and intelligences (Table I and Table II).

TABLE I
ACTIVITIES - COMPETENCIES

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1,2,3 4,5,6 7,8,9 10	2,5,6 7,8 10	2,5	2,4,5 7,10	2,9,5	4,9 10	1,4	6,8,7 10	5,6,7 8,9	7,8

TABLE II
ACTIVITIES – MULTIPLE INTELLIGENCE APPROACH

MI1	MI2	MI3	MI4	MI5	MI6	MI7
2,5,9	1,10	1,2,5,8	3,6,8,9 10	1	1,5,6,7,8,9 10	1,2,3,4,5 10

VI. EXPERIMENTATION

One random group of 20 students was selected to participate in the activities and 16 were in the control group. None of the students had already been exposed to MI techniques nor the activities proposed. Both groups included a high number of students who are not really "freshmen": they were taking the course for the second or third time. The repeat students had the same course contents in their previous attempts. Hypothetically, we propose that including this kind of activities helps to obtain better results in the course. An initial experimentation was done in 2012. Considering only the students who take the course for first time, in the selected group, 44% (4/9) of them had successful results and in the control group, 22% (2/9) gained the course. For students who took the course a second or third time, there were no significant differences in the results.

VII. CONCLUSION AND FUTURE WORK

The inclusion of activities to promote skills and multiple intelligences seem to provide better results in the case of students taking the course for the first time. The use of these activities in the case of students who were enrolled and did not pass the course previously showed no significant difference in the results. These differences appear in the case of new students. In 2013 we will replicate the experience, with some improvements, in order to validate or not the results.

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Integrating highly-capable corobots into a computing curriculum

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***Abstract*—Robots are typically used at the college level either as a pedagogic platform for introductory programming or for more advanced courses in robotics. With robots becoming cheaper and more plentiful, personal interactions with them will become more commonplace. This project therefore takes the position that undergraduate computing students need the opportunity to explore core computing concepts in a robotics context. Specifically, we will give students the ability to work alongside teams of highly capable and easily programmable corobots, a term used to identify robots that work side by side with humans, rather than being completely autonomous and isolated. A modular approach is used to incorporate corobotics into various computer science (CS) courses such as first-year computing, networking, and data management, thus permitting the students to see these corobots in multiple contexts. This work-in-progress paper describes the corobotics infrastructure that has been developed, and outlines how this infrastructure can be used to support diverse courses in the CS curriculum.**

Keywords—robotics, corobotics, computer science coursework.

I. Introduction

Robots have been used in many universities as a teaching platform, primarily for introductory programming and robotics courses. Student motivation and real-world applicability are continued concerns within CS education [1], and robotics has promise to deliver on both counts. Pedagogic robots however tend to be either simple and inexpensive (for novice programming support and affordability, e.g. [2]) or complex and expensive (supporting more interesting algorithms, but requiring much more background knowledge). In our project, we are taking a different approach and are developing a team of highly capable but easily programmable corobots. The term “corobots” is used to identify systems that work side by side with humans, rather than being completely autonomous and isolated. These corobots will “live” in our department, roaming the (large) floor of our building that houses the Computer Science labs, classrooms and faculty offices, exposing all students to a functional robot system. With the corobots in place and available for coursework, computing or engineering students without robotics expertise will be able to write high-level programs that direct the robot to different locations, take pictures, interact with people in their vicinity, and report back in real time via a web interface.

We are developing the underlying infrastructure to allow our corobots to navigate our building and interact nearly autonomously. Students will make use of a simple API, currently in development in Python and in Java, to direct the corobots. Our past experience has shown us that students are intrigued by using robots to develop course and term projects, but learning and dealing with all of the needed robotics knowledge and/or maintaining the robotics hardware is overly burdensome [3]. The corobotics infrastructure will enable students to ignore details of robot navigation and the like, allowing them to develop meaningful software for many different types of tasks that also has a physical presence in their environment.

With this corobotics infrastructure in advanced development, we are creating course modules for a variety of computer science courses. For example, a course module in a networking course would have students use the infrastructure to develop and use ad-hoc networking protocols, thus ensuring corobots and humans can share information on an as-needed basis. A module in a data management course would have students use the infrastructure to develop a database application that will allow both corobots and humans can contribute to, query from, and analyze a shared database of information (e.g., photos of the building). In the long run, our goal is that the presence of this team of corobots will inspire students to develop novel applications to help drive the progress of the field as robotics becomes even more prevalent in everyday life.

In this WIP paper, we describe our corobotics infrastructure and discuss how it can be leveraged in diverse computer science courses such as first-year computing, networking, and data management.

II. The Corobotics Infrastructure

The corobotics infrastructure consists of two main components: the robots themselves (both the hardware and software), and the server and API as seen by the students. The robots are based on the iRobot Create platform, augmented with a Microsoft Kinect, two cameras, and a Linux-based laptop that runs the navigation and control code. This hardware is similar to the popular Turtlebot developed by Willow Garage [4], but with two important differences: first, the presence of the extra cameras allows the robots to detect QR codes to aid in localization; and second, the laptop is mounted in such a way that it is visible to and usable by humans in the vicinity. In this way, the robots become part of the community of the department, as they can more effectively interact with passers-by, such as to offer tours or request assistance. This type of system is also similar in spirit to the Cobot system developed

```
# Take control of a robot
robot = corobot.acquire_robot()
# Store the current pose for later
pose = robot.get_pose()
# Go to the break room, program pauses here
robot.navigate_to("BreakRoom1",wait=True)
# Ask for coffee
robot.display_message("Please make some coffee!")
# Wait for someone to make the coffee (5 mins)
robot.wait_for_confirm(300)
# Return to the original location
robot.nav_xy(pose.x, pose.y, wait=False)
```

Fig. 1. Sample code to control a corobot

at CMU [5], but our focus is on integrating the corobots with an API that allows students to program them as part of general coursework.

The most critical piece of the system, however, is our development of fully-functional robot control along with a closed API. The goal of the control and the API is to free the programmer from any direct involvement with the robotics (obstacle avoidance, navigation, etc.) unless they specifically desire it, while still allowing the programmer to integrate robot commands with any other code they desire. In addition, a small API allows us to more easily predict and control the performance of the robots when directed by those who are not robotics experts.

On the control side, the robots use standard techniques to perform localization and navigation, aided by the fact that they will work only in our building. Local navigation is simply standard obstacle avoidance, using the 3D Kinect data to avoid any objects in the robot's intended path. The localization uses an Extended Kalman Filter (EKF) approach to incorporate Kinect data, wheel odometry, and QR detection to determine the robot's position. The QR detection, based on the ZBar barcode detection library [6], not only uses the identity of the barcode, but also its location within the image, and as such is currently able to determine an absolute robot position within the building with 2-10 cm error when one code is visible. The other sensors are then used by the EKF to maintain position understanding during travel. We have put bar codes beside each office and classroom door, and we have chosen to use QR codes so that they will not only be useful for robot navigation, but also link to appropriate web pages for people using smartphones with barcode-reading apps. For long-distance path planning and navigation, we have hard-coded a high-level roadmap within the building so that the robots can easily search for paths to a specified location, and so that points can be named in a student program (such as `"GraphicsLab"` or `"Office3451"` rather than an X, Y location in some arbitrary coordinate system). The control code then uses a standard A* search over this roadmap, and the map is created such that at least one waypoint is visible from anywhere that the robot is intended to travel.

With the navigation capability built into our corobots, our API can then enable students to write simple code such as shown in Fig. 1. This small example just shows a sequence of a few robot commands, written in Python, but would invoke a non-trivial amount of planning, motion and obstacle avoidance. Additionally, it can be seen how such code could easily be interleaved with any other Python code as demanded by the

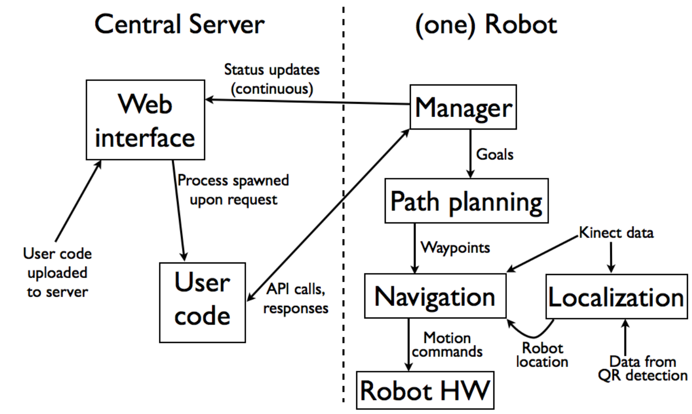

Fig. 2. Schematic of corobot software/hardware architecture, showing processes running on the server and one of (potentially) many robots.

student's task. We have also written a simple simulator that implements the API in a primitive way to serve as a simple verification process before submitting code to the physical robots. Students are able to log in using a web interface to submit code to the corobot and monitor its progress. Our current infrastructure does not as yet provide full authentication, but this will be incorporated shortly. The web interface also presents the current status of all robots, visible to anyone. Once logged in, a student can upload code, review previously uploaded code, and request code deployment either on a specific robot or on the first robot available. Student code is then run in a sandboxed process that communicate with the corobot over WiFi. In addition to real-time feedback, a log is also created and returned to the student. Figure 2 gives an overview of how the server and robot components work together.

III. Corobotics in the CS Curriculum

Once the infrastructure is ready and the team of corobots operational, we plan to develop and deliver course modules at least three different courses, as detailed below. Each target course covers standard topics in the CS curriculum, i.e., these modules may be adoptable at other colleges and universities.

A. *First-year Computing*

The first year of computing usually consists of an introductory course in computer science (often called CS1) that introduces students to the basic concepts of compuer science using a problem-centered approach. Specific topics covered include the expression of algorithms in pseudo code and a programming language; problem solving; basic searching and sorting; and elementary data structures such as lists, trees, and graphs. The second course (CS2) delves further into problem solving by expanding the coverage of data structures including tree and graph structures and nested data structures.

The first course module focuses on making graphs and simple graph traversals in CS2 more relevant to first year students. Our corobot system is equipped with a roadmap with named locations, and these locations include neighbor relationships, forming a graph. This provides a natural basis for a breadth-first search. The sample course module being developed is centered around a problem where a corobot is summoned to a particular location on the floor to then interactively lead a human to a desired destination. The student's program is provided with the locations and neighbors of the named waypoints in the roadmap as input data, along with a particular start and goal point. The student code then generates the shortest path connecting several waypoints. For slightly more advanced students, the actual physical locations of the waypoints can be used to create weighted edges (where the weight is equal to the actual distance) and Dijkstra's algorithm used over this weighted graph to determine the fastest route between the given locations. In either case, this programming assignment can be set up like any other CS2 assignment, as the robotics aspect will be a small amount of additional coding relative to a fairly traditional graph algorithm implementation.

B. Networking

A typical introductory computer computer science course in Computer Networking covers concepts and principles of computer networks. Standard topics include transport, network, and data link protocols and algorithms. The course may also include an introduction to local area networks, data transmission fundamentals, and network security. Students typically design and implement projects using application protocols, but the relevance of networking in the modern interconnected world of computing is often not brought into the course.

For such a course, we plan to develop a course module that covers an *ad-hoc routing protocol* using the corobots. As the robots move around the building, they may join or leave the network. The module will allow students to build a scalable, efficient, self-organizing, and fault-tolerant routing protocol, thus addressing two main challenges in networking: (a) lack of a fixed infrastructure for routing and (b) appropriate handling of mobility. Given these challenges, it is a meaningful task to build a scalable, efficient, self-organizing, and fault-tolerant routing protocol that runs among mobile entities.

C. Data Management

A traditional introductory Data Management course in computer science typically provides a broad introduction to the principles and practice of modern data management, with an emphasis on the relational database model. Topics include data modeling and the relational model; relational algebra; Structured Query Language (SQL); and data quality, transactions, integrity and security. Students also learn how to build database application programs.

Such a course lends itself well to the world of corobots where humans and robots will need to share data consistently and reliably to achieve a common goal. To support this course, our infrastructure will provide suitable APIs between the corobots, and their local and remote databases. Our planned corobotics module for this course covers the management of data consistency when data is partitioned across multiple databases. The course module will permit students to examine issues underlying consistent data sharing when parts of the data are stored within the robots and in remote databases, with both corobots and humans dynamically accessing and changing this data. The challenge is that the data might become stale and inconsistent, and students need to learn techniques to prevent or minimize such data inconsistencies. The use of corobots thus immediately brings a real-world focus to these issues of data quality, integrity and security, and the need for transactions, which is often lacking in a tradtional client-server database setting.

IV. Current Status and Ongoing Work

At present, we have implemented the core robot functionality and are in the testing phase for the hardware. The server is essentially functional and we are working on its usability and visual appeal for the general student population. We are starting to develop sample applications as mentioned, expanding the student API as the planned course modules require. The current plan is to produce a full team of corobots during summer 2013. Throughout the course of the project, our software infrastructure and design documents will continue to be open source and publicly available through GitHub so that once mature it can be adopted by other schools.

The course modules mentioned in this paper will be developed over the course of the summer of 2013, and the course modules will be offered as part of a trial section of each of the three courses over the next academic year. As each course is required in our curriculum, and thus typically offered in multiple sections per term, we plan to use these parallel offerings to assess whether the use of the corobots results in improved student learning as compared with existing versions of these courses. As the project continues, we plan to investigate the use of corobots in other courses, as well as a project platform for independent studies and MS capstone projects, so that students can have multiple different interactions with the corobots in different guises. Our hope is that this will lead students to investigate the possibilities that such a system provides and drive further development of the robots, the API, and the possible applications of such systems.

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EEG-based Comparisons of Performance on a Mental Rotation Task between Learning Styles and Gender

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***Abstract*— Retention and diversity are central issues in engineering schools. Students' learning styles may hinder understanding of course material if presented in an incompatible way. While learning styles assessments are informative in determining the students' preferences in how they learn, there have been few studies that correlate student learning styles with cognitive and intellectual abilities. The goal of this study was to determine the relationship between students' learning styles, as determined by the Felder-Solomon Inventory of Learning Styles (ILS), and their cognitive abilities. This study uses functional electroencephalography (EEG) to evaluate the areas of neural activation in the brain while engineering students are performing a mental rotation task. Learning style preferences and mental rotation scores are correlated with the EEG activation. Learning styles differences were observed, primarily across gender. Most of these differences were in EEG patterns as opposed to actual task performance, indicating that individuals of different gender and learning style preference might be engaging different parts of the brain on a task while exhibiting similar performance on the task.**

Keywords—mental rotation; EEG; electroencephalography; learning styles

I. Introduction

A. Learning Styles Assessment

Learning styles assessments are often used in engineering education to determine the preferred learning styles of engineering students, and to provide insight into how students learn in different environments. The Felder Silverman Learning Styles Inventory (FSLSI) is a popular learning styles instrument designed specifically for assessing learning styles of engineering students. It consists of forty questions that measure learning style preferences across four scales: active-reflective; sensing-intuitive; sequential-global; and, visual verbal [1]. Active learners prefer to learn through hands-on activites, while reflective learners prefer to think things through first. Sensing learners are good with facts and methodologies, while intuitive learners are good at grasping new concepts and models. Sequential learners prefer to learn in logical steps, while global learners tend to learn in non-linear jumps. Finally, visual learners learn from what they see, compared to verbal learners who learn from "words" that they hear or read. According to the descriptions given in [1], no one is on one end of the scale all of the time – for example, even learners who are strong active learners will have some characteristics of reflective learners. The FSLSI has been shown to have consistence results across engineering groups as well as a test-retest capability up to eight months [2].

Learning styles inventories have been used in engineering education to aid in understanding issues such as recruitment and retention facing engineering schools, and to address ways to adjust educational environments and approaches to curriculum development to appeal to a wider, more diverse range of students. Attempts have been made to look at correlations of learning styles to performance on standard concept inventories in both Signals & Systems and Dynamics courses [3-4]. Similar attempts were made in [5] to correlate learning styles with longitudinal performance in Physics courses. Results have been inconsistent in these and other published studies looking at learning styles and performance assessments in subject specific areas. No studies have looked at the relationship between learning styles and EEG.

Understanding how to individualize learning is significant for engineering programs to expand student recruitment and retention. As new e-learning environments and technologies are coming on-line that can use adaptive technologies to vary the materials based on student responses, it becomes even more important to understand and quantify students' learning style preferences on a more fundamental level.

In this study, we looked at the relationships between student learning styles as measured by the FSLSI, and brain activity measured by electroencephalography (EEG) during a cognitive task (specifically, a mental rotation task) designed to engage different cognitive abilities. The goal was to determine whether students with different learning styles utilize different brain regions and networks when solving problems. In the course of evaluating the data, it became evident that gender was a significant contributing variable; hence, gender was added as a factor in the analysis of the relationships between brain activation as measured by EEG and learning styles. Ultimately, the results of studies such as this one can result in brain activation patterns being coupled with learning models and theories and with teaching practices to better engage students in the educational process.

B. Mental Rotation Overview

Three stimuli are commonly used in mental rotation: the 3D block stimulus, alphanumeric figures, and abstract objects [6]. There are various experimental designs for mental rotation. One such design is to compare rotated images to determine whether they are identical or mirror images [7-10]. Others use translation of objects (in [9-10]) or matching of rotated objects (in [11-12]). Presentation of mental rotation tasks can be either 2D or 3D, with many researchers describing significant gender differences in 3D rotation, but not in 2D [13]. Mental rotation involves visualizing the image, mentally rotating the image, making a comparison between the rotated image and the comparison image, making a "same or different" decision, and finally, sharing the decision [14]. The steps in mental rotation were also reported in [15], where the authors attempted to separate the processes involved in mental rotation (encoding, mental rotation proper and object matching) in a neuroimaging study. Reference [15] found that the right frontal lobe is responsible for encoding and comparison/decision making while the left parietal and left temporal regions are most involved in generation of images and their mental rotation. A number of cognitive domains are believed to be involved in the various stages of mental rotation, leading to many areas of brain activation [16]. Some cognitive domains, like visual processing and visual-spatial memory, are obvious. Others are not immediately obvious – motor and motor imagery processes are involved, as is executive planning. In some cases, verbal processing and verbal memory abilities are also related to performance on mental rotation tasks. The wide array of cognitive processes associated with mental rotation make it a good task to use for comparison across different learning styles.

From an educational standpoint, mental rotation is an interesting task for two key reasons: first, it has been shown that there are significant differences between male and female performance on mental rotation tasks in 3D [13]; and second, it is known that training programs can significantly improve mental rotation scores [13,17]. Mental rotation represents a common set of skills needed in engineering. As an example, in Electrical Engineering, students must perform mathematical operations such as cross products using the right hand rule. The right hand rule requires a visualization of a rotation vector in 3D space. Some students grasp this concept easily, while others struggle with the visualization aspects of it. Other fields of engineering also involve the use of 2D space to represent 3D objects. Even the basic sciences contain examples of the application of skills like those used in mental rotation tasks. Stoichiometry and the visualization of molecular bonds and structures; electromagnetic fields and antenna patterns; and many other examples from engineering, biology, chemistry, and physics require this skill to some degree. One can observe some students using their hands while others might talk or reason themselves through the problem. What is observed in the classroom is reflected in data obtained from neuroimaging studies: there are different cognitive approaches to the mental rotation problem that result in activation of different brain regions. These cognitive approaches might very well be related to learning preferences as well. For example, when considering learning styles, active learners might take a motor-oriented approach to the rotation task because they are more prone to want to work in a "hands on" manner, as opposed to reflective learners who might not engage the motor rotation processes in the brain. This would presumably result in different scores and reaction times between the two learning types as well as in the activation of different brain regions that are active during the task. Hence, the goal of this study was to understand the effect of learning styles on performance and brain function during a mental rotation task. The results of student performance and brain function as measured by EEG on Mental Rotation were compared with the FSILS to determine whether any relationships exist between learning style preferences and cognitive abilities, and whether these relationships are constant across gender.

II. Methods

A. Participant Selection and Setup

This study was approved by a Human Subjects Internal Review Board. Student participants were selected from within the Whitacre College of Engineering, primarily from the undergraduate population and distributed across departments, with Mechanical and Electrical Engineering majors having the greatest number of students in the study, combining to comprise almost 60% of the participants. Of the 51 participants, 19 were female and 33 were male. This reflected an over-representation of female students when compared to the College of Engineering demographics. As is standard in most neuroimaging studies, all particpants were given a handedness questionnaire: forty-four students were right handed, 1 was left handed, 3 were ambidextrous with a preference for right and 3 were ambidextrous with a preference for left.

Study participants were asked to complete the Felder Silverman Learning Styles Inventory (FSLSI) and their scores were recorded across all four scales. The mental rotation task was administered along with two other, unrelated tasks, using a computer based testing system, e-Prime, that presented the test questions and tracked scores and reaction times as participants responded using response pad buttons. Participants received an EEG while performing the task. The EEG was acquired using EGI 64-channel HydroCel Geodesic Sensor Nets at a sampling rate of 500 samples per second. The 64 channels on the net correspond to the standard EEG 10-20 electrode arrangement based on the diagram shown in Fig. 1.

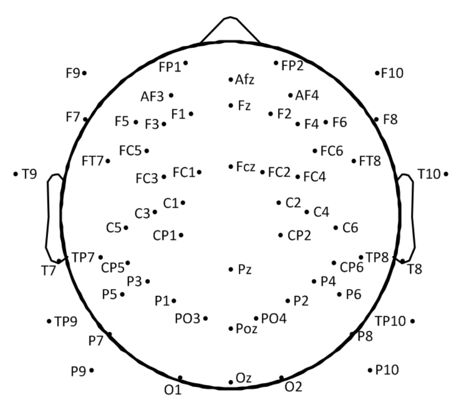

Fig. 1. EEG Channel Locations

The EEG was taken in a sound-proof, unlit room to eliminate artifactual signals. The task stimuli were presented on a 10.25" by 13.25" monitor. Participants were given a keypad with four buttons corresponding to four multiple choice answers for each question.

B. EEG

EEG measures scalp potentials using electrodes (or channels) placed on the head – in this case, using a "net" of electrodes. The scalp potentials represent the linear superposition of electric dipoles within the brain. It is important to be aware that when this paper refers to power in the left frontal region, this means power as measured by electrodes in the left frontal region – the actual signal sources can be distributed throughout other brain regions. EEG signals are commonly separated into five frequency bands for analysis: delta(1-5Hz), theta(5-8Hz), alpha(8-12Hz), beta(12-30Hz), and gamma(30-50Hz). Power levels in each frequency band are associated with different brain processes – conventional analysis focuses on alpha and beta bands for awake and alert adults; however, more recent research indicates that activity in other bands might be relevant to cognition as well.

The EEG data were pre-processed using EEGLAB [18]. The data were low pass and high pass filtered with cutoff frequencies of 50 and 0.5 Hz, respectively. Artifacts in the data due to eye blinks, muscle movement, and other spurious signals were removed using independent component analysis (ICA) as implemented in EEGLAB [19]. For each type of mental rotation question, the EEG was segmented in time to include 1-second segments (referred to as epochs) beginning with the time that the stimulus was presented, and ending after 6 1-second segments. Each epoch or segment was analyzed separately in order to capture the sub-processes of mental rotation described in [15]. To reduce the dataset sizes, the central channels (Afz, Fz, Fcz, Pz, Poz, and Oz) were removed and the remaining 54 channels were divided into 22 regions, 11 in each hemisphere, shown in Fig. 2.

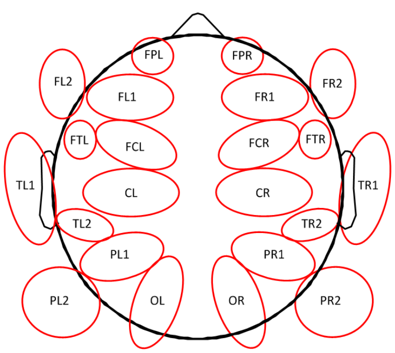

Fig. 2. EEG Regions; Notation: F – frontal, P – parietal, T – temporal, O – occipital, C – central, L – left, and R - right

After the data were epoched and sorted by task type, the frequency spectrum was determined in Matlab, and average power levels were determined for each of the aforementioned frequency bands. Note that the power levels used were for electrode locations, and while these are indicative of power in those immediate brain regions, it is possible that other sources from deep within the brain are contributing to the power at a given channel location.

C. Mental Rotation Task

The mental rotation task was designed similar to that used in [20], involving "3D" figures. The participant matches one of four figures with a top figure. The matching figure is either a rotated, mirrored, or identical version of the top figure. The baseline task (identical figure) was designed for an fMRI version of this test, not reported in this paper, and so were not considered. There are three kinds of rotations: rotation in the plane of the screen, depth of the screen, or a combination of both. There are a total of 48 stimuli for the task. The questions are arranged in a block format with alternating blocks of 3 depth, 3 plane, 3 combination, 3 mirror and 4 baseline tasks. In this paper, only the depth rotation, plane rotation, and mirror tasks will be analyzed. These three tasks, depth rotation, plane rotation, and mirror, will be referred to as D, P, and M, respectively. Fig. 3 shows examples of each of these three tasks.

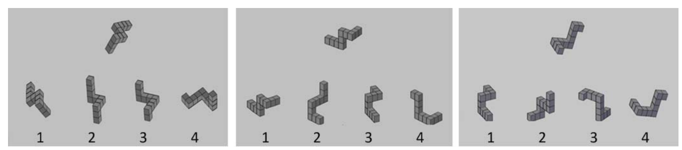

Fig. 3. Plane rotation(left), depth rotation(center), and mirror(right)

III. RESULTS

A. Learning Styles Results

The FSLSI assessment ranks participants in four cognitive domains using a scale from 11a to 11b, depicted in Fig. 4. For example, in the category of VIS/VRB, 9a-11a is strong preference towards visual, and 9b-11b is a strong preference towards verbal. Scores between 1a/b-3a/b indicate a fairly well balanced learning preference, and between 5a/b-7a/b indicate a moderate learning preference. Fig. 4 shows the distribution of FSLSI scores among the 51 participants for all 4 scales.

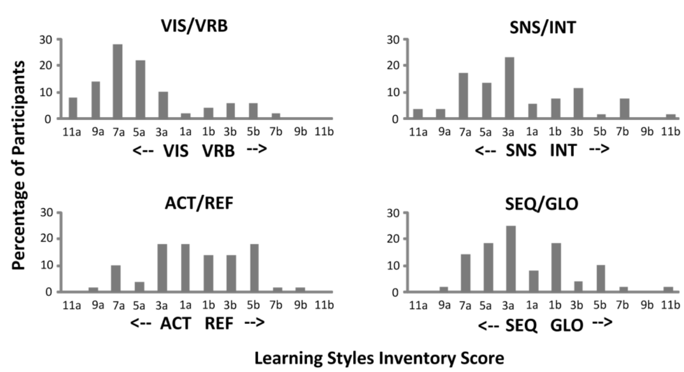

Fig. 4. Distribution of Learning Styles

The histograms presented in Fig. 4 do not indicate a smooth or even Gaussian distribution across the entire spectrum (ACT versus REF is closest to a normal distribution [2]), hence both correlations and t-test comparisons between groups with different learning styles are used in this study. The distributions look almost bimodal, with only the active-reflective scale appearing to peak near the center of the continuum.

Table I gives the distribution of learning styles broken down by gender, with the numbers shown as well as percentages given in parentheses. In general, the distributions between styles are similar across gender category with the exception of the sensing/intuitive scale, where the women participants show a much stronger skewing toward sensing as opposed to intuitive. The results are comparable to previous studies where engineering students are predominately active, sensing, sequential, and visual [2].

TABLE I.

Gender	ACT	SNS	SEQ	VIS
Male	18(55%)	20(61%)	21(63%)	28(84%)
Female	8(44%)	15(83%)	12(67%)	14(78%)
	REF	INT	GLO	VRB
Male	15(45%)	13(39%)	12(37%)	5(16%)
Female	10(56%)	3(17%)	6(33%)	4(22%)

In the following sections, participants' scores, response times, and EEG activation are correlated with their learning styles scores. Correlations were determined using both a continuous scale and a divided scale. For example, on the visual/verbal scale, the visual end of the scale (the "a" end) ranges from a weak score of 1 to a strong score of 11, as does the verbal end of the scale (the "b" end) For a divided scale, correlations were run for each end of the scale separately, with scores running from 1 to 11. For a continuous scale, correlations were run for both ends of the scale simultaneously, with scores running from -11 (visual end) to +11 (verbal end). This was done because, in some cases, the learning style distribution appears to be more continuous, while in other cases it appears to be more bimodal.

B. Mental Rotation Results

The average scores and response times for each of the three tasks, D, P, and M, are given in Table II, and are shown broken down into results for gender and learning styles groups. A statistical t-test was done to determine if scores or response times differed significantly across gender or group (M vs. F, ACT vs. REF, SEQ vs. GLO). Comparisons with statistically significant difference (as determined by the t-test with a p-value of .05) are indicated with asterisks in Table II.

TABLE II.

	Scores (% correct)									
Task	***M***	***F***	***ACT***	***REF***	***SNS***	***INT***	***SEQ***	***GLO***	***VIS***	***VRB***
D	79	70	74	78	74	80	73	80	75	80
P	64	56	63	60	60	65	61	62	62	58
M	63*	51*	63*	54*	57	63	55*	66*	60	51
	RT (seconds)									
Task	***M***	***F***	***ACT***	***REF***	***SNS***	***INT***	***SEQ***	***GLO***	***VIS***	***VRB***
D	6.0	6.4	5.9	6.4	6.3	5.8	6.2	6.0	6.1	6.2
P	7.7	7.8	7.5	8.0	7.9	7.4	7.9	7.3	7.6	8.2
M	7.3	7.9	7.6	7.4	7.8	7.0	7.7	7.1	7.7	6.8

Table II shows that female participants scored significantly lower on the mirror rotation task than males, while active and global learners scored significantly higher than referential and sequential learners, respectively. Across every group, scores decrease from depth rotation to plane rotation and mirror task, indicating these tasks are more difficult for all participants. Response times are also longer for plane rotation and mirror when compared to depth rotation.

Each learning styles group was further divided into male and female and a t-test was performed within a gender category for scores and response times. Plane rotation response times were significantly different ($p<.05$) between visual and verbal females with verbal females having a two second longer response time than visual females.

Scores and response times on the D, P, and M tasks were correlated with both divided and continuous LSI scales for males (M), females (F), and all male and female learning styles groups (i.e. ACT F, ACT M, REF F, REF M, etc.). The correlations that were statistically significant ($p<.05$) are shown in Table III. A positive or negative correlation is indicated by a plus or minus sign in parenthesis next to the passed correlation.

TABLE III.

Learning Styles Category	Correlation
SEQ M	M RT(-)
SNS/INT F	D RT(-)
REF F	D Score(+)
SEQ F	D Score(-)

There were very few correlations between learning styles and mental rotation scores or reaction times that were statistically significant. Sequential males have a negative correlation between mirror response time and their sequential score. This indicates that of the men studied, the more sequential they were, the faster they respond to the mirror task. Reflective and sequential females had opposite correlation results on the depth rotation task. Females with higher reflective LSI scores had higher depth rotation scores while females with higher sequential LSI scores had lower depth rotation scores. On a continuous SNS/INT LSI scale, females had a negative correlation with their response time on the depth rotation task. Females who were more intuitive as opposed to sensing had faster response times.

C. EEG Results

Comparisons between groups' EEG power were made using a t-test. The following groups were compared: males and females (M/F), ACT/REF learners, SEQ/GLO learners, SNS/INT learners, and VIS/VRB learners. Within the delta and theta bands, the only significant ($p<.01$) differences in EEG power were between males and females, occurring across every epoch and almost all channels. Due to the large number of differences observed in males and females for these two frequency bands, the data will not be presented in a table. The channels with statistical differences in EEG power between groups in the alpha, beta, and gamma bands are given in Table IV. If a channel passed as significant for more than one of the six epochs within a task, the percent difference between groups was averaged for every epoch it appeared.

TABLE IV.

Groups	Alpha			Beta			Gamma		
	Region	*Task*	*% Diff**	*Region*	*Task*	*% Diff**	*Region*	*Task*	*% Diff**
M/F	FL2	All	39	FPL	P, M	-20	FPL	All	-25
	PL2	M	32	FL2	All	24	FL2	D	27
				TL1	D	20	TR1	All	33
				PL2	D	29	PR2	All	24
				TR1	All	25	TL2	D	26
				PR2	All	22			
				PR2	D	19			
ACT/REF							TR2	M	-18
							PR1	P, M	-19
SNS/INT				FR1	P	-20	FR1	P	-27
SEQ/GLO				PL2	P	29	PR1	P	15
VIS/VRB							PL2	P, D	-45

*Percent difference is calculated by (Group1-Group2)/average(group1,group2)

Overall in this study, males and females had more statistical differences in EEG power on all tasks than all the learning styles groups. Electrode impedances were measured and reviewed to insure no differences among genders or outliers. There were no statistically significant differences in any impedances. Females had statistically higher power in the left pre-frontal channel on all tasks in the gamma and beta bands. Males had statistically higher power in the right temporal-parietal region on all tasks in the beta and gamma bands. Males also had higher power in the left frontal region on all tasks in the alpha, beta, and gamma band. Reflective learners had statistically higher power than active learners in the right temporal-parietal area on the M and P tasks for the gamma band. INT learners had statistically significantly higher power than sensing learners for the right frontal area on the P task. Sequential learners had statistically significant higher power than global learners on the P task for the left temporal region in the beta band and the right parietal region in the gamma band. Verbal learners had higher power than visual learners in the left temporal region on the P and D tasks in the gamma band.

D. Correlation with EEG Power

EEG average power in all five frequency bands across each task for males (M) and females (F) was correlated with two measurements: 1) LSI scores on the continuous and divided scales and 2) D, P, and M scores. Only the correlations that had statistical significance are reported (p<.01). A smaller p-value was used compared to the correlations between LSI scores and mental rotation scores because a very large number of correlations were significant. We will focus on the beta frequency band because it is commonly associated with an active cognitive state. The results for the beta frequency band are presented in Tables V(correlation with LSI scores) and VI (correlation with D, P, and M scores). A positive or negative correlation is indicated by a plus or minus sign in parenthesis next to the correlated LSI scale or correlated task (scores). The results from these correlations will be discussed in Section IV.

TABLE V.

LSI Scale	**Task**	**Correlated Regions**			
ACT M(+)	D,P,M	PR2			
SNS F(+)	D	TL2	PL1		
SNS F(+)	P	OR			
SNS F(+)	M	PL2			
SNS M(-)	P	PR2			
SNS/INT M(-)	D	TL1	FR1		
SEQ M(+)	D	FTL			
GLO F(+)	D	CL	PL1	OR	
GLO F(+)	P	CL	PL2	FR1	
GLO F(+)	M	FL1	FCL	CL	PL2
GLO M(-)	P,M	FR1			
SEQ/GLO M(-)	D	FPR			
VIS M(-)	D,M	FR1	FR2		
VRB F(+)	D,P,M	FL2			
VRB F(-)	D	CL	PL1		
VRB F(-)	P	FL1			
VRB F(-)	D,P,M	TL2			

TABLE VI.

Group	**Task**	**Correlated Regions**								
ACT F	D(+)	FR1	FCR							
ACT F	P(+)	TR1								
ACT M	M(-)	FCL	FTR							
REF M	M(-)	FR1								
SNS F	P(-)	FCL	CR							
SNS F	P(+)	FR1	FR2	TR1						
SNS F	M(+)	FCL								
SNS F	D(+)	PL1								
SNS M	D(+)	FR2								
INT M	P(+)	FCL	CL	FCR	CR					
INT M	D(-)	PR2								
SEQ M	D(-)	FL1								
SEQ M	P(+)	FCL	CL	TL1	PL1	POL	CR	TR2	PR1	POR
SEQ M	M(-)	FR1	PR2							
GLO F	P(+)	FR2	FTR	TR1						
GLO M	P(-)	FTR								
VRB F	M(-)	FL1	FL2	PR1						
VRB F	M(+)	FPR								
VRB F	D(-)	FR1	FR2							
VRB F	P(-)	FR2	FCR							
VRB M	M(-)	TL1	FCR	FTR						

IV. DISCUSSION

Differences between groups occur primarily across gender rather than across learning styles as indicated by both the correlations and t-tests. While observing differences across gender, it is important to remember that the prefrontal cortex develops slower in males that females, not maturing until the late 20's. This anatomical difference could influence results [21]. For this reason, the correlations between EEG power and LSI scores/mental rotation scores will be discussed separately for males and females.

A. Females

Correlations between EEG power in females and mental rotation scores occur predominantly in verbal and sensing learning styles. Female verbal learners exhibited a positive correlation for right frontal EEG power with mirror scores, but a negative correlation between right frontal power and the depth/plane rotation scores. Recall that in [15], right frontal power was associated with encoding on a rotation task. Verbal females who use encoding seem to benefit by it on the mirror task, but not the rotation tasks. Female verbal LSI scores were positively correlated with left frontal power across all tasks, but negatively correlated with left temporal power, indicating that female verbal learners are clearly engaging the verbal mediation process across all tasks. Their left frontal power correlated negatively with mirror scores. These correlations suggest that the verbal females in this study who attempt to verbally mitigate the mirror part of the task tend to have decreased mirror task scores.

Female active learners showed positive correlation with right frontal regions and depth rotation, opposite with what we discussed in verbal females. Active females also had a positive correlation with right temporal regions and plane rotation. They had no significant correlations with their active LSI scores and EEG power.

On the depth rotation task, sensing females had positive correlations between left parietal power and both their sensing LSI scores and depth rotation scores. The relationship between left parietal regions and depth rotation is expected, as the parietal region is associated with visual spatial processing tasks. Similar to active females, sensing females had a positive correlation with EEG power in right temporal regions and plane rotation. They also had a positive correlation with EEG power in right frontal regions and plane rotation, an opposite effect seen in verbal females.

Global females' plane rotation scores correlated positively with right frontal and temporal regions, similar to sensing and active females, but opposite to verbal females and global males. Across all tasks, global females had a positive correlation with left parietal power and their global LSI scores, indicating the global females were using visual spatial processes to perform the tasks. Only on the mirror task, global females had a positive correlation between their global LSI scores and left frontal power. This indicates that they may have switched strategy for this process to recruit verbal mediation processes.

B. Males

While females only had significant correlations between EEG power levels and their learning scales when the divided scale was used, males showed a different pattern, with EEG power correlating with scores on continuous sensing/intuitive and global/sequential scales. In both cases, EEG power in the right frontal regions was negatively correlated with LSI scale scores. In other words, the more intuitive and sequential the learning style in the studied males, the lower the EEG power in the right frontal lobe, used in the encoding stage of mental rotation.

In males, unlike females, correlations between EEG power and mental rotation scores occur predominantly in sequential and intuitive learning styles. Male sequential learners show positive correlations between plane rotation scores and EEG power in both left and right temporal, parietal, and occipital regions. This pattern of activity is consistent with the generation and rotating of images described in [15], with the exception that the activity is present on both sides of the brain, similar to the bilateral patterns of activation observed in [11] using fMRI studies of mental rotation tasks in math-gifted adolescent boys. Sequential male learners showed negative correlations between depth rotation and left frontal power, and between mirror rotation and right frontal and parietal powers, indicating that perhaps sequential male learners who score well in mirror and depth rotation do not utilize the frontal regions as strongly as do those with lower scores.

Intuitive males also had positive correlations between plane rotation and left and right frontal-central regions, showing once again the bilateral activity for plane rotation in those who score well in plane rotation tasks. Depth rotation was negatively correlated with the right parietal power, indicating that males who score lower on depth rotation do not use the right parietal regions as much as those who score higher.

Active, reflective, sequential, and verbal males all had negative correlations between their right frontal/right frontal temporal power and mirror scores. This means that males who used less right frontal power, associated with encoding, had lower scores on the mirror task than those who used more right frontal power.

V. CONCLUSIONS

When comparing EEG power between learning styles types and genders using the t-test, very few significant differences were observed. However, when comparing learning styles types using their significant correlations between EEG power and LSI scores/mental rotation scores, many differences were observed. There are two postulated reasons for the differences between the t-tests and correlations. First, the effect might be stronger on one end of the continuous LSI scale, hence passing correlations, but not t-tests. Second, LSI scales may not be truly independent. For example, verbal learners might be more skewed to also contain active qualities. Future work needs to include a study into the dependencies within learning styles.

As seen from the t-test results between groups on scores and response times, rotation scores and reaction times do not indicate a difference in performance, but t-tests for EEG power between groups indicate differences in brain activity. Correlations between EEG power and LSI scores/mental rotation scores also produced more significant correlations than the correlations between LSI scores and mental rotation scores. This indicates that even though performance may not correlate with learning styles, the students are using very different brain regions and cognitive strategies.

Plane, mirror, and depth rotation all result in very different correlations between EEG vs. LSI and between EEG vs. rotation scores, indicating that unique processes are going on for each type of rotation. Correlations between EEG vs. LSI and between EEG vs. rotation scores are also quite different across gender. This could translate into a couple of things: learning styles mean different things for different genders or mental rotation process is different across genders. Notice that within females, only one side of each learning scale showed significant correlations while the other exhibited no significant correlations. However, within males, both sides of each learning scale were present with significant correlations. Also, males had continuous scales show up as significant for correlations between LSI and power. The results of our study underscore that more is needed than just designing curriculum based on learning styles: gender is also significant in learning. When it comes to tasks that involve visual spatial processes, strategies that use verbal mediation and other skills may be significant, particularly in female students.

From a practical point of view, this study underscores the importance of engaging students in the engineering classroom through a variety of experiences. One example strategy would be to provide time for reflection after asking a question in class before soliciting student responses and to ask students to verbally describe how they reached an answer. Visual spatial processing might be enhanced through the use of actual or virtual 3D models – for example, bringing a bread-boarded circuit to class or showing a 3D computer aided design sketch rather than only sketching a circuit schematic on the board. It is important to consider using different means of delivering information in different ways in the classroom as well as to allow students to respond to that information in different ways (written answers, verbal answers, graphical illustrations).

This study is limited to engineering students. For this reason, the results should not be generalized to all male and female students, or even all STEM students. The study was intended to demonstrate that learning styles could be correlated with brain activation patterns and performance on cognitive tasks. Future studies involving a verbal task would provide additional information that might be of use in an educational setting.

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Detection and Assistance to Students Who Show Frustration in Learning of Algorithms

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Abstract— **This paper presents a research work on the detection of students who show signs of frustration in learning activities in the area of algorithms, to then assist them with proactive support actions. Our motivation for the development of this work comes from students' difficulty in learning the concepts and techniques for building algorithms, which constitutes one of the main factors for the high dropout rates of computing courses. With the intent of giving a contribution to the reduction of such evasion, this research highlights the importance of considering students' affective states, trying to motivate them to study and work out their difficulties, with the assistance of computer systems. For research validation purposes, a tool was built to: a) infer the student's affective state of frustration while solving exercises of algorithms; b) detect signs associated with frustration, to provide resources to support student learning. Case studies were conducted with students of algorithms at the Faculty of Technology Senac Pelotas, in 2011 and 2012. The rules generated by the data mining software used to identify students' affective state of frustration, as well as an analysis of students' performance are presented in this article.**

Keywords—Affective Computing; Teaching and Learning of Algorithms; Informatics Education.

I. INTRODUCTION

Algorithms is an essential subject for courses in the Computer Science field [1]. It is also known for the learning difficulties imposed upon the students, being considered by many authors as co-responsible for the high evasion rates in the courses within the field [2][3]. Among the activities conducted in algorithm classes we can highlight the preparation of exercises containing the required steps (statements) to solve a problem. These exercises can be implemented and tested within a programming environment, thereby creating a great number of interactions between the student and the computer.

It is possible to store the data from these interactions and provide the teacher with a set of indicators of the student's performance. On the basis of studies stressing the importance of considering affective aspects of the learning process [4][5], this research intends to investigate possible relationships between data from such interactions and a feeling of frustration that students may have when studying algorithms [6][7]. Since it is virtually impossible for a teacher to monitor the activities of everyone in classes with a large number of students, it is understood that providing a computer system with proactive actions supporting a learning process at the time when the student demonstrates frustration can be a major source of help for the student.

The field that focuses on the study of the detection and expression of affective states in computer systems is part of the area so-called Affective Computing. The expression was first used by Rosalind Picard in [8]. The author argues that a computer with emotional capabilities should be able to understand and express its own emotions, to recognize emotions in others, to control affection and use humor and emotions to encourage adaptation behaviors.

In order to implement Affective Computing techniques and methods in computer systems, one can try to associate a standard behavior to a certain affective state based on the detection of physiological or behavioral characteristics of the user [9][10]. The same holds true for the expression of emotions. It is possible to use affective agents to interact with the user by transmitting and inducing emotions based on facial expressions, gestures and looks. This is not a trivial process and different research is being developed in this field of study [11][12].

Within the context of Computer Science, courses of algorithms show a high fail and dropout rates [13]. This makes educational practices for the teaching of algorithms a target of countless studies seeking to minimize the difficulties of students [13][14]. Thus, this research seeks to contribute to the algorithm learning process, using Affective Computing methods to target specific support to students who feel frustrated when conducting their activities.

This document is organized as follows: sections 2 and 3 highlight aspects related to the teaching of algorithms and the Affective Computing field. Section 4 presents a tool built to validate this research, with emphasis on the resources to detect the affective state of frustration and help students who show this sign. Finally, some final considerations and and directions for future work are presented.

II. TEACHING ALGORITHMS

A. *Algorithms: Overview*

An algorithm is a path, a sequence of steps to be taken in order to reach the solution of a problem [15]. It should be noted that there are many ways that can lead to a satisfactory solution to a problem. Thus, a problem can be solved by different algorithms – all of them equally correct.

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The field of algorithms and its formalization in computer programs is an essential part in the field of computing. When implementing an algorithm, a student describes a set of statements following a specific syntax in order to solve a computer problem. Statement syntax means the set of rules regulating the usage of words and punctuation [16]. A text or graphic representation may be used in order to allow a student to organize and represent his or her strategy to solve the proposed problems.

The computation of the harmonic mean of a student's grade or the validation of a user's password are examples of exercises proposed in courses of algorithms. Thus, each exercise presents a new problem to the student and, along the semester, problems requiring the use of logical resources such as iteration, logical decisions, loops and data list handling (vectors) are proposed. It is often the case that, for each type of problem, the student is given a list of exercises for the understanding and practicing of algorithmic methods. However, one of the biggest problem for students is the difficulty to abstract and describe solutions to these problems using few and simple structures [17].

In short, solving problems by writing algorithms entails the need to understand the problem, to adopt a set of actions in a sequence of steps, to represent this set in a given language (or a flow chart) and then to convert it into a program, describing it according to a specific syntax. Since it is the student who runs and tests the program, he or she must check whether his or her algorithm has produced the expected and correct results. Recurrent errors identified in tests of programs written by the students may result in a feeling of frustration. This as well as other affective states, such as confusion, anger and anxiety may affect productivity, learning, social relations and the general well-being of the students [18]. In this context, it is important to detect this affective state in the student, so actions can be taken to help him or her tackle the subject [19].

Jenkins [20] notes that programming is a tough ability to master, being considered by most students as a "boring and difficult" task. The author stresses that some of the difficulties in learning algorithms are related to the nature of the required programming skills, while others concern the teaching and learning methods of some skills.

The relationship between the difficulties in learning algorithms and the feeling of frustration caused by these difficulties can be verified in several articles on the topic. Castro et al. [6] stress that students face a huge obstacle to apply their previous skills when they have their first contact with algorithms, which creates fear and frustration. The authors further point out that the consequences of this obstacle are constant fails, apathy, low self-esteem and dropouts, which ultimately encourages evasion. Sirotheau et al. [7] also claim that, for many computer science students, their first exposure to learning programming is usually frustrating. The reasons for the student's frustration are discussed in the authors' work, such as lack of a view of what is intended to be solved and need for abstraction of the operation of the chosen mechanisms. The authors add that the obstacles tend to lead to problematic situations such as high fail and evasion rates.

Helping students with learning difficulties is not an easy task, since matters connected to school failure are always complex and there is no ready recipe or miracle methods [21]. The supporting approach adopted by this research seeks to help students by combining methods focused on: i) using computer system for the purpose of supporting the student [22][14]; ii) considering the affective aspects of students in the process of teaching-learning algorithms [4][5]; and iii) adopting a special strategy for dealing with students displaying difficulties in learning the subject [21].

B. Related Works

Research related to teaching algorithms try to present alternatives in order to make programming a less arduous task for beginning students in Computer Science courses. Piteira and Costa [23] note that the works prepared to support the teaching and learning of computer programming are based on the development of tools and strategies intended to help with the major challenge of teaching algorithms.

Rodrigo and Baker [24] attempt to identify the student's frustration in the subject of algorithms by applying a mathematical formula drawn from the student's actions during the writing of programs using the BlueJ framework. The main difference between the authors' proposition and this research is that our work attempts to help the student at the time he or she begins to show signs of the affective state of frustration. Furthermore, it is believed that a tool using pseudocode may avoid a number of likely difficulties for a student beginning with the BlueJ framework which, for some authors, is better suited to teaching Object-Oriented Programming [25].

In another example investigates the factors leading to difficulties learning programming and discuss alternatives for teaching algorithms [14]. The authors conducted a study involving 182 students of the Multimedia University in Malaysia and proposed a solution based on learning games, which increased the students' interest in the Computer Programming I subject.

The game-based approach is usually interesting to motivate the students. However, it is understood that such method may at times deviate the student's view of the actual programming tasks. Our approach tries to ease the algorithm-building process by creating a tool that allows students to make the exercises by writing their programs in pseudocode. This tool includes features to capture the student's affective aspects in order to support learning when the student shows signs of frustration.

III. AFFECTIVE COMPUTING

Affective Computing, according to [8], is the field of Computer Science that investigates how to detect affective states of the user of a computer system, and how to express affective states accordingly. For Tao and Tan [26], Affective Computing tries to assign human abilities to computers, such as observation, interpretation and generation of affective behavior, thus improving the quality of human-computer communication.

Duo and Song [27] note that Affective Computing has attracted the attention of educators as it enables them to develop computer tools that are able to assess the affective states of students, thus allowing for the implementation of customizable educational strategies. Inferring the students' affective states may help to predict the evasion of certain individuals and the likelihood of poor school performance [28]. For the authors, Affective Computing may enable the assignment of human psychological features to a virtual learning environment, thus minimizing the possibility of leading the students to boredom and frustration.

According to Picard et al. [19], one of the relevant points of Affective Computing studies in the field of education is trying to correct an imbalance in the use of the computer as an educational tool that favors cognitive over affective aspects. Affection is interconnected with cognition and guides rational behavior, memory recovery and creativity, among other elements [4]. The term cognition refers to the set of mental processes that participate in the acquisition of knowledge, in the perception of the world (and ourselves) and how this world is represented [29].

Several discoveries have shown that affective states tend to affect various behaviors in subsequent tasks [30]. In education, identifying the affective states of students may enable actions to be taken in order to help them in their studies [8].

The work of neuroscientist Damasio [4] underscores the role of emotion and feeling for the individual. According to him: a) emotion exerts influence in mental processes; b) brain processes devoted to emotion are intrinsically connected to the processes devoted to reason; c) the mind cannot be separated from the body. The book is titled "Descartes' Error" because Descartes believed in the separation between body and mind – where the mind only needed the body to be able to operate, without any other connection between them. But Damasio believes exactly in the opposite, that body and mind are closely connected. The mind commands the entire body, but it is the sensations that the body sends to the mind, along with cognition, that induce it to operate that way.

A. Emotion Detection Methods

Pattern-recognition methods can be used to recognize emotions in a computer system. According to [30], users' data can be collected from physiological sources as well as from task performances, also named behavioral observations. The authors further state that there is plenty of room for the discovery of new methods and these are only a few of the possibilities.

Physiological methods use computers equipped with sensors capable of detecting physiological changes in users and then associate them to affective states. However, detecting changes and assigning them to the correct affective state are two different problems [31]. In this process, error interpretation may occur, both between people and between people and machines - as can be observed in [32]. The authors analyze aspects of a smile that may be related to a user's frustration or pleasure.

Another research example of the use of physiological methods for the detection of affective states employs four devices to collect data from users: a) facial expression detection systems on devices such as webcams; b) chair with posture analysis sensor; c) mouse pressure sensor; d) skin sensors.

A different approach to the detection of affective states is based on the observation of the user's behavior, by monitoring his/her actions when using a computer system. In education, the number of errors in questions about a topic, the time devoted to the solution of one exercise, the number of attempts to perform an activity correctly or the number of clicks on a help button can be used to infer information about a student. A computer model can then be used to find behavioral patterns and to relate each pattern to certain affective states. In other words, the events preceding the detected affective state are assessed.

Based on the understanding that a programming environment for learning algorithms can produce information that may be associated to the student's affective state of frustration, the detection based on the analysis of behavioral observation was the method chosen in this research. Furthermore, even though hardware sensors may be used in a laboratory environment, it is difficult to implement such strategy in a classroom or school laboratory when a large number of students is involved [34]. Other studies use sentiment analysis to extract subjective information from text material, such as users' opinion, judgment, or affective state [49][50]. This approach has not been considered here as our focus has been to support students in solving problems in algorithms, an activity that does not involve a lot of writing.

B. Frustration

Frustration is an emotional state resulting from the occurrence of an obstacle preventing the satisfaction of a need. Reynolds [36] searches for a definition of the term in Psychology, which regards frustration as a negative feeling that arises when an attempt to reach a goal is thwarted. On the other hand, Amsel [37] indicates that one of the main causes of frustration is associated to a delay in obtaining conditioned responses. There is also a number of writers on the topic that associate frustration with aggression [35].

Rosenzweig [38] states that frustration is a phenomenon originated by deprivation, dissatisfaction or conflict involving states preventing or creating obstacles to the consummation of an impulse or a need.

A research conducted by Moura [39] associates frustration with a feeling that arises in the individual when facing the demands required by the current globalized scenario. Such demands may be considered continuous sources of rebellion, hopelessness and depression in individuals. These feelings, which are considered universal or typical of human nature, may be associated with the concept of frustration.

Frustration is also traditionally understood from two standpoints: a) Firstly, frustration may be understood as the representation of an object preventing the fulfillment of a need, something outside the subject, i.e., an obstacle or an event; b) secondly, frustration is used as a term describing a negative feeling representing failure or sadness for not achieving something intended [39]. Thus, the phenomenon is understood under these two conceptual subdivisions: frustration as the object itself and frustration as a feeling.

In the field of education, Schank and Neaman [40] recognize that fear of failure is a significant barrier for learning. In this context, Kapoor et al. [9] believe that such failure may be treated in several ways: a) by minimizing the student's discouragement through the reduction of likely humiliations; b) by fostering the understanding that the consequences of failure will be minimal; and c) by providing motivation to overcome or divert the student's attention from failure's unpleasant aspects. The authors further stress that perseverance with failure may be turned into learning, but should not lead to intense frustration, which often results in the students' desire to quit their studies in order to avoid similar experiences.

As for computer systems dealing with the affective feeling of frustration, Hone [41] states that the purpose of creating systems responding to the user's frustration is to develop interventions to try to lessen it. Kappor et al. [9] follow the same line when they state that developing systems capable of detecting whether a student is frustrated may allow for positive intervention, with the purpose of helping students to use their frustration as a learning opportunity indicator.

C. Supporting Theories for the Proposed Model

The implementation of the proposed model for the detection of the student's frustration, as well as the use of behavioral variables, is supported by the following works:

a) Kapoor, Burleson and Picard [9]: in this research, while a student worked on a Tower of Hanoi exercise, his/her data was collected with the use of complex equipment. The purpose was to store a set of the user's affective expressions preceding the user's clicking on the "I'm Frustrated" button. Therefore, each new occurrence of this set of affective expressions was an indication that the user was frustrated;

b) Bercht [10] indicated that affective states could be detected by a computer system from several behavioral variables of the student..

Aligned with the ideas of Kapoor et al. [9], the research presented here seeks to record the students' actions while they perform certain activities, trying to associate the collected data with information about the students' affective states. However, our research employs data collected from the students' interaction in a programming environment as a way to identify situations that can lead them to the affective state of frustration. The advantages of this detection method are highlighted in section A of the next section.

IV. THE TOOL TO DETECT AFFECTIVE STATES

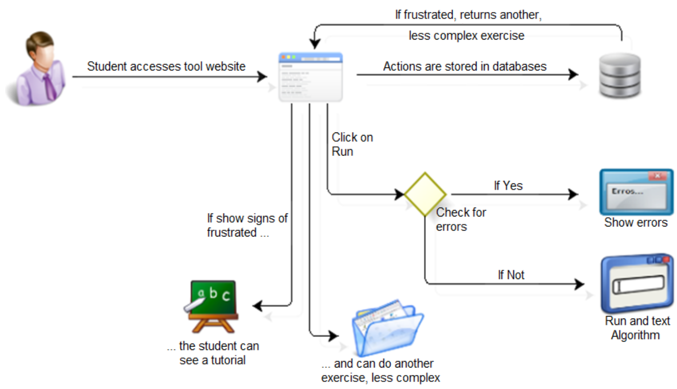
In order to validate this research, a tool has been developed for the purpose of capturing the student's behavioral variables while working on algorithm exercises. In the writing and testing of an algorithm, a student generates hundreds of even thousands of interactions with the computer. The system implemented stores these interactions, which may be later associated to the students' affective state of frustration.

Initially, apart from typical buttons of a programming environment, the tool also included the button "I'm Frustrated". The following actions have been captured by the tool: (a) the number of times the student compiled the program; (b) the total number of mistakes; (c) the amount of time between the beginning of the exercise and the last compilation of the program; (d) number of previous attempts without solving the problem; (e) number of compilations without syntax errors. When a student clicked on the "I'm Frustrated" button, the data collected is then associated to a situation that produced the student's affective state of frustration.

Systems of this nature, in which the user is required to inform his or her affective states, are used based on researches indicating that humans are more prone to inform negative feelings about themselves to computerized systems than to other humans [42] [43].

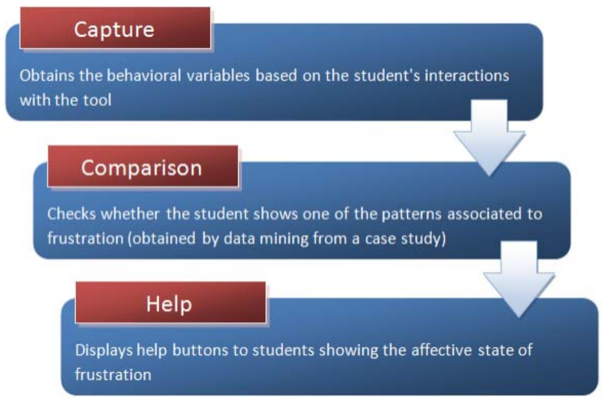
Later, once the variables associated to the student's affective state of frustration have been cataloged, the reference values are used to identify the students who presented signs of frustration and provide these students with educational supporting actions - as illustrated by figure 1.

Fig. 1: Tool operation



The importance of adding resources to respond to students in an affective manner is highlighted in [44][45]. Figure 2 presents the main actions performed by the tool.

Fig. 2: Actions performed by the tool



The assistance proposed by the system attempts to provide a different learning strategy to fill the cognitive gaps of a student who shows difficulties in solving the given problems, as proposed by [21].

As an analogy to the process developed in this work, one could relate it to a car's ability to detect the driver's fatigue. The system captures data assessing changes in the steering wheel and, on the basis of a behavioral pattern, it indicates possible fatigue of the driver. Sound and visual signs are displayed, suggesting the driver to stop.

A. Frustration Detection

In order to capture the behavioral variables associated to the student's affective state of frustration, three case studies were developed. The first one involved 58 students. The second had 14 students and the third one had 6 students, the latter a qualitative study used to assess the student's performance and participation. The number of records stored to keep track of students' interactions has been very high. In the first experiment, the button "Run" has been clicked 2197 times, generating a number even higher of records for the 58 participating students. These were the records used in this research.

The first study had the purpose of identifying patterns in the users' data relating their behavior when working with the system and their indicated state of frustration. The results obtained in this case study allowed the identification of:

a) The existence of situations showing the great difficulty of students when doing the exercises;

b) The fact that these extremely difficult situations can be captured by the tool;

c) Consistency between what the student revealed to the environment and the student's affective state of frustration, according to the difficulties found by the student when doing the exercises;

d) The possibility of associating the affective state of frustration to the student's behavioral variables while he or she used the programming environment.

The findings of the study led to the delineation of the next steps of the research.

The second step attempted to elicit from the collected data the rules that enabled the identification of the behavioral variables associated to the student's affective state of frustration. The WizRule Data Mining software has been used for this purpose, a software by WizSoft (www.wizsoft.com). Witten and Frank [46] state that, in the process of data mining, the patterns discovered must be meaningful so as to provide some advantage to the domain in which they are used. Fayyad [47] stresses this same idea by saying that data mining can potentially help users to identify useful and understandable patterns in large volumes of data.

The rules obtained from the second case study are shown in figure 3.

Fig. 3: Rules associated to the student's affective state of frustration

a) If **number_of_compilations_with_errors** *is* **High** *Then*
frustrated *is* **True**
Rule's probability: **0,800**

b) If **number_of_compilations_without_errors** *is* **High** *Then*
frustrated *is* **True**
Rule's probability: **1,000**

c) If **duration** *is* **High**
and **consecutive_programs_with_errors** *is* **High** *Then*
frustrated *is* **True**
Rule's probability: **1,000**

d) If **consecutive_programs_with_errors** *is* **High**
and **number_of_compilations_with_errors** *is* **High** *Then*
frustrated *is* **True**
Rule's probability: **1,000**

e) If **consecutive_programs_with_errors** *is* **High** *Then*
frustrated *is* **True**
Rule's probability: **0,750**

As it is possible to observe in the rules generated by the data mining process, the students indicated that they were frustrated in situations where: (a) they could not solve a problem due to syntax errors in their programs; (b) there were probable logical mistakes in the solution (occurence of several compilations without syntax errors); (c) the student spent a large amount trying to solve the exercise; (d) the students had difficulties in consecutive exercises.

The third case study attempted to check whether the generated rules were correct. In other words, if the tool was able to detect the times when the students were about to feel frustrated doing the exercises. Table I shows some of the students' comments obtained from questions included in the tool itself.

TABLE I. CONFIRMATION OF RULES ASSOCIATED TO FRUSTRATION

Yes / No	Comment
Yes	One error complicates the entire exercise
Yes	I can't understand the contents from the start
Yes	Compilation errors are time-consuming, making the search for the correct meaning tiring when writing the program
Yes	An algorithm is like mathematics, it has to be exercised. Of course some are easier than others, as the logic is clearer.

B. Learning Assistance

In order to support the learning process of students who showed signs of frustration when doing the algorithm exercises, the following features were added in the form of buttons displayed on the tool:

- The provision of a step-by-step tutorial with the solution of the exercise the student had difficulty doing.
- The recommendation of a new exercise previously added by the teacher, which was more linear in terms of the complexity level of the concepts exercised by that point of the subject.

Zabala [48] provides several examples that support the research methods employed in this research. He states that the different learning paces of students must be respected by providing different types and number of activities. In another moment the author states that it is appropriate "to use different strategies to represent the problems… among them the utilization of simpler problems, which encourages and strengthens the mastering of heuristic strategies".

Figure 4 shows the tool screen featuring the buttons "Tutorial with the Solution to This Exercise" and "Get Another, Less Complex Exercise". They are displayed at the time of the occurrence of one of the rules displayed in figure 3. They try to provide special treatment to a student experiencing difficulties doing an exercise. Thus, the idea is to turn the student's frustration into a learning opportunity, as proposed by [9].

Figure 5 shows the aid given to the student. He can see the development of the exercise in a step by step fashion, and he can then go back or forward depending on his pace of learning.

Fig. 4: Tool screen featuring buttons to help the student

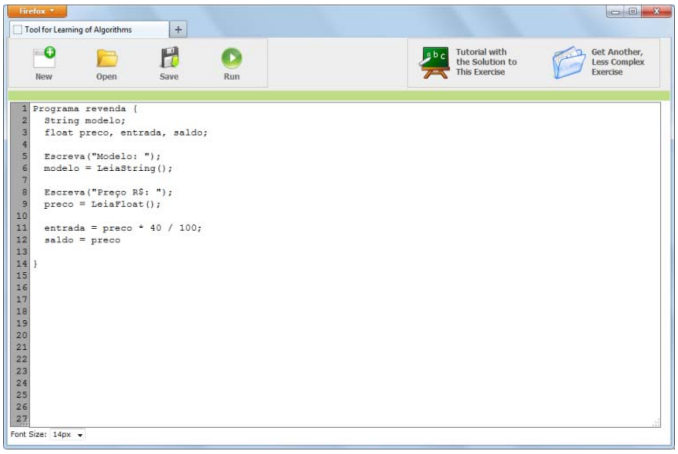
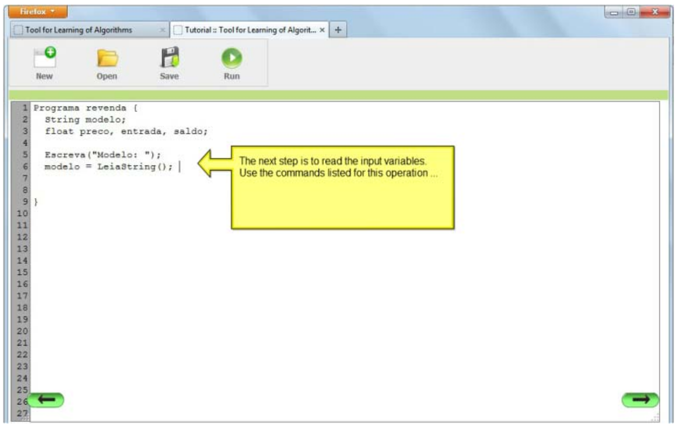
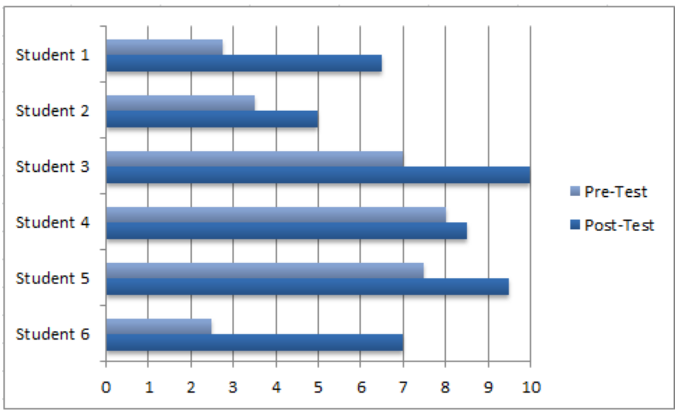


Fig. 5: Tutorial with the solution to exercise



In order to assess the possible benefits of helping the students when they begin to show one of the behaviors associated to the affective state of frustration, a supplementary course on algorithms was offered to those who had difficulties in learning. The analysis was based on two evaluations conducted before and after the course. Each evaluation had 4 exercises. Figure 6 presents a chart with a comparison between the students' performance in pre and post-test.

Fig. 6: Chart depicting students' performance in pre and post-testing



It has been possible to observe during the workshop carried out with the students that they often used the resources that were made available to them, such as the tutorials and the offer of less complex exercises. Such tools have contributed with the good results the students obtained in the post-tests.

V. FINAL CONSIDERATIONS

The work developed in this study had the purpose of investigating how to detect and help students showing signs of frustration in their learning process of algorithms, from the discovery of behavioral patterns in the student's actions in a programming environment. The employment of Affective Computing methods attempted to help the teachers of the subject to focus their attention to students who may be displaying affective states which can negatively affect their learning process, as suggested by [19].

The purpose of this work has been to associate the behavioral variables produced by the students in a programming environment to the students' affective state of frustration. In order to validate the study, a tool converting pseudocode into computer programs was created in order to capture the student's actions. The development of case studies enabled the detection of a pattern to identify students who were likely to be feeling frustrated in the subject.

Another step tried to help these students by offering them a step-by-step tutorial with the resolution of the exercise in which they were showing some difficulty. A new and less complex exercise was also presented to the student. From the case studies conducted, the following conclusions were drawn:

- There is evidence that the behavioral variables produced by the students' interactions with the programming tool were associated with repeated coding errors and delays in completing the exercise. These actions were associated to the student's affective state of frustration.

- It was possible to help the students in their learning processes at the time when they showed one of these behaviors associated to frustration, by using a teaching method focused on their difficulties.

It should be further noted that this approach can be used both for in-class and distance-learning courses, especially in the first classes, where a larger number of dropouts is observed. For in-class courses, it especially contemplates shy students who may ultimately give up on the course without the teacher's perception, as they do not ask for help or demonstrate their difficulties. For distance-learning courses, the use of a tool to detect and help students showing signs of frustration may be important for teachers/tutors to perceive the students' actual difficulties. The recommendation of simpler exercises which are more appropriate to the student's level may be a good strategy to tackle such problem.

For future works, we are starting to investigate the integration of this approach with other research focused on addressing the students' motivational aspects. The development of a portal for learning algorithms is also planned, in order to make the tool built here available to algorithm teachers, including a set of exercises and tutorials.

Finally, another contribution of this research has been to show that it is possible to develop educational applications that make use Affective Computing methods to infer students affective states, without necessarily using complex equipment to capture physiological data.

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Students' Collaborative Note-Taking Activities While Using Electronic and Paper-Based Enhanced Guided Notes: Viewed from Metacognitive and Social Network Perspectives

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***Abstract*—Previous studies suggested that the implementation of note-taking strategies impacted students' learning process and performance. Research also suggested that collaborative learning facilitates students to learn from different views of interpreting information. The objective of this study was to investigate students' metacognitive skills and social networks while using electronic and paper-based enhanced guided notes. Students' worked in groups of three or four to complete the EGN. The impact of the collaborative note-taking activities on the students' collaboration processes was examined using social network analysis. Our findings revealed that students' cognitive and metacognitive strategies between electronic and paper-based EGN groups were relatively similar. Our data analysis of students' social networks revealed two clusters of students, high and low groups that represented the level of students' connectivity in a collaborations network. The findings suggested that the high group outperformed students in the low group in the use of cognitive, monitoring, and regulating strategies. Implications of the use of collaborative note-taking in engineering classroom will be discussed.**

Keywords— collaborative note-taking; engineering college; enhanced guided notes

I. INTRODUCTION

A wide body of literature suggests that students learn best when they take an active role in learning through discussion, practicing, and applying concepts and ideas [1]; however, these activities are often impractical to conduct, particularly in large classes. In engineering education, most instructors present engineering concepts and teach engineering problem-solving skills by lecturing. Many of those lectures, especially in the general engineering courses, are delivered to large numbers of students in lecture halls. The major concern that most instructors have is about the effectiveness of the lectures in facilitating students' learning. According to some studies [2-4], students' attention during lectures declines after 10-15 minutes. Hartley and Davis [3] also found that the amount of notes written declined over the course of a lecture. Unless the students' attention is focused on what the instructor is saying, there is little chance that meaningful processing and note-taking will follow. As a result, some students fail to record the primary ideas; instead, they try to record all the information that they hear without critically judging the importance of the lecture content. In practice, maintaining attention and focus presents a considerable challenge for both instructor and students.

Compared to the traditional lecturing method practiced in most colleges, these new learning materials and strategies may offer students an enhanced learning experience that more effectively utilizes the lecture time. By combining the guided notes together with a collaborative note-taking process, students are encouraged to exercise metacognitive skills and participate in team activities. Metacognitive skills play a significant role in students' control of their cognition such as planning, monitoring, and regulating their own cognitive strategies. These activities help students to learn how to encode information received from the lecture and ultimately improve note-taking skills. It is the intent of this study to implement a new type of note-taking activity that not only helps engineering students to actively engage in learning during lectures but also helps them become better at note-taking. Although many studies have revealed a positive correlation between collaborative learning and student performance, few studies have investigated students' profiles on the collaborative note-taking activity and its relationship with metacognitive strategies and social networks. The main objective of this study was to investigate students' metacognitive skills and social networks while learning using electronic and paper-based EGN.

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II. RELEVANT LITERATURE REVIEW

A. Standard versus Enhanced Guided Notes

Standard guided notes have been used in classrooms for quite some time, and multiple studies have been conducted to evaluate their effectiveness. The guided notes consist of incomplete information with blank spaces available for student notes. They may consist of concepts, diagrams, problems, and conclusions. Previous studies revealed that students who used a guided note-taking method performed better on conceptual tests and increased their attention level during lectures [5-7]. Kiewra argued that this effectiveness is associated with the increased encoding required by the students as they strive to complete the missing details [8].

Compared to standard guided notes, enhanced guided notes (EGN) contain more than blank spaces in which students need to provide detail information. An example of part of the EGN is provided at the Appendix. The EGN of the current study, based upon lessons learned from previous research [5], included two new components that are not present in standard guided notes: (1) questions that prompt students to assess their metacognitive knowledge throughout the guided notes [9], and (2) the notes will be further enhanced through the inclusion of outside class activities. This study added additional note-taking activities with a metacognitive knowledge component to the standard guided notes. Metacognition is a fundamental tool that enables learners to control their own cognition [10]. This leads learners to learn better [11]. By imposing note-sharing with others in the class and prompting metacognition of this collaborative process, we will further enhance the students' metacognition. Lehrl and Fischer connected the information processing theory to the social constructivist theory introduced by Vygotsky, which suggested that learning occurs when students actively construct their knowledge based upon social interaction [12]. In educational practice, these interactions should assist students to become actively aware of their knowledge.

B. Collaborative Note-Taking and Social Network Analysis

The collaborative note-taking was added to our EGN for three reasons: (1) to help students explore other essential information that may not be included in the guided notes; (2) to become familiar with different views of interpreting information from other students; and (3) to expose students to alternative note-taking strategies. The first reason for including collaborative note-taking is that for each topic, there are aspects of the course materials that are not covered during the lecture. The materials may be part of the course materials, but insufficient time is available for detailed coverage during lectures. The second reason is to help students to become familiar with different views and clarify information with their classmates. When the faculty is unavailable, access to information occurs through the social networks. Moreover, the collaborative note-taking implemented electronically will give new learning experiences to students.

The impacts of the collaborative online note-taking activities on the students' collaboration processes can be examined using social network analysis techniques. Marin and Wellman [13] described social network as "a set of socially relevant nodes connected by one or more relations" (p. 11). In this study, nodes refer to students who work together with their peers. In addition to mapping the networks, centrality metrics will be used to capture positional information for each individual in a collaborations network. We will examine individual student position within the classroom using In-degree Centrality to examine the students' direct connectivity to other players (a measurement of a group leadership role) [14-16].

C. Metacognition in a Self-Regulated Learning Framework

Extensive research has been conducted to evaluate the importance of metacognition in learning, especially in problem-solving ability [17-19]. Flavell [21], who coined the term *metacognition* categorized it as metacognitive knowledge and metacognitive experience. He described metacognitive knowledge as "one's knowledge concerning one's own cognitive processes and products or anything related to them" (p. 232). He also identifies three different types of metacognitive knowledge: person (the knowledge a person has about him or herself and others as cognitive processors); task (the knowledge a person has about the information and resources they need to undertake a task); and strategy (knowledge regarding the strategies which are likely to be effective in achieving goals and undertaking tasks) [22]. In another research, Paris and Winograd [23] offered a more comprehensive view in which metacognition can be observed through two essential features: cognitive self-appraisal (CSA) and cognitive self-management (CSM). Lawanto & Johnson [24] noted that CSA and CSM are distinct, easy to identify, and position the learner as the central part of the metacognition issue. CSA refers to learners' personal judgments about their ability to meet a cognitive goal; CSM refers to learners' abilities to make necessary adjustments and revisions during their work.

The association between cognitive and metacognitive strategies can be captured by a self-regulated learning framework. According to Pintrich [25], self-regulated learning is ''an active, constructive process whereby learners set goals for learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment'' (p. 453). In addition, Zimmerman [26] stated that self-regulated learners are "metacognitively, motivationally, and behaviorally active participants in their own learning process" (p. 329). While many theoretical perspectives of metacognition and self-regulated learning have been proposed, we chose Butler and Cartier's model of self-regulation [27-30] because it defines the interplay between metacognitive knowledge and metacognitive control, conceptualized as cycles of "self-regulation in action," within a particular learning activity.

Butler and Cartier's SRL model consists of eight major features (i.e., SRL features) that interact with each other: layers of context, what individuals bring, mediating variables, task interpretation, personal objectives, SRL processes, cognitive strategies, and performance criteria. The current study focused on two major features of the SRL model: SRL processes and cognitive strategies; SRL processes represent students' metacognitive strategies. Students manage their engagement in academic work by using the sixth feature in the Butler and Cartier model: planning, monitoring, evaluating, adjusting approaches to learning. Students prepare their learning activity, select strategies for task completion, self-monitor progress, and adjust goals, plans, or strategies based upon self-perceptions of progress or feedback and performance. These strategies are iterative and dynamic endeavors. The seventh feature, cognitive strategies, refers to students' cognitive activities as they engage in learning, as planned, monitored, and adjusted through self-regulating strategies.

III. THE STUDY

A. The Participants and Context of the Course

Sixty-six engineering students enrolled in the Fundamental Electronics for Engineers course participated in this study. The electronic group was given an iPad 2™ tablet for shared note-taking. The selected students were given an opportunity to accept or reject the offer. This process took several iterations until all available iPads were distributed. Some additional students who had their own electronic devices also chose to participate. While 32 students used electronic devices, 34 students used paper-based EGN to take notes. Two formats of EGN were provided: electronic (iPad) and paper-based EGN. Students' worked in groups of three or four to complete the EGN. Electronic group students were required to download blank EGN through a repository server. After taking and reviewing notes in classroom, the students were asked to submit their EGN into the repository server. They were also suggested to review both their own and peers' EGN. On the other hand, the paper-based group students were asked to complete their EGN by discussing it with their group. After completing the EGN, they submitted one set of EGN that represented their group for each topic.

The course covered the study and application of direct DC/AC and digital concepts including circuit fundamentals, theorems, laws, analysis, components, digital design fundamentals, and combinational circuits design, equipment, and measuring devices. The use of these guided notes was intended to replace the one-way communication that was typical of class meetings.

B. Instrumentation

A self-regulated learning survey instrument developed using Butler and Cartier's SRL model was used to capture students' cognitive and metacognitive strategies. The SRL survey was adapted from the Inquiry Learning Questionnaire (ILQ) by Butler and Cartier based on their theoretical model [27-30]. Students were asked to rate themselves on a 4-point Likert scale (1 = *almost never*, 2 = *sometimes*, 3 = *often*, 4 = *almost always*). Four subscales were developed to capture students' cognitive and metacognitive skills at the beginning and end of the semester. The subscales were planning, monitoring, regulating, and cognitive strategies. Subscales of the questionnaire had Cronbach's Alpha scores ranging from .637 to .870 (see Table I for samples of the SRL questionnaire items). Furthermore, online social networking surveys were conducted twice, at the beginning and end of the semester. To map the networks, in-degree centrality metrics were used to capture positional information for each individual in a collaborations network.

TABLE IA: PLANNING STRATEGIES

No	**Before I begin the activity of learning and solving math, science, or engineering problems involving new concepts, I start by…**
1	planning my time
2	choosing a method for completing the problems
3	creating a strategy
4	checking the scope of the activity

TABLE IB: MONITORING STRATEGIES

No	**When learning and solving math, science, or engineering problems involving new concepts, I…**
1	judge the quality of my work
2	check now and then to see of my work is going well
3	check to make sure I have completed everything required for the activity
4	identify what I do and don't understand
5	check whether I can describe the main topic of the subject
6	check that I have found all the important concept
7	check what I can remember from what I learned
8	keep track how much time I have to finish my work
9	ask myself whether my methods for solving problems are good
10	ask myself whether I will get a good grade
11	check to make sure I come up with a n answer that makes sense to me

TABLE IC: REGULATING STRATEGIES

No	**When I have difficulties learning and solving math, science, or engineering problems involving new concepts, I…**
1	check to make sure I have completed everything required for the activity
2	review the difficult concepts again
3	try to make links between concepts
4	make links between concepts I am learning and problem I solved
5	try to memorize concepts
6	try to use better methods for working

TABLE ID: COGNITIVE STRATEGIES

No	**While I am learning and solving math, science, or engineering problems involving new concepts, I…**
1	pay attention to underlined or bolded words in learning resources, if there are any
2	pay attention to important concepts
3	take notes on the important concepts
4	think about what I already know about the subject
5	draw conclusions from what I have learned
6	think of related examples
7	think of how I can apply the new learned concepts to solve a problem or respond to questions
8	find links between concepts

C. Data Collection and Analysis

Students were asked to complete a self-regulated learning questionnaire at the end of the semester. Data from the questionnaire were analyzed using descriptive statistics to investigate students' cognitive and metacognitive skill profiles. We also conducted a non-parametric statistical test (i.e., Mann-Whitney) to investigate whether the groups had different levels of cognitive and metacognitive skills at the end of the semester.

Furthermore, the impact of the collaborative note-taking activities on the students' collaboration processes was examined using social network analysis. Online social networking surveys were conducted at the end of the semester. The data were gathered using a social-networking survey based on those described by Schreuders and Mannon [31] and Cross and Parkers [32]. To map the networks, in-degree centrality metrics were used to capture positional information for each individual in a collaborations network. Node-XL application was used to visualize the networks. A cluster analysis was conducted to investigate whether there was a variation on level of students' direct connectivity to other students in the network.

IV. Findings

The objective of this study was to investigate the impact of the collaborative note-taking on students' cognitive-metacognitive skills and social networks while using electronic and paper-based enhanced guided notes. According to the study objective, the research questions guiding the current study included: (1) Was there any difference between electronic and paper-based EGN groups regarding their cognitive and metacognitive strategies and social networks?; and (2) How did students' social networks relate to their cognitive and metacognitive strategies?

A. Was There Any Difference Between Electronic and Paper-Based EGN Groups Regarding Their Cognitive and Metacognitive Strategies and Social Networks?

1) Cognitive and Metacognitive Strategies in Electronic and Paper-Based EGN Groups

The mean value of each SRL feature was used to describe students' SRL profiles that belonged to the groups of students. Descriptive statistics of groups' cognitive and metacognitive strategies while learning electric circuit concepts using electronic and paper-based EGN are shown in Table II below.

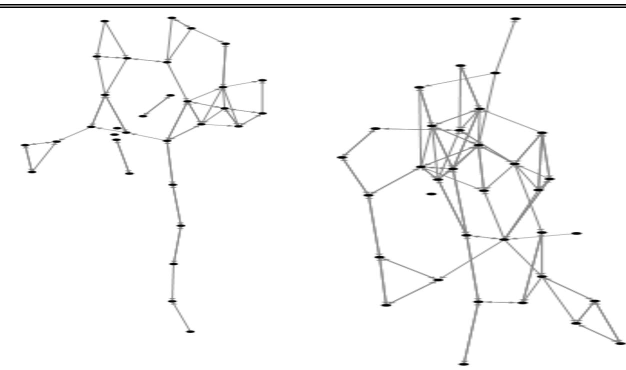
TABLE II: Mean Scores and Standard Deviations of Cognitive and Metacognitive Strategies between Electronic and Paper-based Groups

Feature	Electronic EGN Group (n = 32)	Paper-based EGN Group (n = 34)
	***M* (*SD*)**	***M* (*SD*)**
Planning Strategies	2.52 (.50)	2.61 (.51)
Monitoring Strategies	3.08 (.38)	3.06 (.50)
Regulating Strategies	2.92 (.41)	3.06 (.49)
Cognitive Strategies	3.14 (.35)	3.21 (.48)

From the descriptive statistics, we found students' cognitive and metacognitive strategies between electronic and paper-based EGN groups were relatively similar. Although overall there was no significant difference found between both groups, our findings suggested differences in the questionnaire-item level specifically on planning, monitoring, and regulating strategies. We found that the paper-based EGN group outperformed the electronic group on items such as "creating a strategy" (PS: Z = -1.865, p =.031), "review the difficult concepts again" (REG: Z = -1.814; p = .035) and "try to use better methods for working" (REG: Z = 2.156; p = .015). On the other hand, the electronic group outperformed the paper-based EGN group on "ask myself whether I will get a good grade" (MON: Z = -2.080, p = .019). These findings suggested that overall both groups had a similar level of SRL skills after using enhanced guided notes, either electronic or paper-based EGN.

2) Students' Social Networks Between Electronic and Paper-Based EGN Groups

An analysis of in-degree centrality showed that the paper-based group had more connections among the students than did the electronic group (see Figure 1). We found from Chi-square tests conducted that the difference in the total number of connections between both groups was significant ($\chi 2$ = 8.100, df = 1, p = .004).

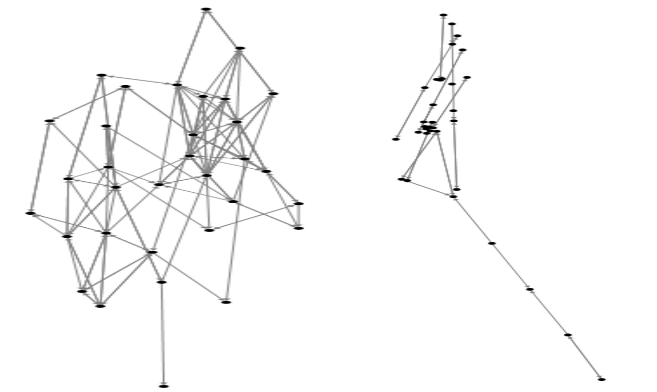


Electronic group (Total connections: 62)	Paper-based group (Total connections: 98)

Fig. 1. In-degree centrality graphs between both groups at the end of the semester

B. How Did Students' Networks Relate to Their Cognitive and Metacognitive Strategies?

We further examined students' social networks to evaluate whether the level of social networking reflected students' competence. A cluster analysis was conducted to examine the different social networking levels among the students. In-degree centrality, which examines the students' direct connectivity to other class members (a measurement of a student leadership role) [14-15], was used as a parameter to conduct the cluster analysis. Our analysis found two clusters: high and low levels of social networking. An analysis of in-degree centrality found that the high level of direct connectivity group had more connections among the students than did the low level of direct connectivity group (see Figure 2). We found from Chi-square tests conducted that the difference in the total number of segments per student between both groups was significant ($\chi 2 = 71.122$, $df = 1$, $p = .000$).



High level of direct connectivity (Total connections: 136)	Low level of direct connectivity (Total connections: 28)

Fig. 2. In-degree centrality between high and low levels of direct connectivity

Descriptive statistics of the groups' cognitive and metacognitive strategies between high and low levels of direct connectivity are shown in Table III below. Significant differences were found between both groups on cognitive (Z = -1.967, p = .024), monitoring (Z = -1.861, p = .031), and regulating strategies (Z = -2.160, p = .015).

TABLE III: MEAN SCORES AND STANDARD DEVIATIONS OF COGNITIVE AND METACOGNITIVE STRATEGIES BETWEEN HIGH AND LOW LEVELS OF DIRECT CONNECTIVITY

Feature	High Level of Connectivity (n = 33)	Low Level of Connectivity (n = 33)
	***M* (*SD*)**	***M* (*SD*)**
Planning Strategies	2.73 (.55)	2.57 (.48)
Monitoring Strategies*	3.18 (.42)	2.96 (.44)
Regulating Strategies*	3.11 (.44)	2.80 (.43)
Cognitive Strategies*	3.30 (.44)	3.05 (.36)

Our findings also suggested differences in the questionnaire item level on monitoring, regulating, and cognitive strategies. We found that the high level of direct connectivity group outperformed the low level of direct connectivity group on cognitive strategy items including "pay attention to important concepts" (CS: Z = -1.865, p < .05), "think of how I can apply the new learned concepts to solve a problem or respond to questions" (CS: Z = -1.814; p < .05) and "find links between concepts" (CS: Z = -2.156; p < .05). The high level group also outperformed the low level group on monitoring strategies: "check now and then to see if my work is going well" (MON: Z = -1.890, p < .05), "check whether I can describe the main topic of the subject" (MON: Z = -2.463, p < .01), "check what I can remember from what I learned" (MON: Z = -1.982, p < .05), "check to make sure I come up with an answer that makes sense to me" (MON: Z = -1.856, p < .05), and regulating strategies: "review the difficult concepts again" (REG: Z = -2.013, p < .05), "try to make links between concepts" (REG: Z = -2.352, p < .05), "try to memorize concepts" (REG: Z = -2.478, p < .05), and "try to use better methods for working" (REG: Z = -1.890, p < .01).

V. CONCLUSIONS

This paper provides insights into shared note-taking activity using metacognitive and social network perspectives. In the current study, electronic and paper-based enhanced guided notes were used to implement collaborative note-taking activity in the Fundamental Electronics for Engineers course. Our evaluation of students' metacognitive skills between electronic and paper-based EGN groups showed that their skills were relatively similar. Although overall there was no significant SRL difference between both groups, our findings suggested differences in the questionnaire-item levels on planning, monitoring, and regulating strategies.

An evaluation of students' social networks revealed that the paper-based group had more connections among the students than did the electronic group. Furthermore, social network analysis was also conducted to investigate whether the level of social networking reflected students' competence. A cluster analysis revealed two clusters: a high and low level of social networking. Our findings showed that the high level of direct connectivity group outperformed the low level group on cognitive, monitoring, and regulating strategies.

VI. IMPLICATIONS

Several implications resulted from the current study: *First*, educators may offer the use of electronic and paper-based EGN based on students' preference for a collaborative note-taking activity. Our evaluation found that groups who were willing to utilize both electronic and paper-based media had similar self-regulated learning skills. Data analysis revealed significant differences only on a few items. Specific improvements on the electronic EGN need to be conducted to improve the use of the guided notes. *Second*, the nature of collaboration between electronic and paper-based EGN groups may explain why students in paper group had more connections on their social networks. Electronic group students had direct access to their peers' EGN through a repository server. They were asked to review their peers' EGN to complete their own notes. Electronic students could complete the task required by their teacher although they did not meet face-to-face during the semester. It might limit these students' collaborative activities with other students in the class. On the other hand, paper-based group were asked to have a face-to-face collaboration with their peers to complete their EGN. This activity might provide paper-based students more chances to collaborate with their classmates than electronic group. It may be helpful to obtain more detailed information about the way both groups communicate and learn with their team members. The teacher may encourage both groups to set up regular communication with their peers either using recorded asynchronous online discussion or face to face meetings.

As suggested by the findings, students who have more direct connectivity on their social networks showed a higher level of metacognitive skills compare to their peers who had less direct connectivity. Also, according to the findings, teachers may collect students' social networks information at the middle of semester to rearrange team membership or suggest different collaborative activities based on social network analysis.

Two directions are proposed for the improvement of future work. *First*, because some of our findings were suggestive and this study included a limited number of participants, any interpretation should be done with caution, and future work in this area is highly recommended. Studies should be conducted with a larger sample size to determine generalizability of the findings. *Second*, future research should compare collaborative and non-collaborative note-taking activities using an experimental research design to better understand students' metacognitive skills in a collaborative setting while using enhanced guided notes. A longitudinal study may be useful to see how the intervention of a collaborative note-taking activity using enhanced guided notes impacts the next level of classes.

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Part A Before We Begin EGN Set 6: *Network Theorems*

Readings

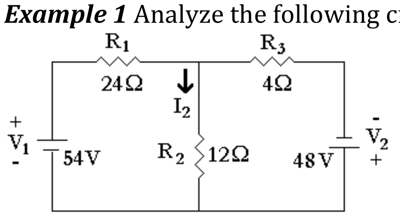
Superposition Theorem- Book Vol. 1, pg. 309-316	Thevenin's Theorem – Book Vol. 1, pg. 316-327

Part B Conceptual Layout

1. Superposition Theorem

Objectives: (1) To analyze networks with two or more sources; and (2) To analyze the impact of each source on the quantity of interest.

Example 1 Analyze the following circuit to calculate I_2.



What theoretical principles or laws do you need to use to solve this problem?

How do you use your theoretical principles or laws?

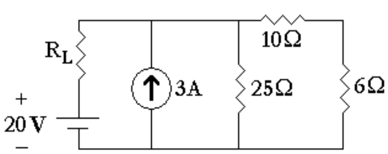
Should you expect to get these answers?

To use superposition theorem, we need to activate one source at a time. Let's activate V_1 and deactivate ___________ by __________________.

Part C Problem Solving

…

Problem 2: Find the simplest equivalent circuit external to R_L



Select and, if possible, sort the use of relevant concepts in this box to solve this problem:

Write your solution below:

Part D Quick Reflections

1. Conclusions

- The main objective of using superposition, Thevenin's, and Norton's theorems is to simplify circuits.
- ……..

2. Self-evaluation

	Statement	My answer
1	When using the superposition theorem on a two-source network, if the current produced by one source is in one direction, while that produced by the other source is in the opposite direction through the same resistor, (a) All voltage sources were not properly converted to current sources. (b) The absolute values of the two currents add algebraically, and the direction is the same as the direction of the larger current. (c) A mistake in the sign of the result occurred. (d) The resulting current is the difference of the two and has the direction of the larger current.	A B C D

Cognitive Pathways to Engineering

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***Abstract*—We collected qualitative data to examine how engineering students' previous experiences, present academic course work, and future goals create cognitive pathways to a career in engineering. Using future time perspective theory as our literature base, we conceptualize cognitive pathways as relationships or links between reconstructed-past, present-active, and imagined-future events that lead to a career in engineering. Our goal is to begin to develop evidence for cognitive linkages between past, present, and future that motivate students to pursue careers in engineering. To gather the data, 21 students were interviewed after they completed a timeline of their lives, consisting of their developmental experiences, present academic work, and their imagined future. We used purposive sampling to recruit participants who are strong engineering students to provide preliminary evidence for what ideal cognitive pathways might look like. The data are being collected as part of a funded "seed" project to conduct exploratory work that can ultimately lead to a well-designed larger project. Here, we present some preliminary results of our analysis, including example case study of a participant timeline. The results are primarily descriptive, and provide a glimpse into our analytic techniques and mixed method approach to the data.**

Keywords—future time perspective, engineering education, growth modeling

I. Introduction

Elan Vital is a philosophical concept originally coined to describe the complexity and self-organizing nature of organisms as they evolve [1]. Translated commonly as "vital impetus," it has been used a number of ways across a wide variety of disciplines. One area where the concept gained a strong foothold is in the study of how people think about time. Minkowski, an early phenomenological psychiatrist who studied among other things schizophrenia, co-opted the phrase to describe the cogency of a person's spatial temporal representation of time [2]. Rappaport, an admirer of Minkowski's work, adopted the principle to advance the study of time perspective, or how a person's spatial temporal representation of time is related to success and overall well-being [3]. For Rappaport, *Elan Vital* is akin to a river of perceived time, where a person's reconstructed past, present experiences, and imagined future flow together seamlessly as one long connected stream. In a nut shell, Rappaport proposed that *Elan Vital* – as defined by a person's perception of time – was central to mental health and well-being. Using a timeline technique he developed, called the Rappaport Time Line (RTL), he spent the majority of his career documenting disturbances in *Elan Vital* in his patients. He found that the ways in which people cognitively represent time along spatial temporal dimensions and how they experience time in certain contexts was related to their mental health and personal success.

II. Project Purpose and Analysis

In the current project, we have attempted to examine *Elan Vital* in a sample of engineering students. We hypothesized that, similar to Rappaport's body of work, successful engineering students would possess *Elan Vital*, and that we could find evidence of cogent cognitive pathways, sprung from developmental experiences and leading to present behaviors and an imagined future, using Rappaport's RTL technique. We used purposeful sampling techniques to recruit senior engineering students who described themselves as hardworking and successful students. All of the students in the initial sample had achieved high GPA's, were involved in an internship in the immediate area, and were graduating at the end of the semester they participated in the study. We focused on mechanical engineering students with interests in energy, and offered them a small incentive to participate in our study. We asked participants to complete a personal timeline of their lives (using Rappaport's protocol), followed by a forty five minute interview where they were asked to describe their timeline and the events they included. All participants were read the following prompt:

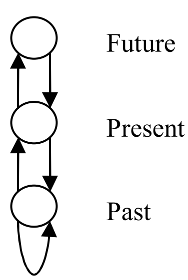
> Imagine this piece of paper represents your entire life, past, present, and future. Please mark any significant life experiences on it. You can organize it however you like. Please include events that have happened, those that are happening, and those that will happen, and indicate an age for each experience. Please include any events, not just those related to engineering.

Then, they were left alone for fifteen or twenty minutes to complete the task. Afterwards, the researcher engaged the participant in a semi-structured interview where the student was asked questions about the various events in their timeline and how they eventually chose to pursue a career in engineering.

We have begun our analysis of the data by focusing on the timelines created by the participants. Specifically, we have documented how far into the past and the future their individual timelines extend, as well as the number and the types of events they identified. We have begun to code the events in the timelines using a protocol we developed in a previous, related study [4]. We have proceeded on a case by case basis, identifying past and future events related to a career in engineering and calculating past and future extension. To produce evidence for *Elan Vital*, we have developed some preliminary differential equations to simulate whether the predicted growth in the number of events in their future in engineering matches the shape of the growth described in the developmental future time perspective literature.

Willy Lens, a future time perspective researcher, using a similar timeline technique, studied how far into the imagined future people tend to extend their future goals [5]. Studying people from across the developmental and social economic spectrum, he found a very stable "inverted U" shaped pattern, where the amount of future time and number of future events one thinks about on a regular basis increases slowly into adulthood and then drops radically. Using the number of engineering events students described in their timelines and the dimensions of their spatial-temporal representations of time, we simulated the growth of engineering student's future engineering events, as well as the predicted growth of their present and past constructions.

For our preliminary growth models of an individual cognitive system, let *dx/dt* represent the growth of events in cognitive space (i.e. past, present, and future); let X equal the number of engineering events listed in the past, present and future, respectively, on the timeline; let b equal the growth rate of the cognitive space (set equal to 1); and let a equal the cognitive limitation placed on engineering events (calculated by subtracting the proportion of the past, present and future devoted to engineering events from 1). We modeled the variables as a complex system, so that future *dx/dt* was determined by the present *dx/dt* and the present *dx/dt* was determined by the past *dx/dt*:



These are the same types of models used to analyze food webs, population growth, and other types of complex systems where system components are interrelated [6].

For our model, we defined three trophic levels, past, present, and future, with past ($X1$) as the primary tropic level and so on:

$$dx_1/dt = X1(b_1 - a_{11}X1 - a_{12}X2)$$

$$dx_2/dt = X2(-b_2 + a_{21}X1 - a_{23}X3)$$

$$dx_3/dt = X3(-b_3 + a_{32}X2)$$

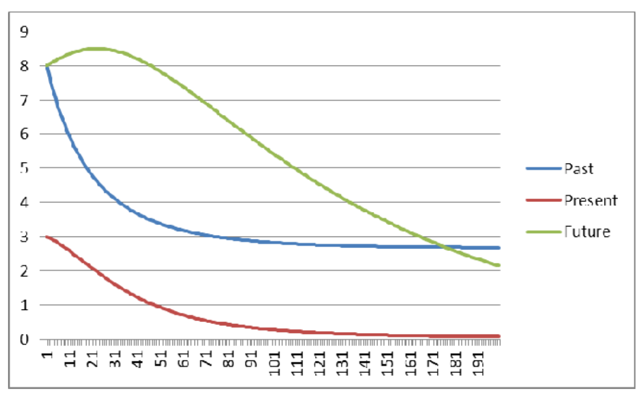
To model our simple three component system for each individual, we used the fill in function of a basic spread sheet and set a very small, arbitrary incremental time step of Δt = .01. In the first row of the first three columns of our spread sheet we entered the initial values for $X1$, $X2$, and $X3$, or the number of engineering events recorded on the timeline for the past, the present, and the future. These acted as our start values. In the second row of cells, we entered our equations, with X+(.01) as a multiplier of the initial X value at all three trophic levels to stimulate growth. The equations were entered for each participant into the spread sheet as such (example model from the study),

=A1+(0.01)*A1*(1-(0.36*A1)-(0.5*B1))

=B2+(0.01)*B2*(-1+(0.36*A1)-(0.38*C1))

=C1+(0.01)*C1*(-1+(0.5*B1))

and then the fill down function was used to simulate growth for 200 iterations of the system. In this example, the participant listed 8 past engineering events, 3 present engineering events, and 8 future engineering events. These were his start values. From the timeline, we determined that 36% of his spatial temporal past was devoted to events not related to his engineering career, 38% of his spatial temporal future was devoted to events other than those related to his engineering career, and 50% of his present events were related to something other than his engineering career. These were entered as cognitive limitations. In our simulation, we were looking to see if, given the individual constraints, the changes in the number of future events overtime matched the "inverted U" shape. In this example, the shape of his projected number of future events matched the shape of the extension describe by Lens et al.



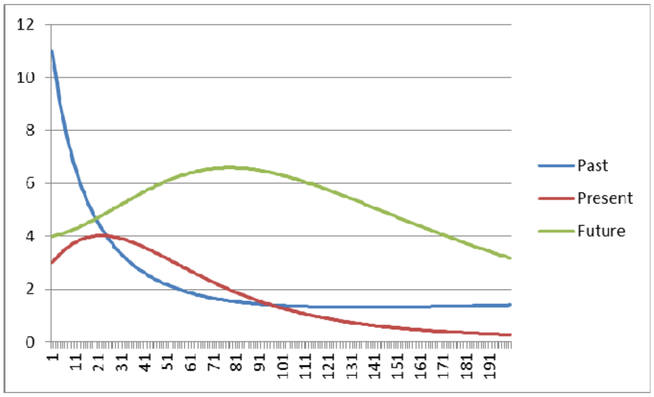
For a comparison, we ran a simulation for a student who was more past oriented. This student listed 14 past events related to her engineering degree, but only 1 in the present and four in the future. However, only 25% of her future events were related to something other than engineering, suggesting an intense focus despite her past orientation. Her model was as follows:

=A1+(0.01)*A1*(1-(0.5*A1)-(0.5*B1))

=B1+(0.01)*B1*(-1+(0.5*A1)-(0.25*C1))

=C1+(0.01)*C1*(-1+(0.5*B1))

And produced the following line graph:



Again, given the characteristics of her timeline, we can see that her projected number of future events, reflective of her extension into her imagined future as an engineer, produces the inverted U shape described by Lens et al. and perhaps she is likely to increase her focus on the future over time as described by future time perspective researchers.

As described by Rappaport, those students who listed positive engineering events in the past and future, and devoted a large portion of their cognitive space to engineering related events produced simulations that matched the "inverted U" shaped described by Lens et al. We believe that these findings can be viewed as very preliminary, but interesting evidence for the power of *Elan Vital* to maintain engineering students' focus on achieving future goals and persisting in the field. Future simulations based on participants with different timeline characteristics will help us to continue to make progress in these types of analyses.

III. Discussion

Our preliminary results suggest that students who possess *Elan Vital* in their timelines may have a better chance of continuing along a typical developmental path when it comes to setting and attaining future goals in an engineering career. Perturbations to the cognitive system, perhaps in the form of counseling or advising, that may help a student to develop a cogent pathway to engineering by reconstructing the past experiences that were important to their development, and using them to construct a cogent pathway into the imagined future, may be an important tool for retaining engineering students through to graduation. In our presentation, we will provide further information about our simulated models, as well as evidence from the narratives and timelines to support our claims.

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Preventing Persistent Misconceptions with First-year Engineering Students

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Abstract—Previous studies on student misconceptions of science and engineering concepts focused on repairing and correcting misconceptions after they have formed. However, it may be too difficult or too late to correct and repair such misconceptions by the time misconceptions have been formed or identified in engineering students. This work-in-progress focuses on a different approach towards treating persistent misconceptions, switching from correcting and repairing persistent misconceptions to preventing those misconceptions from forming.

Keywords—misconception; preventing misconception; conceptual change

I. INTRODUCTION

Misconceptions refer to students' personal conceptions that are different from accepted scientific conceptions [1], [4]. Students come to class with a variety of experience, existing ideas or explanations about some science and engineering concepts that can differ from what is generally accepted by scientists [1], [5]. Reference [6] stated that misconceptions are more than misunderstandings about a concept. Misconceptions are "part of a larger knowledge system that involves many interrelated concepts" (p. 437) and are "extensions of effective knowledge required to function productively within a specific context" (p. 438). Thus the development of misconceptions can be sequential in that once a misconception has been formed it may be further enforced and built upon [7], [8].

There are different kinds of misconceptions. Some misconceptions are due to simple confusion or misunderstanding; some are due to a lack of information or knowledge [9]. These types of misconceptions are relatively easier to treat at the time when they are spotted. However, there are fundamental misconceptions such as diffusion process, which differ from other observable and macro level processes, for instance blood circulation. These misconceptions are due to the differences in the way that some small-scale engineering processes differ from other observable and macro level processes, which are persistent against instruction and remediation [10]. Such misconceptions may also get reinforced through formal instruction or coursework [8]. Effective strategies must be identified and designed to eliminate or prevent misconceptions in order for meaningful learning to occur [1], [11].

II. A SYNERGISTIC APPROACH TO PREVENT PERSISTENT MISCONCEPTIONS

This work-in-progress reports a synergistic approach that utilizes effective instructional design (ID) and the development of mental representations of complex concepts and phenomena in thermo-fluid sciences to help prevent misconceptions. ID is a systematic process to design and develop instruction and learning activities by addressing five "Ws" and one "H", which are why, who, what, where, when, and how to teach [12]. The development of mental representations refers to helping students develop a cognitive mental framework of two scientific processes (emerging and sequential processes) [9] and small-scale complex and difficult concepts. We have carefully analyzed five "Ws" and one "H" of the ID process in this particular context as the foundation of the synergistic approach.

Why? (1) Persistent misconceptions exist among junior and senior engineering students after they have taken related college-level [13] and (2) remedy strategies seemed to be ineffective in repairing some misconceptions of difficult concepts [8], [7]. The prevalent and persistent nature of misconceptions of core engineering concepts presents an issue not only for students' overall learning outcome, but also their retention in engineering majors. Therefore, new effort needs to be targeted towards how to prevent students from forming persistent misconceptions.

Who? We choose to work with first-year engineering students due to (1) the learning impediment or possibility that formal instruction actually reinforces misconceptions [14], [7] and (2) enormous amount of time and resources that have been spent on repairing misconceptions but persistent and

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robust misconceptions still prevail among undergraduate engineering students.

What? Thermo-fluid sciences was selected as the subject domain because misconceptions of such concepts are (1) prevalent among undergraduate engineering students [13]; and (2) persistent against and robust to instruction and remedy interventions [15], [8], [10]. Therefore, thermo-fluid sciences is a good subject candidate for exploration of the proposed synergistic approach to research.

Where? Computer-based learning modules hosted in Moodle (a learning management system) that is very accessible provided to participants. A designated classroom for participants who desire to interact with subject experts while studying learning modules will also be provided to accommodate multiple learning pathways and different learning preferences.

When? Ideally, it seems that in order to prevent persistent misconceptions among undergraduate engineering students and the learning impediment, it is necessary to work with students prior to any instruction on difficult concepts, especially for particularly challenging concepts such as those in heat transfer [16], [8]. Thus, we work with first-year engineering students who have completed basic college-level science and math courses but prior to taking any course related to thermo-fluid sciences.

How (How are we going to teach the What to Who?)? The How includes the selection of instructional strategies, tools, and organization of learning activities to ensure/enhance learning outcomes and experience. After reviewing various strategies for treating misconceptions, we selected and designed three instructional strategies for the design and development of learning materials and learning activities. First, we selected the interactive learning strategy for "teaching" our subject content to bring better learning outcomes [17]. Interactive learning activities in this project refer to student actions with learning materials and technology tools through interactive reflection and inquiry prompts to promote conceptual understanding [18]. Interactive reflection and inquiry prompts ask students to reflect on their learning and describe in their own words about the subject content, providing an opportunity not only for deep understanding but also guided-construction of new knowledge [17].

Second, we will train students in forming mental representations of scientific processes (SPs) (domain-general training) [10], [19]. We will train students on sequential and emergent processes (domain-general training) that have distinct underlying mechanisms in terms of overall interactions among their constituent elements. The domain-general training on two SPs will help students form a cognitive mental structure of emergent processes and provide a special anchor for assimilating and encoding new information while learning difficult concepts [10], [19]. Third, difficult thermo-fluid concepts and phenomena will be explained and described in the language of two scientific processes (SPs) (emergent and sequential processes), especially emergent processes. This strategy is a domain-specific approach and one step further of the domain general training on two SPs. Our "mapping" of difficult concepts with properties of emergent and sequential processes reflects a new effort on learning difficult engineering concepts with the development of students' mental representations of two SPs to prevent misconceptions. The "mapping" further places students in the context of the emergent processes framework to understand difficult concepts as proposed by the National Research Council study of How People Learn [20]. Last but not least, computer simulations will be designed or selected for difficult concepts/phenomena and also help "teach" our subject content. Computer simulations allow students' manipulations of abstract engineering phenomena at small-scale levels and provide them an opportunity to study complex phenomena that are not possible with other tools [21].

Currently, the project training materials including computer simulations for difficult engineering concepts are under development. A group of first year engineering students will be recruited to receive the training in an experimental study after they finish necessary courses in physics, chemistry, biology, and math. The same group of students will be recruited again for a follow up study after they have completed relevant coursework in thermodynamics, fluid mechanics and/or heat transfer. If participants in the experimental group perform better in the follow-up post-test, we can infer they did not have to repair as many misconceptions and the synergistic approach achieved the purpose of preventing persistent misconceptions of difficult engineering concepts.

ACKNOWLEDGEMENT

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Creating an intrinsic-motivation-driven course design method

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***Abstract*— The low-cost intrinsic motivation (IM) course conversion project is an effort to create a new system of course design that focuses on creating scalable and sustainable courses that emphasize promoting students' IM to learn. Unlike many course design methods such as idea-based learning, project- or problem-driven learning, or "flipped" classrooms, which first ask, "How do we help students learn X better," we ask "how do we foster intrinsically-motivated learners who want to learn X?" While this course design method still uses theories of cognition to design course structures, it uses motivational constructs such as purpose, autonomy, relatedness, and competence as the primary design considerations of a course. Secondarily, the course design method considers and documents the financial, time, political, and psychological costs of course design. In this paper, we present a preliminary attempt to formalize this IM-driven course design method as well as a system for evaluating the short- and long-term costs of implementing a specific course design.**

Keywords—intrinsic motivation; course design; learning theory; engagement

I. INTRODUCTION

While course design has historically favored the cognitive outcomes of learning, there is a growing understanding in educational theory that the affective or motivational outcomes of learning moderate the cognitive outcomes as motivational constructs such as self-efficacy beliefs can accelerate how students learn challenging course material and help them persist in learning activities when they fail [1-5]. Concurrently, research on why instructors do not adopt effective teaching practices often cite that instructors are unwilling to overcome the time and financial costs needed to learn and implement new teaching techniques [4, 5]. Further, many instructors who attempt to adopt new teaching methods are often discouraged by students' initial apathy or even hostility toward new teaching methods [4]. In this paper, we present a course design method called the low-cost intrinsic motivation course conversions that maximizes learning by focusing on both student and instructor motivation [6]. While content and techniques are still important, they play complementary or secondary roles to the goal of fostering motivated learners and designing courses that instructors are motivated to teach.

The paper begins with brief backgrounds on motivational theory and course design methods followed by a description of the course design method. The method has three stages: evaluate the current course, create structured spaciousness, and manage the cost of the design. The paper concludes by applying the method to a sophomore level computer engineering course. By creating purpose-rich assessments that provided students with autonomy over their learning objectives, the revised course provided better support for students' intrinsic motivations to learn and increased performance on standard cognitive learning outcomes as compared to an active learning focused design [6].

II. A PRIMER ON MOTIVATIONAL CONSTRUCTS

While any motivation theory can help an instructor better motivate students, we chose Self-Determination Theory (SDT) and its emphasis on psychological needs. SDT describes how the satisfaction of certain psychological needs can shape the orientation and amount of an individual's motivation in a situation or context [7]. This sole focus on needs provides a condense set of constructs that can serve as the quality criteria for a course design method. The orientation of motivation affects the amount and quality of learning and ranges on a continuum from amotivation through extrinsic motivation (receiving rewards such as grades, complying with rules) to intrinsic motivation (deriving from the inherent value of an activity) [2,7]. Table 1 presents four motivational orientations to simplify SDT to a digestible and memorable continuum: amotivation, external regulation, identified regulation, and intrinsic motivation.

TABLE I. FOUR MOTIVATIONAL ORIENTATIONS FROM SELF-DETERMINATION THEORY

Motivational Orientation	Simplified Description
Amotivation	Disengagement from an activity or context (e.g., "I'm not good at math.")
External Regulation	Engagement is regulated by the threat of punishment or promise of reward (e.g., "I need an A.")
Identified Regulation	Engagement is regulated by a desire to achieve internalized values or goals. (e.g., "I hate proofs, but they help me understand the concepts.")
Intrinsic Motivation	Engagement satisfies intrinsic psychological needs. (e.g., "I love solving proofs because I enjoy figuring out why things work.")

Students tend to learn more when they are intrinsically motivated to learn [1,2]. We can support students' motivation

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generally and shift them towards an intrinsic orientation by supporting their senses of Purpose (what I do matters), Autonomy (I am in control), Relatedness (others care about me), and Competence (I can be effective) [7] (PARC needs).

The type of motivation also has a hierarchical structure that varies by time scale or domain [8]. Motivation can be situational (e.g., a homework assignment or a group meeting), contextual (e.g., a semester-long project, a course, or learning engineering), or global (e.g., a person's default motivational orientation). A person's motivational orientation may vary across these three levels in every situation and over time [8]. For example, a student may globally use identified regulation with the goal of self-betterment, but contextually be intrinsically motivated to write a simulation program, but situationally be externally regulated by a deadline simultaneously. As students experience more situations in engineering courses that intrinsically motivate them to learn, these situational motivations can lead to a contextual intrinsic motivation to learn engineering [9]. Conversely, students who are initially intrinsically motivated to learn may become amotivated as they experience amotivating situations [9].

III. Brief Background on Course Design

Research has documented five main categories of course design methods [10]. These course design methods often focus on desired cognitive learning outcomes, careful sequencing of learning activities for optimal learning, or departmental pressures and mandates [10]. Backwards course design, and its successor idea-based learning, was the first course design method and was cognitively focused [11-13]. In idea-based learning, a designer's first objective is to identify a small number of "big ideas" or central concepts that connect the course content (e.g., force and energy in mechanics or equilibrium in fluid mechanics) [11]. These central concepts are broken down into enduring understandings: canonical examples that critically inform how students will think about the concepts [11-12]. Students' enduring understandings are then supported by situational learning activities. The course designer's goal is to create a series of learning activities that spiral around these central concepts by stepping through the enduring understandings with the goal of helping students develop an integrated conceptual framework of the material that leads to deeper learning [11].

Course design methods such as the "flipped classroom" or just-in-time teaching are structured around the cognitive principles of providing rapid feedback; repeated, spaced exposures to content; and opportunities to actively manipulate concepts [14]. A designer may not change the order of topics or the course content, but the method of content delivery is modified so that students are exposed to content outside the classroom and actively engage with content in the classroom.

Course design methods such as problem-based learning and inquiry-based learning focus on a mixture of cognitive and affective outcomes in their design principles [15-17]. A primary critique of traditional course design strategies is that the cognitive skills needed to succeed in the traditional classroom are not the skills needed in authentic tasks in industry or the "real world" [15]. Problem-based and inquiry-based methods in contrast promote the cognitive skills of critical, analytical, or metacognitive thinking by requiring students to engage with more "authentic" learning environments [16]. A secondary goal is that students will be more motivated to learn as they engage in problems that they encounter in the real world with their peers (i.e., increased senses of purpose and relatedness) [15].

Although each of these research-based course design methods can improve students' motivation to learn, most instructors who implement these methods have at best only their intuitions about how to better motivate their students. In other words, the course is designed first to promote certain cognitive outcomes, and promoting students' motivations to learn is considered as a matter for troubleshooting student resistance or amotivation [18]. For example in Hansen's recent book on idea-based learning, students' motivations are only briefly mentioned as part of the development of learners as they become more mature in their learning. [11].

IV. The IM-Course Design Method

The philosophy of the IM-course design method is captured by a central image of structured spaciousness. This image is composed of two complementary palettes that may need to be held in tension. First, the structure of instruction provides objectives that communicate the purpose of instruction and instill the confidence in learners to succeed. Spaciousness conveys a sense of freedom or self-determination, but also the time and place for the cultivation of community and relatedness. With this central image, we present a general framework for creating structured spaciousness.

Following the principle of creating structured spaciousness, this course design method intends to provide structures that guide and embolden the course designer, yet provide spaciousness so that the course design method is not prescriptive. We provide examples as illustrations of the principles rather than as masters to be copied. A course design will be most effective only when the instructors also possess the senses of purpose, autonomy, relatedness, and competence about their courses that undergird their motivation to teach.

The design method is iterative and has three primary steps: A) Evaluate the current course design's support of students' intrinsic motivation, B) create structured spaciousness by generating potential modifications to improve the course design's support of intrinsic motivation, and C) manage the cost of the proposed modifications to inform decisions about which modifications to adopt. After managing the costs, the designer should evaluate the course conversion to determine if the design objectives were met. If not, then additional iterations may be needed.

A. Evaluate the current course design

An evaluation of a course's existing design can provide a point of reference for reimagining the course and assessing the costs of any revisions. To perform this evaluation, the course designer must consider how students in the course would experience the course and how it meets their psychological

PARC needs. For example, the designer could rate the course as providing low, moderate, or high levels of support for each need (see Table 2). After evaluating the course, the designer can use the evaluation to identify opportunities to improve the course's effect on students' motivations to learn. For example, a designer might rate the purpose of the course as low because the homework assignments lack meaningful contexts that connect with students' interests, so the designer might create assignments based on students' expressed interests in taking the course or replace homework with projects.

TABLE II. COURSE EVALUATION GRID: BASED ON SUPPORT OF PSYCHOLOGICAL (PARC) NEEDS FOR MOTIVATION

	Rate the course's support of each need		
Purpose	*Low*	*Moderate*	*High*
I believe that this course is a valuable part of my education			
I find the course's learning objectives to be compelling, useful, and comprehensible			
The course material captures my interest and is relevant to my life			
Autonomy	*Low*	*Moderate*	*High*
I have control over learning goals and content			
I get to develop and use my own learning strategies			
I get to choose deliverables, resources, due dates, teammates, or specify course policies			
Relatedness	*Low*	*Moderate*	*High*
I get to work collaboratively with my peers			
I feel connected to my instructors			
My work has positive impacts on people outside the classroom			
Competence	*Low*	*Moderate*	*High*
I believe I can be successful and achieve the learning goals			
I can engage in challenging and meaningful goals			
I get positive formative feedback on my learning process, not just my performance			

The designer must also evaluate the costs that are incurred by teaching the course in its original form. A more detailed description of cost analysis is provided in the section on cost management. The goal of an IM course conversion, though, is to either maintain or lower the costs required to teach the course. This goal cannot be achieved without careful accounting of the costs of teaching the current course. Identifying high cost components of a course can similarly reveal opportunities for improvement in the course design.

B. *Create structured spaciousness*

Based on the analysis of the original course design, the designer should generate a list of potential modifications for the base course design. These modifications could be major or minor, but at this point in the design process the goal should be focused on imagining idealistic designs regardless of their feasibility. While the designer's ideals may not be realizable, identifying these ideals is critical for creating a sense of aspiration or stronger sense of purpose in the design process. This stronger sense of purpose is critical during the cost negotiation phase which requires critical evaluation of the ideas and a priority structure for decision making. For example, in one course, the designer wanted to focus on developing students' collaborative problem solving skills, but was required to administer a final examination. While the ideal summative feedback was identified to be a final project completed in teams, this option became untenable. However, the identification of this ideal informed the structure of the final examination, which became more design focused and required students to create smaller components of a bigger system as if they were working in teams.

Further, the designer is also encouraged to borrow or use principles of course design from other course design methods. However, the evaluation of these methods will be based on motivational rather than cognitive outcomes. For example, the designer can use problem-based learning techniques to better support students' sense of purpose.

To facilitate ideation around modifications, we use our image of structured spaciousness to guide the ideation process.

1) *Identify a strategic core (Creating structure)*

From both the motivational and cognitive perspectives [11], the designer needs to determine a narrow strategic core of goals, outcomes, and/or objectives of the course. From the perspective of IM course design, the focus for identifying a strategic core is primarily to enhance the students' sense of purpose in taking the course. In other words, the focus is on *why* certain concepts and skills are important and not simply on what should be on the list of possibly important concepts or skills. Identifying a strategic core secondarily provides a decision-making framework for determining which activities or content are negotiable or non-negotiable for the students. Without a strategic core, the course can easily become bloated, overwhelming students with excess content. Alternatively, the purpose of the course can become diluted, and students fail to understand why the course is valuable or important.

A narrowly defined strategic core can also improve students' sense of competence by creating a manageable list of course goals. If the designer can reduce the course goals to two or three strategic objectives, students can develop a better sense of what they need to master to be successful, which in turn can increase their sense of competence. Further, a strategic core can reveal what assessment activities to include in the course and provide stronger rationales for them, thereby helping students feel that they are receiving the feedback that they need to succeed.

The identification of a strategic core can lead in many directions that depend on how the course fits within its broader curriculum; a first-year course which serves as the gateway to the discipline will have a different type of core from an upper-level technical course. For gateway courses, the purpose of the course may lean more towards helping students understand the value and nature of the discipline or helping the students to better understand the expectations of the discipline. For technical courses, promoting purpose and competence can often be achieved by narrowing the focus of the course to a few core concepts or skills that will be critical to the students' later success. Purpose can also be promoted by providing opportunities that intersect with students' broader interests or that demonstrate the usefulness of the course material.

As mentioned earlier, we encourage designers to identify the ideal forms of feedback and assessment that they believe would best support students' sense of competence and reinforce the purpose of the course. A discussion of feedback methods is beyond the scope of this paper, but there is an abundance of literature on effective feedback techniques (e.g., [19]). For example, the use of rubrics can support purpose and competence by specifying what students are expected to do and learn [20].

As an example of redefining the strategic core, a sophomore-level technical course was originally defined by a week-by-week list of topics that was incomprehensible to the incoming student and lacked a week-to-week cohesion between the topics. This lack of cohesion diluted the purpose of the course and many students delayed taking the course for as long as possible because they did not understand why the course was useful. To refine this course, we identified the conceptual core "big ideas" as prescribed by idea-based learning [21]. Identifying the core big ideas empowered the instructors to cut the number of topics covered by the course in half and to provide a greater sense of purpose to the course. The course objectives now consist of three core big ideas and choices for students to explore how those big ideas are used in practice. In accordance, course assignments and feedback changed to help students better achieve mastery of these three big ideas. For example, the instructors and teaching assistants (TAs) now create a menu of short projects that demonstrate how the core concepts apply to different sub-disciplines [6, 22]. Students complete these projects during the first five weeks of the semester. The instructors and TAs each become a supervisor for the project that they find to be most interesting (e.g., a TA researching sensors would likely choose to supervise projects related to sensors). Similarly, the students choose one project that they find most interesting. By pairing students with instructors based on interests, we found that the instructors and TAs were more eager to provide feedback to the student project teams, improving course performance and the course climate's support of the students' intrinsic motivation to learn [6, 22].

Identifying a strategic core may provide a tertiary benefit by lowering the psychological tolls assessed when engaging instructors who are normally resistant to pedagogical change or reform. For many instructors, their sense of competence may be based on their sense of expertise and knowledge of the course material. If a reformer begins the conversation about change with an instructor by addressing pedagogy first rather than content, the reformer is situated as the expert rather than the instructor. This power structure can be demotivating for the instructor who may seek to maintain their sense of competence in content rather than engage in their lack of competence in pedagogy. With careful engagement about the content, these instructors gain increased autonomy to make changes and reconsider the structure of a course, thereby increasing their motivation for change. The reformer's goal is then to nudge and guide the application of the instructor's motivation.

2) Designing supportive spaciousness

From the perspective of SDT, an instructor's level of autonomy supportiveness is the most critical aspect of promoting students' intrinsic motivation to learn [23-26]. Autonomy supportiveness can be derived situationally from the instructor's attitudes and actions during instruction or contextually from the course design and the cumulative effect of the instructor's attitudes and actions [24]. Different course designs can facilitate or discourage an instructor's use of autonomy-supportive behaviors [24-26], so the designer must carefully construct spaciousness in the course to facilitate the instructors' use of autonomy-supportive behaviors. Designers can create this spaciousness in the course design by intentionally giving students control over course policies, choices in content coverage or deliverables, or using inquiry-based course designs that are driven by students' questions.

In conjunction with creating spacious course structures, instructors must also consider how they interact with students and reformers must help instructors identify and value autonomy-supportive behaviors. For example, autonomy-supportive instructors spend more time listening, articulate fewer directives, ask more questions about what the student wants, verbalize fewer solutions to problems, make more empathetic statements, and offer greater support for students' internalization of learning goals (e.g., providing more rationale for why an assignment should be accomplished or for the value of the learning goals) [25-26].

Similarly, the designer can use their initial evaluation of the course to reveal opportunities to promote students' sense relatedness. For example, students' sense of relatedness with their peers can be promoted through the use of team-based learning techniques. While a review of effective team-based learning techniques is beyond the scope of this paper, instructors can use the principles of SDT to provide some guidance on how to promote positive team environments. For example, instructors need to help students develop their sense of purpose in their teams. Instructors can help students internalize the importance of learning in teams, help structure teams around a common interest or purpose, or help students identify complementary roles in their teams in order to create good teams which in turn promote students' sense of relatedness. Since relatedness can take time to form, the designer must craft the space for this relatedness to grow.

C. Manage the costs of potential course designs

In order to evaluate the cost of an innovation or to determine how to best minimize the costs of an innovation, there needs to be an accounting of the resources available to, and costs incurred by, the course.

1) Costs of reform and course design

In our efforts to reform courses, we have identified four major costs that act as barriers to change for instructors: time sinks, financial costs, psychological tolls, and political taxes. While the barriers of time, money, and politics (tenure and promotion) are often well documented [5], the psychological tolls are rarely formally discussed in the literature.

Time sinks (e.g., grading, lecture preparation, course management, etc.) reduce the likelihood that a future instructor will adopt a similar teaching method. Financial costs can constrain the design and analysis tools available to students or restrict hiring additional teaching assistants. Political taxes can restrict what types of innovations will be acceptable to a department. Finally, psychological tolls can reduce an instructor's willingness to try new techniques. The psychological tolls of an innovation are particularly critical to address since they are also best addressed by understanding motivation and other affective orientations of the instructors. By addressing an instructors' understanding of their own motivation, it may help them better understand how to address their students' motivations. The remainder of this subsection is anecdotal from our experiences in executing education reform, but also develops from critical reflection of theory in practice.

To better understand the nature of psychological tolls, let's discuss common barriers to adoption from the perspective of the needs outlined by SDT.

Purpose-barriers: Many instructors refuse to adopt new pedagogies, because the effort required to make the change does not fit within their value system. Perhaps the instructor does not believe that teaching is valued. Perhaps the instructor does not value the proposed outcomes of the teaching method. Perhaps the instructor does not believe that a teaching method is so much better that it justifies the increased financial or time costs. Instructors with this barrier may benefit from journal articles and cognitive arguments, but they may also need to believe that a specific teaching method is beneficial to themselves and not just the students. Discussions of cost-benefit analysis or appeals to intellectual stimulation may prove more successful than evidence of effectiveness.

Autonomy-barriers: Many instructors are threatened by giving students autonomy because they then feel a loss of control and a loss of their own autonomy. In the presence of this loss of control, many instructors may perceive a course as a failure despite its successes. For example, letting students wrestle with core concepts in groups without direct supervision (high autonomy for students) can feel like a failure if the students do not get the right answer during that group work. For many instructors, they feel that instruction has only been successful if the students report the right answer with affirmation from an expert (low autonomy for students). This desire for control can persuade many instructors that many active learning or inquiry-based learning techniques are ineffective, despite any evidence to the contrary. The concept of structure spaciousness may be valuable in helping instructors redefine their sense of control and autonomy. Instructors can feel a greater sense of autonomy when they better understand where and when they are choosing to delegate control to their students and what types of control benefit learning.

Competence-barriers: When attempting to use a new teaching method, an instructor's sense of competence can easily be lowered by the unfamiliar. Early failures in attempts with new teaching methods can further lower the sense of competency. An instructor who has tried and failed may not need to be convinced of the efficacy of a method, but rather may need better support structures, mentoring, or simply a positive experience with a pedagogy.

Relatedness-barriers: Students often resist pedagogies that differ too much from their expectations and create an adversarial environment. Instructors can easily be deterred by negative student feedback as it can erode their sense of relatedness with their students. Instructors can also feel a depleted sense of relatedness if they are isolated in their attempts to adopt new pedagogies. Without a community of supportive colleagues, the aforementioned losses of competence or autonomy cannot be offset by a strong sense of communal values and support. This barrier can be addressed by fostering supportive instructor communities or bolstering an instructor's sense of competence so that criticisms are not as damaging.

Knowing how to address an instructor's concerns and objections requires careful noticing of, listening to, and questioning of assumptions, experiences, and beliefs. Alternatively, instructors must critically reflect on their objections to better understand how their motivations may be directing their cognitive decisions and processes.

Finally, costs can be short-term or long-term. For example, generation of video lectures might be a high short-term cost of video production and have low long-term costs of hosting the videos. In contrast, assigning written homework assignments from a textbook might have a low short-term cost of selecting problems and incur a high long-term cost of grading. High short-term costs can block initial adoption of a pedagogy, and high long-term costs can block the sustainability of a pedagogy after initial champions stop paying for those costs.

2) Resource identification and generation

The course designer needs to identify what resources are available to the course and how those resources are being used in order to develop a strategy for how to offset the long-term and short-term costs of an innovation. A low-cost IM course conversion creates change to the course through a mechanism of deliberate cost-swapping.

It is best to invest in short-term costs when those short-term costs can lower the long-term costs of teaching a course. For example, investing in the creation of video lectures, online grading systems, and problem solving activities for a flipped classroom has a high short term cost, but it can potentially lower long-term costs as the entire course becomes scripted, the instructors no longer need to prepare lectures, and fewer assignments need to be manually graded.

Cost swapping can also take the form of exchanging costs of the same type. For example, changing course content or using drastically different pedagogies from a departmental norm can incur high political taxes and resistance. To offset this tax, our reform efforts tend to focus on the large enrollment required courses that few, if any, instructors want to teach. While some political systems might dislike our pedagogies, other political systems gratefully accept our help with these understaffed and poorly rated courses.

Finally, course designers should also consider how any high costs can be distributed among the students. Students can contribute to an IM course conversion by deciding content (e.g., finding interesting real-world examples), creating course materials (e.g., homework assignments, video lectures, etc.), content delivery (e.g., collaborative creation of wikis), and formative and summative assessment (e.g., peer review) [27]. By carefully distributing some of the cost of reform among the students, the course design can further support students' purpose, autonomy, relatedness, and competence, fostering their intrinsic motivation to learn [27]. In perhaps a best possible scenario, intrinsically motivated students can become the engine that drives education reform rather than the instructors. We have seen hints of this new engine forming in our efforts as students who experienced an IM course conversion have returned to help teach the course for free as peer mentors, others have filmed video lectures, and still others are developing online auto-grading tools.

As the designer manages the costs of different course modifications, the modifications will change and present new costs or new resources. Consequently, the evaluation and decision process must necessarily be iterative. After the design, costs, and resources of the modifications stabilizes, the designers should evaluate and compare the costs and IM support of the different proposed modifications. The final course design should reflect a balance between strong support of students' IM to learn, yet with low costs to the instructors and institution.

V. An Example IM Course Conversion Process

In this section, we conclude by providing an example of how this course design method was used to perform a low-cost IM course conversion on a large enrollment course that focused on technical computer engineering skills during the sophomore year.

Every semester, the course enrolled 200-250 students. The students would attend two lectures and one discussion section (~30 students per section) per week. Prior to the course conversion, students would complete a weekly battery of online homework problems and then a written homework problem set. Students would also complete seven prescriptive laboratory exercises over the semester and two or three midterm examinations depending on instructor preference. The course culminated with a comprehensive final examination.

A. Evaluating the current course design

The initial evaluation of the course revealed that the weekly homework problem sets created one of the greatest hindrances to students' motivation to learn and highest costs to the course.

1) Evaluating support of PARC needs

Written homework problem sets typically contained four to eight problems assigned after a week of instruction on the topics. Students were given a week to complete the assignment, and then students would receive their graded problem sets at least a week after turning it in. The problem sets often used rote, context-less problems (low purpose). All students completed the same assignments (low autonomy). Students were required to submit their assignments independently (low relatedness). Because it would take on average of three weeks for students to receive feedback, student rarely read the TA's comments and the feedback did not provide students with feedback on how to adjust their learning strategies (low competence). Finally, the large enrollment and impersonal nature of the problem sets led to rampant cheating (low relatedness and competence).

2) Evaluating course costs

The course employed a cohort of TAs to help with the course for a total of 80 hours per week of which an estimated 64 of those hours were spent grading. The remaining TA hours were divided between instructing discussion sections, office hours, and staff meetings. Due to this high grading load, the course also needed to hire undergraduate graders to lighten the grading load on the TAs so that they could engage in their other course duties. New problem sets were written each semester in an attempt to combat cheating.

B. Creating structured spaciousness

Because grading consumed so many resources and students were not receiving effective feedback, we focused on changing the mechanism for feedback on the homework assignments. We created a construct called the weekly consultation meeting. The weekly consultation meeting took place the week after students were introduced to the course material, shortening the feedback cycle (high competence). During the weekly consultation meeting, the TAs met with teams of five students for an hour to discuss the homework assignment (high relatedness) and address students' personal difficulties (high competence). Students received 50% of the homework grade for bringing a completed homework assignment and could earn the remaining 50% by contributing meaningfully to the group discussion about the assignment (high relatedness). Further, we added a menu of challenge problems to the homework assignments which were based on various real-world design problems that highlighted how the course material was relevant (moderate purpose). Students picked one challenge problem from the menu to solve based on their interests (moderate autonomy).

As a byproduct, the emphasis on oral discussion of the problem sets virtually eliminated the cheating problem in the course as writing down the correct answer was no longer sufficient for full credit. Rather than coming to the consultation meetings with copied answers, students would come with targeted questions.

C. Managing the costs of potential course designs

We made this modification low cost by swapping the time intensive process of grading for a similarly time intensive process of weekly consultation meetings. With 250 students in the course and five student teams, the TAs needed to spend 50 hours per week providing feedback to students on their homework assignments. With this reduction from 64 hours of grading, we also no longer needed to hire an undergraduate grader to support the course, and thus reduced the financial cost of the course as well. Changing the TAs' duties also incurred low political taxes and psychological tolls. Since most TAs had never taught with different pedagogies, they did not resist the new grading paradigm.

We also maintained a lower time cost to the modification by not requiring the primary course instructors to change their preferred lecture delivery methods. Further, allowing the instructors to continue teaching with familiar methods also reduced the political tax and psychological toll of the innovation.

Iterations on the design method revealed additional opportunities to increase students' sense of purpose and autonomy in the course. The weekly consultation meetings created the time and place to infuse student-led project-based learning in the course. Since students had weekly team meetings with course staff, they could work with these same teams on extended, purpose-driven projects in lieu of midterm examinations. At the beginning of the semester, students were given a choice of projects to complete and were organized into teams based on their expressed interest in different projects (high purpose, high autonomy, and high relatedness). This switch to projects created a new short-term cost of creating rubrics and project ideas, and this cost was swapped with the long-term cost of writing and grading examinations.

As we demonstrate in other publications [6, 22], this deliberate cost swapping method created a low-cost innovation which better supported students' intrinsic motivation to learn as indicated by the Learning Climate Questionnaire. Climate scores rose from five points out of seven on a Likert scale to six points [22]. The course conversion additionally improved students' cognitive outcomes and conceptual learning as students' learning gains as indicated by a concept inventory revealed that students' conceptual understanding improved to 50% learning gains as compared to 25% learning gains in previous offerings of the course [22].

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Expectations and Realities for Community College Engineering Transfers at a Large University

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Abstract—**This paper is focused on identifying the factors that worry potential and new transfer students in engineering. Special efforts to help students transfer smoothly into engineering and computer science have been in place since 2002 at Arizona State University (ASU) through an Academic Success and Professional Development class and a Motivated Engineering Transfer Student (METS) Center. During this time, we have become aware that transfer students come to a university with certain expectations and preconceived ideas, some which are true and some which are not. In addition, many transfer students are not aware of some of the realities they will face as a transfer. In order to check on what the actual expectations and realities are for transfer students, we surveyed 120 transfer students who were enrolled in the Academic Success Class during Fall 2012. The top six expectations were reality over which the transfer students had little control: higher tuition, some very large classes, expensive parking, a large campus, a long commute, and difficulty in parking. These expectations were followed closely by several factors to which the students had some control: GPA shock, a faster pace of classes, feeling like a freshman all over again, and not knowing where resources are. The top four expectations upon transferring were the same as the top four realities, although in a different order. For half of the students, the fifth most prevalent reality was that the METS Center helped in their transfer. The next most frequent realities were that the pace of classes was faster and that classes had more assigned homework than they had at the community college. We also examined gender differences. We detail what we are doing to help transfer students with these realities.**

We will use the data in this paper to inform potential and new transfer students and to help them plan for success. Even though much of this knowledge may be well known, a new transfer often does not believe that the challenges will affect him. By using the results of this study, at this university, the facts are more believable. We encourage others working with transfer students to become familiar with the expectations and realities of their own transfer students in order to help them be successful.

Keywords-intentional advising, recruitment, retention, survey, transfer expectations, transfer shock

I. INTRODUCTION

Two major factors are responsible for the recent increased interest in community colleges as a source for more engineers in the U.S. First, due to economic, health, and environmental concerns, President Obama has called for an increase in at least 10,000 engineering graduates per year in the US. [1] Secondly, due to the recent economic down turn, it is more difficult for students to be able to afford the rising tuition of both private and public universities. The community college then is a largely untapped resource for additional engineering students, especially for females and underrepresented minority students, and also offers a much more affordable education for the first two years of college.

In order to graduate more transfer engineering students from four-year institutions, we need to have more students at the two-year institutions choose engineering and the right policies and programs need to be in place. [2] Students at the community college (CC) need to be encouraged, motivated, mentored, and supported to choose an engineering degree and to transfer to a four-year college. Often both academic and financial support are needed. We can begin to understand how difficult this task is for engineering when we consider that for all majors, nearly 60% of students entering four-year institutions earn a bachelor's degree in six years, but only 31 percent of public CC students go on to complete either an associate or a bachelor's degree in six years according to U.S. Education Department data. The U.S. Education Department further reports that only 26% of U.S. CC students transfer to four-year institutions.[2] This percentage is even smaller for underrepresented students.

Getting CC students to be aware of engineering and to consider it as a major is a topic all in itself. We were surprised to learn several years ago when we first started to visit five non-metropolitan CCs, that we were the first engineering faculty and staff to set foot on their campus and talk to students about the excitement and opportunities available in an engineering career. We know that a captive audience in a classroom is the best way to communicate with non-metropolitan CC students. We continue to do research on the best ways to interest more students in engineering. [3-5]The literature on "promising practices for community college student success" include many good programs that work both at the CC and at the four-year transfer institution. [6] For example, while the CC needs to have an emphasis on the first year experience, the four year institutions need to have an emphasis on the first transfer semester (as well as their first year native students).

In this paper we want to identify the particular factors that concern potential transfer students and the actual realities that they face after they transfer to Arizona State University (ASU) in engineering and computer science. Henceforth, unless otherwise noted, the term "engineering" shall include computer science.

There are many policies and programs that can ease the transfer process in general for community college students. A first step is having a transfer equivalency guide so that students at a CC will know which courses will transfer to a particular four-year college. The state of Arizona has a state-wide equivalency guide between its three universities and 21 CCs. In addition, an engineering student needs to know which CC courses will count toward their particular major at their intended transfer university. "METS (Motivated Engineering Transfer Students) Pathways" will soon be in place to do just this at Arizona State University and five targeted Arizona non-metropolitan CCs who have been partnering for the past four years.[6]

A second step in this process for potential transfer students is for there to be a supportive, academic environment at the CC to be encouraging the CC students, to answer their questions, to help make sure that they are making timely steps toward transfer. There several good sources of material on how to best do this including "A Matter of Degrees: Promising Practices for Community College Student Success" which discusses the planning for success, initiating success, and sustaining success.[7] CCs and universities need to have knowledgeable advisors to assist with transfer and orientation sessions at both institutions and should include information on transfers. [8]

The third step is the actual transfer and first semester at the four-year school. This process is so well known for being difficult that it has its own name: "transfer shock." The term "transfer shock" was coined by John R. Hills of the University System of Georgia in 1965. [9] The term grew out of the discussions on whether a community college transfer student does as well as a native student in their studies. The term generally refers to GPA shock and the fact that, in general, transfer students suffer about .5 grade drop during their first semester of transfer relative to their average GPA at the CC. Forty-five years later, the term is still active. However, new transfer students generally go through many "shocking" things when they transfer in addition to a drop in grades. [10]

There are several things that the four-year school can do to ease the transition. We make visits to the CCs and encourage the CC students to start talking to the academic advisors at ASU long before they actually transfer. Sometimes taking a course the summer before the fall transfer can save a semester later in a series of courses that need to be taken. Potential transfer students are encouraged to apply by January if they expect to transfer in the fall or the spring semester after, in order to be eligible for scholarships which have a February 1 deadline. A time flow chart is given to the students with important check points in a transfer, as well as contact numbers for ASU advisors and financial aid. Students are warned to not take all of their courses on two days so they can work the other three. The students are offered the assistance of an ASU mentor, but few students take advantage of this support. Potential transfer students are invited to come to a transfer orientation in the METS Center to meet the staff, have a tour of the engineering buildings, and to meet and talk with students who have transferred from their CC. It is helpful for a potential student to know that others have transferred from their CC and are doing well.

A fourth step for a successful transfer student is to have a continuing supportive and encouraging environment with available help for problems they may encounter and need assistance with. This step is covered with our academic scholarship programs and a two semester hour credit class, Academic Success and Professional Development. This program has been explained in other papers. [11-14] Donna O. Johnson's "4.0 Plan" is used for academic support. [15] Our program follows Tinto's four major components needed for college retention: high expectations, support (academic, social, and, perhaps, financial), assessment with frequent feedback, and involvement. [16]

Special efforts to help students transfer smoothly into engineering in the Ira A. Fulton Schools of Engineering have been in place since 2002 at ASU. Visiting the CCs; hosting open houses for potential transfer students; providing a METS Center for transfer students to study, network, use a computer, have free printing, and ask questions; and offering an Academic Success and Professional Development course are all done to smooth the transition process. After transfer, the students are given tools and encouragement to help them graduate and go right on to graduate school. The program has been successful: 95% of upper division transfer scholarship students graduate (vs. 70% for men and 64% for women upper division transfers, in general) and over 50% go to graduate school versus less than 20% in the nation.

This paper is focused on identifying the factors that worry potential and new transfer students in engineering. We surveyed the 133 transfer students enrolled in the fall 2012 FSE 394 Class, "Academic Success and Professional Development. The class had one hour credit which counted in the GPA, but not the program of study. An on-line survey asked the students questions about their anticipated fears regarding their ASU transfer, as well as their actual problems encountered after transfer. By analyzing these responses, we try will try to improve ways in which we can help solve some of the angst or at least warn the students and give help for dealing with the challenges. Hopefully by knowing that this is recent data at ASU, the students will understand that they may face the same problems.

II. THE SURVEY

During the fall 2012 semester, 120 of the 133 (90%) transfer students in the FSE 394 Academic Success and Professional Development class completed an on-line survey. This survey is similar to a survey given in 2007 [13] and the same as a survey given in 2010 [14]. These surveys were to smaller groups of transfer students. We wanted to know if a larger group of transfer students would give a different picture of transfer or if there were any noticeable changes in the perception of the transfer process during the past few years. The students were asked what their expectations and fears were upon transferring and what the reality was of their first semester at ASU. The students were asked to check all answers that applied in each case and to add any other situations that applied.

The expectation results of the survey are given in Table I. The percentages of females and males citing each expectation were compared for statistical significance. There were four differences between the females and the males with regard to their expectations. The most pronounced difference was that females expected more than males that the class pace would be much faster (p=.042). There are two areas which show a slight difference. The long commute was more worrisome to females than males (p=.092) and the females were also more concerned than males about the difficulty of parking (p=.092). A slight difference (p=.145) in genders is noted with respect to tuition. A higher percentage of males than females noted that transferring would mean a higher tuition.

Next we look at the realities of the first semester transfer to ASU. These results are shown by gender in Table II. By the percentages of either female or male students reporting, we can see that many of the expectations of transfer became reality. Eight areas were named as realities for over 50% of the females, while only four of the areas were selected by over 50% of the males. If we consider the top eight realities percentage-wise for each gender, we see that the females and males agree on the top four realities and seven of the first eight, although not exactly in the same order. The expections are that the females ranked "overwhelmed with classes/logistics" as tied for number 6, while the males ranked this 13th. On the other hand, males ranked "pace of classes is much faster" 5th, while females ranked it tied for 10th.

There were four areas which were statistically more significant (p<.05) for females than males These areas are: overwhelmed with classes and logistics, classes are harder than expected, lonely (don't know anyone in class), and too many credits hours or too much work. There are four additional areas where the genders differed percentage-wise by .05<p.10. One transfer reality, "worked too much to do well academically" was more prevalent for males (p=.063). The other three areas were more prevalent for females: all of the easy classes taken (p=.057), did not spend much time on campus (p=.066), and easy classes taken, upper division classes are harder (p=.083). Two additional areas are slightly significant with .10<p<.15. One, "hard to get into study groups" (p=.111) was more worrisome for females. The second, "higher tuition" was mentioned by more males (p=.145).

Table I. Expectations of Transferring to ASU

Expectations of Transfer to ASU				
Reason	Females %/Rank n = 24		Males %/Rank n = 96	
**Expensive parking	75	1	56	3
Some classes very large	71	2	57	2
Higher tuition	67	4	82	1
**Long commute	67	4	47	6
*ASU large	67	4	49	4.5
*Class pace much faster	63	6.5	45	8
Difficulty parking	63	6.5	46	7
Transfer GPA may drop	50	8	49	4.5
Lonely (don't know anyone)	38	9	31	10
Easy classes all taken	33	10.5	23	12
Resources locations unknown	33	10.5	28	11
*More assigned HW	29	12	22	13
Feel like freshman again	25	13	39	9
Had friend who would help	4	14	4	14

*** p<.05, **.05<p<.11, *.11<p<..17

Additional expectations:

- Female: Thought I would be disoriented
- Female: Teachers don't care as much and office hours are terrible
- Female: More PPT slides
- Female: Less professor extemporaneous lectures
- Female: Isolated and I would fail all my classes with no one to study with
- Female: Had a friend who would help me

- Male: I may not have the focus or motivation as other University students
- Male: Not finding a good apartment
- Male: Paying tuition

Table II. Realities of Transfer to ASU

Reason	Female Rank/% n = 24		Male Rank/% n = 96	
***Higher tuition	2	67	1	82.8
Expensive parking	2	67	3	57.5
Some classes very large	2	67	2	58.6
ASU is large	4.5	63	4	55.2
METS Center helped	4.5	63	6	47.1
Long commute	6	58	8	41.4
*Ovewrwhelmed with classes/logistics	7.5	54	13	28.7
Difficulty parking	7.5	54	7	42.5
Pace of classes is much faster	9.5	50	5	48.3
Classes have more assigned HW	9.5	50	10	37.9
Classes are harder than expected	12	46	12	33.3
Hard to get into study groups	12	46	15.5	24.1
Lonely (don't know anyone in class)	12	46	18	19.5
**Too many credit hours/too much work	14.5	42	22	13.8
***Easy classses taken, UD classes harder	14.5	42	19	18.4
Did not spend much time on campus	18	38	20	17.2
Had a friend/mentor	18	38	15.5	24.1
Transfer GPA may drop	18	38	9	39.1
**All easy classes taken	18	38	19	18.4
Hard to get to know professors	18	38	11	35.6
Feel like a freshman	21	33	15.5	24.1
Don't know where resources are	22	29	15.5	24.1
Lost	23.5	17	23.5	12.6
No problems	23.5	17	25	4.6
Worked too much to do well academically	25	8	21	16.1

***p<.05, **.05<p<.10, *.10<p<..18

Additional realities noted by the students:

- Female: I am looking forward to doing better. I learned how to network with other students. I met a lot of students at METS
- Female: It's not as bad as I thought
- Female: Tenured profs love PowerPoint
- Male: Family related
- Male: I did really well
- Male: Many resources don't really help
- Male: Requires much more responsibility on the part of the student in order to succeed. Teachers do not baby you through a course.

These comments are thoughtful reactions to transferring and will be included in the next survey. More research is needed to understand what "resources" did not help.

III. Analysis

Top expectations and realities for transferring from a CC to a university were the same, in general, for both females and males. However, since inequities for women are often slight, we look at the main differences in transfer expectations and realities for females and males. Table III gives the main differences and their significant value.

Table III. Significant transfer expectation differences by gender

Expectation	P-value	Fisher exact
**Expensive parking	.066	.108
**Long commute	.069	.110
*ASU is large	.104	.170
*Pace of classes is much faster	.111	.170
*Classes have more homework	.115	.121

*** p<.05, **.05<p<.11, *.11<p<..17

In all five of the significant transfer expectation differences by gender, a higher percentage of females expected to encounter the event than did percentage of males. Expensive parking was expected by 75% of the females and only 56% of the males. The long commute was expected by 67% of the females and 47% of the males. The class pace was expected to be much faster by 63% of the females and only 45% of the males. A higher percentage of females (29%) than males (22%) expected the university classes to have more homework. We are using .11<p<.17 to note that this characteristic may indicate a trend that females have more concerns in these areas than males. However this higher expectation could also mean that females are more prepared to encounter these events at ASU.

Table IV lists the primary differences by gender in regard to the realities that the students faced after they had transferred to ASU. All of the significant differences are due to the females noting an event at a higher percentage than males, except for the first reality, higher tuition. In this case, 90% of the males noted the higher tuition, but only 67% of the females.

Table IV. Significant transfer reality differences by gender

Reality	P-value	Fisher exact
***Higher tuition	.023	.009
*** UD classes are harder	.044	.034
**Took too many credit hours to do well or due to work	.070	.067
**All of the easy classes already taken (non-engr.)	.078	.059
*Overwhelmed with classes/logistics	.167	.174

***p<.05, **.05<p<.10, *.10<p<..18

Forty-two percent of the females found that upper division classes are harder than lower division classes, while this was true for only 25% of the males. Similarly, 42% of the females said that they were taking too many credits relative to their work load, while only 22% of the males said so. A higher percentage of females (38%) noted that all of their easy (non-engineering-related) classes had been taken relative to only 24% of the males. While 39% of the males were overwhelmed with classes and logistics, 54% of the females were overwhelmed. These differences may be some indication that female transfer students have a more difficult time adjusting to the transfer.

It is interesting to also check if any of the realities were either more or less a factor for students than the expected. If we use a pairwise test to see if the number of females who selected an event as expected is the same as the number of females who selected that event as reality, there is no significant difference as a whole. There are, however, a few differences that are worth noting. On the other hand, with a p-value = .012, there is a difference between the percentages of men selecting the events as expected or as reality. We note the major differences in Table V.

Table V. Noted differences between expectation and reality

Event	Expectation #	Reality #
Females: Have a friend/mentor	1	9
More assigned homework	7	12
GPA may drop for transfer	12	9
Pace of classes is much faster	15	12
Males: Had a friend/mentor	4	29
More assigned homework	21	43
ASU is large	47	64
Pace of classes is much faster	43	52

Interestingly, the females and males share three events where reality seemed to be somewhat different than expectations. The largest difference for all of the students was that more of the students had a friend/mentor to help them than had expected to have one. More females and males found that there was much more homework assigned in classes at the university than had expected this before transferring. More females expected there to be a drop in their GPA than actually experienced this. More males found ASU to be very large than had anticipated this as a factor before they transferred. Both females and males found the reality of the pace of ASU classes to be somewhat different than they expected, however less females found this to be a reality, while more males found it to be so. Perhaps females had a more realistic view of university classes or had overestimated the actual pace of the classes before they transferred.

IV. DISCUSSION

Six of the top 8 expectations/fears of transfer by both females and males are all realties of the largest university in the nation with over 73,000 students and the largest single campus in the nation with over 53,000 students. These items are: higher tuition, expensive parking, large classes, a large campus, a long commute, and difficulty parking. It is a fact that the tuition at CCs is much lower than the tuition at four-year schools and universities. There is a wide range of tuitions among public and private institutions. ASU, as a public Research I university, actually has one of the lower tuitions in the nation and has been touted as a good bargain for schooling. However, Arizona is a leading state in the nation for a low percentage of families being able to afford tuition for their children. [17] An estimated over 90% of the transfer students that come to ASU have unmet financial need. We are well aware of this and realize that transfer students often are attending ASU on a combination of scholarships, grants, and loans. In order to help with this, our program has $4,000 scholarships which, at the present time, pay for about 40% of the tuition. We also encourage students to do internships and paid research positions as a way to help finance their education, as well as assist their academic and professional development.

We work with the students on resumes, elevator speeches, how to work a career fair, interviews, portfolios, and a research paper. We alert the students to the career fairs held at ASU, the informational sessions held by companies on campus, notices of possible internships or research opportunities such as the NSF Research Experience for Undergraduates, and having industry speakers with graduate engineering degrees come and speak in the Academic Success and Professional Development Class.

Although paying for an undergraduate education is difficult for most of the transfer students, still, from day one, we encourage them to go directly to graduate school. Industry is becoming more and more high tech and there are many high tech industries in Arizona which are interested in hiring engineers with a Master's or PhD degree. The students in the program hear from a panel of graduate students who have gone through the program. The graduate students in the program encourage the undergraduate students and give them confidence that they, too, can do graduate school. The graduate students also explain that they did not feel that confident about their field with a Bachelor's degree, but during the Master's program they did become more confident in their field. We want the students to find an area in which they are interested and excited and to do research in that area. If a student knows what they are interested in, they can better choose the companies for whom they would like to work. If the new engineer does not choose their area of interest, someone else will choose for them.

The next set of transfer realities include mostly items for which little can be done to change the situation: ASU is large, parking is expensive, some classes are very large, parking is difficult, and the commute may be long. ASU is large and some classes are large, although the higher the level of class, the smaller the size will tend to be. We have tried to make the campus seem smaller by having a METS Center where the students can gather, network, study, use a computer, and work in a study group. In addition, there are always two or three transfer students working in the Center who are available as informal counselors. A Center Director with a Master's degree in engineering and an MBA is also available to help students. We also keep the meetings of the Academic Success and Professional Development class smaller than 30 so the students can network, learn that others are having problems and learning how to overcome them, find study group partners, and become acquainted with other engineering students. Parking difficulty, parking prices, and a long commute are items that we cannot change. Since students at the community college usually have adequate and either free or low cost parking, the parking situation at a large university is a challenge. The long commute may be due to the students who continue to live where they did when they went to the community college. Further investigations needs to be done to see if there is a correlation between those students that have a long commute and those students who have dependents and were not able to easily more nearer to the campus.

The METS Center was included in the top eight transfer realities for both females and males as helpful with their transfer. We are glad that the students are finding that the Center is of help since that is the major reason for the Center's existence. The "pace of classes is much faster" and "overwhelmed with classes/logistics" are addressed with the 4.0 Plan. [15]The time management part of the 4.0 Plan should help with classes and logistics, while the 4.0 Plan for learning, should help the student with a faster paced course since the student will have read the material before class.

The rest of the transfer realities fall into five broad categories: academics, feeling like a freshman all over again with a GPA of 0.0, not knowing where resources are, being lonely or finding it hard to get into a study group, and working too much. Using the 4.0 Plan with our Academic Success Plan has made a big difference for scholarship students. In the Fall of 2010 we tested the effect of the 4.0 Plan and found that the new scholarship transfer students with the 4.0 Plan did not suffer any GPA transfer shock. There was no statistical difference in their first semester transfer GPA and their GPA when they left the CC. On the other hand, the other transfer students in their first semester in engineering averaged about a .45 grade drop.

Having successful transfer students available at all times in the METS Center provides transfer students with a resource: someone who can answer their questions or find someone who can. An example is a new transfer student bemoaning the fact that knowledge of MATLAB is required in a course they are taking and they have never had MATLAB. A METS Center staff could tell the student where to find a good tutorial for MATLAB online that can easily be done in a few hours. Of course, the transfer student in trouble has to ask for help. We try to anticipate a lot of the questions and give answers in the FSE 394 class and we also have over 100 critical questions and answers on line on our website www.mets.engineering.asu.edu. Also to help students academically, we have a free tutoring program available upon request. If a student needs help with tutoring, we try to find a volunteer tutor to help them. Two additional tutoring sites exist for engineering students.

We urge students to spend as much time on campus as possible and to either create or join a study group for each class. Study groups usually meet on campus and so spending more time on campus and being in a study group go together. We encourage students to find someone else in the Academic Success class for a study group so they are working with someone else who wants to achieve. A tip for students working into the early evening is to stay at work for an extra hour or two and to finish the homework so that when they return home, the homework is finished and the student can spend time with their family or doing other things. It is difficult to come home from work, relax, and then start homework.

We know that it is easy to feel lost or lonely on a large campus. We encourage our students to study in the METS Center and to get to know other students at the same time. We also encourage the students to join two student organizations: one in their major such as IEEE or ASME, and another such as the Society of Women Engineers, the American Indian Science and Engineering Society, the National Society of Black Engineers, or the Society of Hispanic Professional Engineers. The students are encouraged to slowly become involved in the organizations and to later take a leadership role. Industry wants to hire engineers who are not only good students academically, but also students, who are leaders, can work in teams, and like to work with others.

Working too much is a continual problem with transfer students and seems to be increasing in the past couple of years. Some students worked full-time and attended a CC full-time and were able to do so with over a 3.0 GPA. However, this does not work at the university. The students are warned that if they want to be a full-time student, they should work no more than 20 hours per week. However, each semester there are students who believe that this rule does not apply to them and they will be able to pull this load and still do well academically. Unforeseen increases in the workload per week can "wreck havoc" on a student's academic program. For example, a student who was working 20-30 hours per week was suddenly told that he must work 40 hours per week because another employee quit and product needs to get out the door. The student was responsible for a family with children and had to work. Soon the student, working full-time, dropped out of school rather than risk very low grades. Loans are a possibility for some students and students in the success class are students are told that there are two good reasons for a loan: to buy a house and to invest in their engineering education. Some students are not willing to go into any type of debt and some students are already up to their loan limit. In over 11 years of doing these programs, the author has seen only one student who has been able to work full-time (in an engineering position), be a student full-time, and do well academically. The female student is married, but has no children. She claims that it was difficult to do at first, but that now she has her schedule set to accomplish this. It is not easy.

V. CONCLUSIONS

In the surveys that have been done with transfer students for over 10 years, this is the first time that any gender differences were noted. Perhaps part of this was due to the fact that the numbers were small and it was difficult to make any conclusions. Although in general, the top expectations and realities of transfer were the same for both genders, several differences did emerge.

Females seemed to expect more challenges upon transfer than males. Only three challenges were identified by more than 50% of the males: higher tuition, large classes, and expensive parking. Eight challenges were identified by more than 50% of the females. The additional five challenges were: a long commute, pace of classes is much faster, ASU is large, difficulty parking, and their GPA may drop.

Females appear to experience more challenges upon transfer than men. There was one area that was statistically significant at $p<.05$: upper division classes were harder than expected. Three areas worth considering as troublesome for females is having a combination of too many credit hours and too much work, being over whelmed with classes and logistics, and that most of the easy non-engineering courses have already been taken, .making the rest of the classes harder. The additional work of the females may have involved family responsibilities. In general, the females had more commute time than the males, which could account for some of the overwhelming with classes and logistics.

These additional females concerns are all items for which help can be given by proper course selection, following the 4.0 Plan, being in a study group, being involved in student organizations, and perhaps reducing the work load. We urge others to survey their transfer students to see if there are areas of concern for which the university can help ease the challenges, including transfer shock.

Additional study will be done to discern if there is a difference between transfer students from non-metropolitan CCs and transfers from metropolitan CCs. We will also investigate if there is a difference in the perception of transfer by students who hold the $4K scholarship and those students who do not.

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The Effect of Matriculation Practices and First-Year Engineering Courses on Engineering Major Selection

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***Abstract*—Sixty-one sophomores were interviewed at six large public institutions to learn why they chose their institution and their engineering major. The institutions were categorized as either requiring a first-year engineering (FYE) program or allowing students to matriculate directly into a major. At these institutions, the first-year experience either required a common introduction to engineering course, required introduction to engineering courses that were not common to all majors or included an optional introduction to engineering course. The impact of the matriculation mode on selection of the institution and the presence or absence of a required first year course are studied. We find that cost of attendance is far more important than matriculation mode for most students choosing their institutions. Required and optional first-year courses, when taken, do tend to help students either affirm their prior choice of major or select an engineering major that suits their interests.**

Keywords—institution selection, major selection, first year programs, introduction to engineering courses

I. Introduction

A. Background

A taxonomy has been created that categorizes the 390 ABET accredited undergraduate engineering programs into nine distinct categories based on 1) whether students are admitted directly to an engineering major concurrent with institutional admission or whether they must pass certain academic hurdles before being admitted to an engineering major and 2) whether an introduction to engineering course is required or optional in the first term of enrollment for all majors [1]. Related work was undertaken using the Multiple Institution Database for Investigating Engineering Longitudinal Development. MIDFIELD contains student record data for 977,950 unique students, 106,000 of whom entered the college of engineering as first-time-in-college (FTIC) students (not transfers) at eleven public institutions in the U.S. from 1987/88 to 2009/10 academic years for whom there were at least eight semesters of data. This work has shown that students who are required to take a common introduction to engineering (CITE) course in their first term of enrollment are more likely to graduate in engineering and in the first engineering major that they declare than students who are not required to take a CITE course. This phenomenon occurs whether they matriculate directly into their engineering major or wait, either by their own choice or institutional requirements, to choose a major [2].

MIDFIELD institutions fall into three of the nine categories identified in the taxonomy – Direct Matriculation-all with a required introduction to engineering course in the first term for all students (DMa), First-Year Engineering (FYE), and Direct Matriculation-partial where an introduction to engineering course is required in the first term for some, but not all, majors (DMp). Those three categories encompass 64% of all undergraduate engineering institutions in the U.S. and 81% of the engineering students. The dynamics of selecting an engineering major at or after matriculation are particularly important in light of the fact that very few students switch into engineering after matriculating into non-engineering majors [3]. Combining recent findings that introductory engineering courses appear to improve persistence and reduce the number of times a student changes majors [2] with other work that indicates that each time a student changes majors results in a concomitant delay in the time to graduation [4] accentuates the need to understand the process of selecting a specific engineering major. Although previous research has studied the fraction of students selecting different majors within engineering [5], those studies have been mostly quantitative. The present study adds a qualitative component to the literature on this critical issue.

B. Selecting an institution, engineering, and a specific major

Institutional choice has been studied extensively and in detail, and continues to be studied given the likelihood that generational differences change the dynamics of institutional choice. Recent work disaggregates traditional students [6] from non-traditional students [7], since the two groups use different criteria to make their selection. Earlier work summarizes a range of factors that influence why students choose engineering [8]. The selection of a specific engineering major is less studied, but prior research provides some important clues that the design of an institution's first year of engineering influences this decision [2], [5].

C. The current study

MIDFIELD is not only a database, but also a long-lasting, diverse partnership of researchers and data providers. To shed light on why students choose engineering and their particular engineering major, 61 sophomore students who entered as FTIC students were interviewed at six of the MIDFIELD partner institutions. Half of these schools require students to take a CITE course and the other half offer introduction to engineering courses but either do not require all students to take them or do not require all students to take the same course. In the taxonomy that has been developed, two of the schools are FYE, two are DMa, and two are DMp [1]. Table 1 shows the matriculation model and presence of a common introduction to engineering course at the study institutions. Pseudonyms are used for the institutions to protect the confidentiality of the students who were interviewed. Note that at F-State, although all majors require an introduction to engineering course, they do not all require the same one and there are many options from which students may choose.

TABLE I. MATRICULATION MODEL AND CITE STATUS OF STUDY INSTITUTIONS.

Institution	Matriculation Model	CITE
A-State	FYE	Yes
B-State	DMa	Yes
C-State	FYE	Yes
D-State	DMp	No
E-State	DMp	No
F-State	DMa	No

Our research questions were:

1. Why did students choose their institution?
2. Did the matriculation model of the institution affect the students' decision to choose that institution?
3. Why did students choose their engineering major?
4. Did an introduction to engineering course, if taken, affect the students' choice of major?

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II. METHODS

A. Gathering information on the matriculation process

A person in the engineering college on each campus with access to email lists of second year students was asked to send an email to students in their second year. The list was restricted to those officially majoring in civil, chemical, computer, electrical, mechanical, and industrial engineering as well as those who were still officially in an FYE program or who were in an engineering undecided or unmatriculated category. Unmatriculated students have expressed a major preference but have not yet met the requirements to matriculate in their major of choice. The email invited students to click a link that would take them to a qualification survey on Survey Monkey™ [9] which asked for contact, demographic, GPA, major, and scheduling availability information. At each campus, 8-12 students were selected to be interviewed with an additional 8-12 students chosen as alternates. The selection criteria were the following:

- At least 3 majors represented plus FYE/undecided/unmatriculated
- At least 2 women
- At least 2 underrepresented minorities
- At least 2 excellent students (>3.5 GPA)
- At least 1 fair student (<2.5 GPA)

Selected students were interviewed in the Fall of 2011, Spring of 2012, Fall of 2012, and Spring of 2013. Students were generally first or second semester sophomores The interviews were semi-structured in nature, using predetermined questions but allowing the interviewer to follow up where appropriate. Students were asked about their decision to attend their school; why they chose engineering in general and their particular major; the influence of the matriculation model at their school (FYE or DM) on their choice of school and of major; the influence of the first year in general on their choice of major; other influencers of their choice of major; planned major for those still in FYE or undecided; and reasons for remaining in FYE or undecided, if applicable. Students who completed the interview were paid $20 for their participation. We then engaged in open coding of the interview transcripts to identify themes related to our research goals.

B. Interview Sample

Table 2 shows the sex, race, and major of the study sample at the time of the interview. The interviewed population was 37% female and 40% non-White, oversampling female and non-white students relative to their population at the institutions and in the selected majors. Females comprise just less than 20% of students in the selected majors and Whites make up 79% of that population. We oversampled women and minorities to make it possible to draw inferences based on gender and race within the relatively small population of interviewees. The interviewed population likewise somewhat oversamples the number of students in industrial, mechanical, civil, and chemical engineering at the third and fourth semester in MIDFIELD and underrepresents computer, electrical, first year, and undecided engineering.

TABLE II. SEX, RACE, AND MAJOR OF STUDY SAMPLE

Race/Sex	CE	CHE	CPE	ECE	EE	FYE	IE	ME	NON	UNE	Total
White Male	3	4	1	1	3	2	2	7		2	25
White Female	3	3				1	1	3	1		12
Asian Male		1	1		1			1		2	6
Hispanic Female		2						3			5
Black Male		1				1	1			1	4
Asian Female					1		2				3
Hispanic Male	1	1					1				3
Black Female	1						1				2
Other Male					1						1
All Male	4	7	2	1	5	3	4	8	0	5	39
All Female	4	5	0	0	1	1	4	6	1	0	22
Grand Total	8	12	2	1	6	4	8	14	1	5	61

III. FINDINGS

The initial analysis has illuminated themes about why students selected their institutions and engineering majors. Quotations have been modified to improve readability by deleting verbal crutches, such as "um" and "you know" and false starts. As indicated earlier, we have assigned pseudonyms to the MIDFIELD schools (A-State, B-State, C-State, D-State, E-State, and F-State) and some of the competing institutions (e.g., University of A) to which students also applied to enhance readability while maintaining institutional confidentiality. Each letter represents a different state so A-State and University of A are in the same state, as is Private A. A school with a national reputation is called Famous Tech. Other pseudonyms are used for regional institutions to reflect geography and whether they are public or private. Speakers are identified by their institution (A, B, C, D, E, or F) and the order in which they were interviewed.

A. Why students choose their institution

MIDFIELD schools are all public and generally much larger than schools that offer ABET accredited engineering programs in the U.S [10]. Together, MIDFIELD schools confer more than 10% of all U.S. engineering bachelor degrees. Because many MIDFIELD schools are also the flagship engineering institution in their state, students often choose to attend these schools because of a combination of their engineering reputation, proximity, and in-state tuition.

I only considered in-state schools. …[B]eforehand I did my research on the college of engineering of those schools…and as far as University of East D, I mean I heard a lot of good things about their college of engineering, [but] I ultimately chose D-State really because of the prestige I would have to say, and its proximity to my hometown. (D4)

Due to its roots as a coalition of southeastern engineering colleges, many students applied to multiple MIDFIELD schools, but most still chose the one in their home state, although reputation, specific programs, or campus characteristics did occasionally cause students to cross state lines in spite of having to pay out-of-state tuition.

I figured there wasn't anything that C-State had offered that D-State couldn't offer that was worth that amount of money. (D2)

[Me] and my mom had a really long conversation about [giving up an in-state merit-based scholarship]. It was between, basically because Famous Tech was out of the question, D-State and E-State and we felt like E-State would give me a better degree… After you get your degree and when you get a job, and how much you'll be able to make, it's more – it's better at E-State than it would be at D-State, and especially for my major as well, engineering. Because we specialize in engineering here at E-State. (E9)

For the MIDFIELD schools that are in states that offer statewide scholarships to highly qualified students, the availability of that scholarship to pay tuition is additional incentive. Occasionally parents or students themselves will limit their choices to in-state schools when applying because of a combination of the scholarships and in-state tuition.

The only other school I considered was University of E because my sister went to [a private school] and that was $40,000 a year. And so my parents were in a good economic standing at that point. And then the economy went all bad and stuff, and they were kind of like "We don't want to do the whole $40,000 a year school." So I lived in State E. I live about 15 minutes away. (E2)

Well, I wanted to do chem engineering and my dad told me I needed to stay in state and there are only two schools that are public that offer it – University of C and C-State. I don't really care for University of C so C-State was it. (C11)

More often, in spite of considering schools out of state or private institutions, the student will choose the MIDFIELD school in state because of the cost.

And then Private A did not have a chemical engineering program and Private Tech was too expensive so I came here…There are only four [engineering] schools in State A, I found out. A-State is the closest, basically…[and] a lot more reasonably priced…A-State is probably the best reputation to cost. So, good education for not 2-1/2 times the amount of money. (A3)

B. Impact of Matriculation Model on Institution Selection

The vast majority of the students interviewed did not know at the time they were applying what the matriculation model of their school was. For most of those who were aware of the model, either at the time they applied or sometime after, the matriculation model did not affect their decision to choose that institution – cost was a much more important consideration. Of the 20 students interviewed at FYE institutions, six indicated that they knew in advance about the FYE model and it was attractive to them because they liked the structure, liked having time to decide, and were afraid of getting stuck in a major that was a poor fit.

When I first heard about it, I [thought] it must be very organized, very structured. They want all students to have a basic foundation. I really wanted to do it. (A6)

[The FYE program] is why I chose A-State over Nearby State U. Because Nearby State, when you first go in, you go in as a ME…So here it gave me a chance to see them all before I got into it. So I would say that was – I guess that it was a big factor but that's why I didn't apply to Nearby State. (A9)

[The FYE program] was something I was interested in…because I thought I wanted to do mechanical engineering because I did First Lego Robotics [sic] all through elementary school and then coached it in high school. But I didn't want to get stuck in something if that wasn't what I was really interested in. (C4)

The students at the two DMa institutions had different perspectives on the effect of the matriculation model on their choice because B-State has a common introduction to engineering (CITE) set of courses, the passing of which are required to advance in the declared major, while F-State, though requiring all students to take some form of introduction to engineering, has a variety of those courses from which students could choose. Students at B-State were generally unaffected by the matriculation model when they were choosing schools. In contrast three of the 10 students interviewed at F-State indicated that it was important to them to be able to choose their major up front so that they could get right into their major studies. One student who had also applied to C-State indicated that he would have preferred the FYE model but other attributes of F-State made it more attractive.

I was pretty set on chemical engineering coming in. My parents tried to persuade me out of it; they're both chemical engineers. And, I was pretty determined about it. So I think that was – it was nice to be in the program to start with and not know that I had to, you know, apply my sophomore year. And what if I didn't get in? (F4)

C. Why students choose their major

The different engineering disciplines attract students for different reasons. Civil engineers like infrastructure, including roads and water systems. Students who switched to civil from environmental engineering indicated that they did so in many cases because of the lower chemistry requirements. The reasons students most often cite for choosing chemical engineering is an aptitude for chemistry and math and often a dislike for physics. Chemical engineering students also mentioned earning potential more than other majors and an initial desire to attend medical school. Many of the students who chose electrical and/or computer engineering were exposed to it through robotics competitions in high school. Six of the nine students in these majors reported having a family member who is an engineer, the highest percentage of any of the majors. Industrial was the major chosen most often by students who entered undecided or from another discipline. Two switched to industrial engineering from biology, one from a smaller engineering discipline, and one from undecided engineering. Mechanical engineering students cite the breadth of the field as a key reason for choosing it. More students in this discipline indicated that they enjoy working with their hands than students in other fields. These students also tend to prefer physics to chemistry.

Many students decided on their engineering major in high school or even earlier. Others, believing that their aptitude for math and science made engineering a good choice for them, were less sure of their specific major when they entered the university. FYE programs are designed to force students to wait to declare a major until they have been exposed to their options in engineering. Other students entered their institutions with an undecided engineering major, voluntarily taking extra time to decide. Students at DMa and DMp institutions are free to declare a major when they enter the institution, and the majority do so. However, of the students interviewed, only a third (12/36) were in the same major at the time of the interview during their sophomore year as they declared when they entered the institution. Some of these students changed majors the summer before their first year or immediately on arrival after further research between the time they were accepted and the time they enrolled. More often, however, there was something about the first-year experience, particularly introductory courses, that had an effect on the students' sophomore major.

People who entered undeclared were much more likely to be female and non-White – of 10 who entered undeclared, 4 were female and three of those were Hispanic. Of the six men, 3 were Asian, 2 White, and one Hispanic. All of those who were still undeclared at the time of the interview were male which may indicate that the undeclared time period is more helpful for placing women in majors than men. The four students who remained in an undeclared engineering status, were academically capable, with three of them reporting GPAs in excess of 3.0. The fourth faced a personal situation that caused his grades to suffer and was not allowed to declare a major until his grades improved. The other three indicated that they were having difficulty selecting a good fit or "wanted to be sure" before committing. They seemed to find multiple disciplines attractive and were having a difficult time making a decision.

I'm leaning towards materials. It's funny because for the longest time, I was like going back and forth between a lot of different fields. [P]eople I talked to they would get confused 'cause you know one day I said I'm going to do this, and then like a few weeks later I said I wanted to do that. But, yeah, I think going to the Introduction to Engineering, that one class where they showed – they demonstrate all of the engineering fields, I think that was really helpful. It gave me an idea rather than going to the website and reading what a field is all about, but then you know to actually have professors or Teacher's Assistants actually – they gave demonstrations and stuff rather than just giving you a lecture of what it's about. I think that was really helpful. But, even after completing that course it seemed like I still didn't have a very solid idea of what field I wanted to take. But it gave – at least it gave me like a better *idea. 'Cause like I think my real problem is that I could see myself in all of the fields, to be honest. And, to narrow it down to one field, it would be kind of a daunting task. But, I think I'll make a solid decision soon. I'm confident that it will be happening. (D4)*

Unlike most of those who still remained undeclared, the four students remaining in FYE had not declared an engineering major due to failing or never taking the required courses to declare a major.

Seven students were interviewed who began their studies in non-engineering disciplines (a few more applied to other disciplines, but changed to engineering before enrolling). Five came from other STEM disciplines – math, biochemistry, biology (2), and zoology and they chose civil, chemical, mechanical, and industrial (2). The biology and zoology majors had initially considered medicine but found that they did not enjoy those majors and decided to switch to engineering. All three were at DMp schools, as was the biochemistry major, which made switching relatively easy. The math major was at an FYE school and therefore was required to switch from math to FYE and complete the requirements before ultimately choosing the civil engineering major.

Two students came from arts and sciences undecided into engineering. One did so strategically because he was advised it would be easier to get into arts and sciences undecided than into the engineering school. He met the requirements and chose mechanical engineering. Another applied to engineering but was offered a path to engineering through arts and sciences undecided and was still in FYE at the time of the interview because he needed to complete the introduction to engineering sequence.

D. Effect of an Introductory Class on Major Selection

At the three schools where a CITE sequence was required, many of the students found the portion of the introductory course where the different disciplines were introduced to be either confirmatory of the major they were sure they wanted or it helped them find a discipline that better suited their interests and skills than what they thought they wanted.

The first year classes definitely solidified it because of the parts of the class that had to do with mechanical engineer[ing], those were my favorite parts because I knew we did electrical, computer engineering and those are the parts I didn't like, but once we got into mechanical, I enjoyed the classes. (C2)

Well, that first engineering [course] we do seminars, so they have all the colleges come in and give us a little spiel about each other. So that was when I really saw what mechanical could be for me and then what IE wasn't. So it kind of opened my eyes to if I chose mechanical, I didn't have to get stuck designing a screw or something like that. I could do multiple things with it. (A9)

I just declared [civil engineering] over winter break. It was in our first semester we learned about all the different engineering things and we went to information sessions and I think that civil interested me the most in what I wanted to do. And also…I saw helpful and nice and enthusiastic staff that it made me kind of excited. (C1)

One student, in addition to confirming his desire to major in electrical engineering added a second major in computer science based on an information session in Engineering I.

I decided on…the electrical engineering major in high school during the design class. But then, I decided on the CS major during the general engineering class we had. We had to go to information sessions. And I was always interested in computer science and I thought about getting a minor in it. But I decided I want a double major during that class, during the presentation because there are just so many more advantages to majoring than simply minoring that I learned during that presentation. (C5)

Of the non-CITE schools, D-State and E-State do not require any introduction to engineering course, but offer them for students who wish to take them. Half the students at D-State chose to take either an introduction to a discipline course or an engineering survey course, the latter being highly recommended for undecided students. One of those students took both. The undecided students who took the engineering survey course found it very helpful for choosing a major.

I took this class called Intro to Engineering where basically they take you to every department of engineering and basically tell you what it's all about. And that was when I discovered industrial engineering….[F]or me it was kind of funny because every week they'll take you to a different department. So industrial engineering was the second segment I went to. So I go there, I learn more about it, and I like automatically fall in love with it. But then there's still the rest of the class, so week after week, after week, it was just kind of like, I don't like this, I don't like this, I don't want to do this with the other majors. So, I think for me it just had a big impact because it really helps me see what it was I was interested in. (D2)

The only student to take it at D-State who was not undecided found, much like students at the CITE schools, that it reaffirmed his interest in civil engineering.

[Intro to Engineering] reaffirmed that I wanted to do civil. So, civil was the most interesting. And then, the other ones, they were interesting [but] I just couldn't see myself doing them. (D7)

F-State requires all students to take at least one introduction to engineering course, but there are a variety from which to choose including introductions to the specific disciplines, an engineering projects course, and an engineering survey course. Half of the 10 students interviewed took the projects course and nine of the 10 took introduction to a major. The introduction to the discipline courses offered students the opportunity to learn from speakers and projects what the career path would be in that discipline and tended to make the students more sure of their choice.

I learned more about what chemical engineering was [in Intro to Chemical Engineering]. I wanted to understand what really chemical engineering was. And, going out and seeing research in the different labs, factories, or research areas it made [me] more interested to know that it's something similar *to what I've been dreaming of in a way. Because I always wanted to work in a lab. …And, when I saw that there was a lot of actual things like that, a lot of jobs that you can do with especially here in State F, that really made me interested in continuing this major. And as well as we wrote a research paper on a choice of medications. And, I researched Ibuprofen and … I found that really interesting and knowing that this is something that I can also do in the long run, this is another option that I can get into or maybe one day find a drug that will somehow help others. But other than [that], it was more of just understanding what chemical engineering was about. …And professional speakers that came to speak with us, I feel like they were the people that encouraged me the most to continue because I wasn't doing really great in my classes GPA-wise and they had told me that grades didn't really matter. At a point they do, but it was more about what you did in college, and the outside things that you did for the college, or for yourself that count the most. And, when I heard that I mean it made me feel more willing to continue even though I was struggling. …And, that to me was what made me continue doing chemical engineering as well, and inspired me. And that's what I really liked about the class the most. (F9)*

One student knew that her career goal was to work with water systems, but after one day in introduction to environmental engineering, realized that the civil engineering major was more suited to her goal and immediately switched to the civil engineering major and the introduction to civil engineering class. Introduction to mechanical allowed students to work in a machine shop with hands-on projects and confirmed their desire for that major when they were not completely sure that was what they wanted to do when they arrived.

I took an Intro to Mechanical Engineering class and it was just, using a lathe or a mill and we made like this bottle opener out of a puck of aluminum. And so that was really cool because it was really hands-on and it was just cool to see what you could do....And you know, in a couple of weeks we made this cool little simple thing, and it's like well imagine what you could do with you know four years and then after that. And so that was probably a deciding factor too. (F3)

IV. Conclusions and Limitations

A. Conclusions

In this paper we have asked why students chose their institution and their particular engineering major and what the effects of the institution's matriculation model and related common introduction to engineering courses were on that choice. We find that, for the most part, students were unaware of the matriculation model when they applied to their institution or, if they were aware, that it was not influential on their choice. Cost of attendance was a much more important factor and tended to influence students to choose engineering schools in their home state. The presence of statewide scholarship programs was another influential factor for students staying in-state in the states that have such programs, but had little impact on the decision to major in engineering, as has been found elsewhere [11].

There is relatively little prior research on why students choose between engineering majors. Most research to date has focused on why students choose engineering as a whole or on single disciplines (e.g., [12], [13]). This study has shown that many students choose engineering or a particular discipline because of experiences before entering college, but that the first-year experience in an engineering program, particularly an introduction to engineering course that includes a survey of available disciplines, affects them by either confirming their prior notions of the suitability of a particular major or giving them the information needed to make an informed choice of a different engineering major.

Many students decided to major in engineering during high school and some settled on a major at that time. Still, the majority of those interviewed who were allowed to declare a major when they entered their institution, changed majors. Women were more likely to come into engineering as undeclared, even when they could make a choice, but once they had the information they needed, they declared a major; some of the men appeared to have more difficulty making up their minds.

Students who enter engineering majors from outside of engineering are relatively rare [3]. In this study, most of those that did came from other STEM majors, which Ohland et al. found was the more likely path for that small group. A couple came from arts and sciences undecided either by their own choice or the institution's, demonstrating that the pathway is viable for students who may need to prove themselves to the colleges of engineering to be admitted.

B. Limitations

The criteria set forth for selecting students to be interviewed lead to an inherent selection bias which means that quantification of the findings may not necessarily be representative of sophomores as a whole. Smaller majors were purposely excluded to determine if there were any commonalities among the larger majors.

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Comprehensive Framework for Significantly Increasing the Number of Highly Trained Engineers: A Model Academic Success and Professional Development (ASAP) Class – Lessons Learned and Strategies Moving Forward

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***Abstract*—This paper describes a comprehensive academic success and professional development (ASAP) framework that has been developed within Arizona State University's (ASU's) Ira Fulton School of Engineering over the past decade. Centered around an ASAP class offered each semester, with need-based scholarships serving as incentives/facilitators, the success of the program has been tremendous – with retention and graduation rates for participating scholars exceeding their counterparts at ASU and at other universities across the nation. Program activities, lessons learned and strategies moving forward are discussed within the paper.**

Keywords*—*academic success and professional development (ASAP); engineering scholarship programs; research projects; life-long learning; graduate school; student-centered mentoring

I. Introduction: Motivation And Summary

Motivation: Issues and Challenges Facing the Nation. As the rate of technological progress continues to soar, the need for highly trained engineers has never been greater. To meet anticipated future technical demands, the nation requires many more engineers. Traditionally, this demand has been addressed, in part, by recruiting talent from around the world. While this approach is expected to remain a critical component of the nation's strategy, it's now widely accepted that the nation must recruit and develop talent from within. This is because a highly trained engineering workforce is essential to fuel innovation, remain economically competitive, and ensure national security. Moreover, it's not healthy for large portions of the population (e.g. women/underrepresented minorities) to be left out of areas of national importance.

Summary. In an effort to address the above, exacerbated by an alarming disinterest in STEM and falling math-science scores, we describe a comprehensive framework for significantly increasing the number of highly trained engineers entering the STEM workforce. This framework has been developed over the past decade at Arizona State University's Fulton School of Engineering. Central to the framework is an Academic Success and Professional Development (ASAP) class that has been offered to lower-division, upper-division, and graduate students participating in one of our NSF funded (CSEMS, S-STEM, STEP) scholarship programs [1]-[18].
The main purpose of the ASAP class – offered each semester – is to expose our selected scholars to time-tested student-centered instructor-driven methods/techniques to help students (1) succeed academically, (2) discover, develop, and nurture their technical passions, and (3) develop essential skills to prepare them for life-long-learning and to enter a highly competitive global STEM workforce which offers a wide range of exciting career opportunities.

While we have strived to provide leadership with respect to nationally practiced ASAP activities, we certainly have built and continue to build upon the successes of others [19]-[37].

The remainder of the paper is organized as follows: Section II describes ASU's institutional setting. Section III provides an overview of ASU's ASAP program. Section IV provides an overview of the student-centered activities covered in the associated ASAP class. Section V provides a summary of Program Results. Section VI provides strategies moving forward. Finally, Section VII summarizes the paper and provides directions for future work.

II. Institutional Setting

The following summarizes ASU's institutional setting:

- ASU is the largest public university in the nation (with over 72K on all of its campuses; over 60K on the Main Tempe campus)
- ASU is a Carnegie Research I University
- Fall 2012 engineering enrollment exceeded 8,700
- This included 1,500 first-time freshmen and 2,800 graduate students
- Research expenditures for FY 2012 was \$77.6M
- 235 tenured or tenure-track faculty
- ASU is situated within the Phoenix metropolitan area. As such, it is surrounded by a very broad industrial engineering-centric base – one which offers ASU's engineering students many great opportunities; e.g. internships, mentoring, jobs, etc.

This work has been supported, in part by NSF S-STEM grants: 0728695, 0807134, 1060226, NSF STEP grant: 0856834, and by a 2012 grant from Women & Philanthropy. See references [1]-[18].

III. OVERVIEW OF ASU'S ASAP PROGRAM

A. Students Served By ASAP Program

ASU's ASAP program serves students across the Ira Fulton School of Engineering. (In this paper, when we write engineering, we mean it to include computer science as well as computer systems engineering.) Our program directly serves freshmen through seniors as well as first and second year graduate students.

Recently, over 30 lower-division students (freshmen and sophomores) and over 80 upper-division students (juniors, seniors, first and second year graduate students) receive our full $4K scholarship (per year). Per NSF requirements, these students are <u>academically-qualified and financially-needy</u> (as determined by their submitted FAFSA form). The above includes transfer students as well as traditional students. Another 30 or so students, receive $300 incentives to take the ASAP class. As word of our program has spread, many students have decided to take our ASAP class. With ASU institutionalizing a version of our ASAP class for transfer students, we expect this trend to continue. While we have served up to 200 students in a year, we are certainly not able to support all of ASU's academically-qualified financially-needy students that wish to become engineers.

Finally, it is important to note that over 60% of our scholars are women or underrepresented minorities.

Recruitment of ASAP Students. We aggressively recruit our scholars from community colleges and high schools across the state of Arizona as well as from within ASU. Freshmen are specifically recruited via ASU's Presidential Award winning Joaquin Bustoz Math-Science Honors Program (Cynthia Romero, Senior Coordinator). Periodic visits are made to and from rural community colleges (CCs) situated far from ASU (3-4 hour drive, one way). An NSF STEP grant supports this activity with partnering CCs: Arizona Western College, Central Arizona College, Cochise College, Eastern Arizona College, Mohave College. We visit each of these schools each semester. We hold sessions with students (typically 20-30 at a time) to discuss the many exciting opportunities that an engineering career can offer. After our visit to the partnering CC, they visit ASU (typically with 10-15 students). The students spend a full day on the ASU campus – having planned seminars on transfer issues, financial aid, as well as engineering opportunities. The students get a chance to visit labs, meet with professors, and meet with students that made the transition from their CC.

B. ASAP Faculty, Staff, and Support

The authors (Drs. Rodriguez and Anderson-Rowland) run ASU's ASAP Program. Both have an extensive background with respect to managing ASAP programs [1]-[18]. Both have managed NSF S-STEM, CSEM, STEP and other grants (e.g. Women & Philanthropy). Both have received numerous awards for mentoring, education and research.

Participating scholars/students use two (2) facilities:

(1) METS (Motivated Engineering Transfer Students) Center

(2) Intelligent Embedded Systems Laboratory (IeSL)

Over 400 students use the METS Center each year. The METS Center Director, Anita Grierson has an MS in Mechanical Engineering as well as an MBA. She helps administer the upper-division program as well as providing one-on-one mentoring to participating ASAP scholars.

The METS Center is staffed by former ASAP scholars. These students further provide assistance to participating ASAP scholars/students. Ideas from [33]-[34] provide the foundation for "students-helping-students."

Both facilities (particularly the METS Center) serve as a home away from home for the students. The *IeSL* provides a place for students to work on projects at any time day or night ("24-7").

Cynthia Romero (Senior Coordinator, Joaquin Bustoz Math-Science Honors Program) has assisted Dr. Rodriguez in administering the lower-division program.

C. Guiding Principles

Our ASAP program is based on the following guiding principles:

(1) <u>*Financial Support*</u>. Many students need financial support. Without it, they cannot focus on their studies. Without it, many are forced to take on low paying time-consuming jobs that detract from more scholarly academic pursuits.
(2) <u>*Mentoring*</u>. Student-centered mentoring by program faculty is critical. Many of the students, particularly women and underrepresented minorities have lacked role models. Even some of the very best students lack essential role models as well as critical technical/career perspective and confidence.
(3) <u>*ASAP Activities*</u>. Students require assistance with their academics as well as professional development.
(4) <u>*Life-Long Learning and Global Economy*</u>. Students must understand the importance of life-long learning and the increasingly competitive global economy.
(5) <u>*Participating in Ongoing Technological Revolution*</u>. Students must be encouraged (and shown how) to

participate in the ongoing and increasingly accelerating technological revolution.

Financial support run our program (i.e. provide scholarships, pay staff) has been provided by NSF as well as other organizations/companies. (2)-(5) are directly addressed within our ASAP class.

In an effort to further articulate our educational philosophy, we find it useful to cite the work of Vincent Tinto, a well-known Distinguished Professor of Education (Syracuse University). He has been concerned with the retention of college students since the 1970's [35]. His most cited work is [36]. His most recent book [37] carefully delineates what students need in order to stay in college and graduate. His four main principles are as follows:

(1) *Expectations.* High expectations are an essential (necessary) condition for student success.
(2) *Support.* Without academic, social, and in some cases, financial support, many students, especially those who enter college academically underprepared, struggle to succeed.
(3) *Assessment and Feedback.* Students are more likely to succeed in institutions that assess their performance and provide frequent feedback in ways that enable students, faculty, and staff alike to adjust their behaviors to better promote student success.
(4) *Involvement (Engagement).* The more students are academically and socially engaged with faculty, staff, and peers, the more likely they are to succeed in college.

Our ASAP program has been aligned with these four principles since its in 2000.

Web Sites. Our program is supported by the following web sites – sites that are still under development:

http://aar.faculty.asu.edu/lapdp.html

http://mets.engineering.asu.edu/

The latter site has been designed to specifically address the needs of transfer students from CCs. Such students often suffer a GPA transfer shock when transferring from a CC to a 4 year school. This is not the case for transfer students participating in our ASAP program.

IV. Overview of ASAP Class Activities

The ASAP class is a two (2) credit class. Program scholars are required to take the class each semester that they are on scholarship. The class is taught at two (2) levels:

- Lower division – including freshmen, sophomores, and transfers from community colleges (CCs) as well as transfers from other 4 year institutions;

- Upper-division – including traditional juniors and seniors as well as transfers from CCs, transfers from other 4 year institutions, and first and second year graduate students.

Several sections are offered in order to accommodate student schedules and to keep the class size below around 30. The classes are jointly taught by the authors – with Dr. Rodriguez assuming primary responsibility for the lower-division students and Dr. Anderson-Rowland assuming primary responsibility for the upper-division students.

ASAP class activities include:

(1) Donna O'Sullivan's Guaranteed 4.0 Learning System (http://www.guaranteed4.com/);

- This learning system addresses critical academic skills such as time-management, effective and efficient study habits, note-taking, test preparation, etc.

(2) Importance of projects to discover, nurture, and develop ones technical passions;

- The idea here is that students who discover, nurture, and develop their technical passions are much more likely to remain motivated, focused, enthusiastic, and engaged – feeling empowered by the fact that they can "see the light at the end of the tunnel;" i.e. understanding what possibilities await them when they complete their BSE.

(3) Applying for a project, research experience, internship, graduate school, scholarship/fellowship, job;

- In addition to shedding light on the various paths that students can choose, we show them how to navigate each of the paths. A critical issue here is being able to demonstrate why the path is worth taking and, more importantly, that the student is capable of getting on the path and successfully completing it. Often, some of the best students lack critical perspective and confidence.

(4) Critical questions that students need answers to;

- It is well understood that students will have to answer or get answers to many critical questions as they progress academically and professionally. To assist students with this, we have compiled a list of 139 questions at:

  http://aar.faculty.asu.edu/critical_questions.pdf

  These questions – which are still under development – currently address each of the following 15 topics (NOTE: Numbers in parentheses indicate the number of questions currently in that group):

  I: BS in Engineering (5)

  II: Why Engineering (8)

- This includes pointing out exciting growth areas within engineering –areas that have been deemed as areas of national importance:

  http://aar.faculty.asu.edu/growth.html

III: Choosing an Engineering Discipline (13)

- This includes explaining what is “traditionally done in each of the engineering disciplines” as well as showing students the breadth of each discipline.
- Students, for example, traditionally associate aerospace engineering with “traditional” topics such as aircraft, spacecraft, propulsion systems, and (possibly) automobile design. Aerospace engineers, however, can work alongside physicians – utilizing their CFD (computational fluid dynamics) knowledge – to develop new cutting-edge sensors to detect and map out the progression of cardiovascular disease and obstructions throughout the body – a very significant contribution that traditionally is not associated with aerospace engineers!
- Traditionally, students have a tendency of viewing their chosen engineering field very narrowly. As systems become more complex, multidisciplinary engineering teams will be called upon to solve the problems at hand. As such, traditional disciplines are increasingly growing with respect to the problems they can address.

IV: Financing My BS in Engineering (8)

V: Why Pursue a BS in Engineering at ASU? (27)

- This topic has many questions so that students can become familiar with the many resources that ASU provides. The following document provides some details:

  http://aar.faculty.asu.edu/AAR_WHY-ASU-ENGINEERING_10_5_11.pdf

VI: Importance of a Mentor (6)

- We believe that one-on-one mentoring is the next critical factor contributing to student success – after financial support, personal commitment, and having a technical interest. Mentors help students answer all kinds of questions (see above). We work hard to connect students with mentors in their fields – a community of mentors. The following is a primer on finding a mentor:

http://aar.faculty.asu.edu/AAR_Finding_a_Mentor.pdf

VII: Importance of Research: Figuring Out What I Want to Do (14)

- We believe this to be one of the most important topics addressed in the class. We use research/projects as a vehicle by which students discover, nurture, and develop their technical passions. See (2) above. The following primer helps students get involved in research:

  http://aar.faculty.asu.edu/AAR_Getting_Involved_In_Research.pdf

- Here, it is important to convey the many exciting areas that exist for students to work in – areas of national importance; some representing grand engineering challenges. See (9) below.

VIII: Important Skills (16)

- Important skills include: problem solving skills, information gathering/research, data analysis, programming, modeling, simulation, virtual prototyping, writing, public speaking (may include multi-lingual to interact with customers abroad), interviewing, etc.

IX: Leadership, Service, and Professional Networking (8)

- Companies want individuals that can work independently as well as in groups. They particularly want individuals that can lead groups of people. For this reason, the following is relevant: special projects, student/professional organizations, community service, tutoring, going to conferences, etc.

X: Importance of Graduate School (5)

- The importance of graduate school is even addressed for incoming freshman. The following document describes writing a statement of purpose – something students must do for many activities; e.g. graduate school, scholarships, fellowships:

  http://aar.faculty.asu.edu/AAR_WRITING-A-STATEMENT-OF-PURPOSE-10_14_11.pdf

  Over 50% of our upper-division scholars go on directly to graduate school - more than twice the national average.

XI: Financing My MS/PhD in Engineering (4)

- For most students, if the finances do not work out, everything suffers. All of our scholars are financially needy (as determined by the FAFSA form). For many of our students, the $4K scholarship allows them to focus on their studies rather than taking a low paying time-consuming job that severely detracts from studying and other scholarly activities.
- Given this, the financial support we offer to our scholars is very critical. To sustain our program long term, we hope to build a partnership between the federal government, the state, and industry. This will be discussed further below when we discuss strategies moving forward.

XII: The MS Thesis (6)

- Many of our students use the project mechanism that we strongly encourage as a vehicle for establishing a foundation for their senior design project, their undergraduate honor’s thesis (required by ASU’s Barrett Honors College) or even their MS thesis.

XIII: Getting a PhD (8)

- Several of our students started as freshman, selected a topic (e.g. policy making with respect to energy and global warming), and are now working on their PhD on the topic they chose as freshman! This is very inspiring to us. We know that with proper support (financial and otherwise), we can get many students to follow suit.

XIV: Starting a Company (6)

- Here, the goal is to get students to think outside the box and to fundamentally encourage a small company entrepreneurial spirit driven by independent thinking and getting a product to market. Several of our scholars have started companies while students.

XV: Choosing a Job and Job Advancement (5)

(5) Importance of a mentor to help students answer critical questions;

- In addition to explaining the importance of mentors, we help the students find mentors (see VI above).

(6) Importance of life-long-learning in an increasingly competitive global economy;

- Since the inception of the program in 2000, Dr. Rodriguez has addressed the significance of the global economy, increasing competition, and the associated need for life-long learning. The Great Recession has made these topics far less abstract for our students. We have seen how freshman very quickly accept the "need to aggressively take control of one's career immediately" and that their futures depend on it.

(7) Importance of graduate school and the many opportunities that an advanced graduate degree opens;

- Graduate school is another critical theme that we expose all of our students to – even freshman. We want them to go to graduate school, not because of the extra salary they will earn, but because of the significantly increased opportunities that will be afforded to them; e.g. increased technical challenges that permit them to work on the "coolest of problems," work schedule flexibility, and much more.

(8) Exciting engineering career opportunities;

- In an effort to convey the many exciting career opportunities that lie before the students, we often bring in speakers from industry. This has included former program participants that have gone on to obtain their MS in engineering and assume challenging positions in industry (e.g. designing hypersonic vehicles at NASA, working on multi-core microprocessor work/heat management algorithms at Intel). Graduate students are also recruited as speakers (e.g. design of micro-air vehicles). Sometimes we have panels of students.

(9) Choosing a technical area – areas of National importance;

- Choosing a technical area is very challenging for most students. Reasons that students give for this are as follows: (i) "too much to choose from," (ii) "do not know enough to choose." Our feeling on this is that the students are partially correct. There is a great deal to choose from and the students often lack critical background. Despite this, we urge the students to start the learning process as soon as possible so they can discover, nurture, and develop technical passions to sustain them as they move forward. We tell them to start selecting as soon as possible – so that they can control their destiny. The consequences of not choosing is that someone else (typically a recruiter from a company) will be making the final choice on what the students will work on. We advise the students to plan ahead, to set job goals, to work the plan, and to pursue the job goals. This is part of the career plan. See (11) below. The alternative is to submit themselves to the randomness of the interviewing process. We have found that this can lead to severe "job disillusionment;" i.e. a misalignment between expectations and reality.
- We work hard to point out cutting-edge areas - areas that have been deemed areas of national importance; e.g. electric vehicle technologies (e.g. batteries), green biofuels, efficient solar cells, cognitive radio for maximizing spectral capacity (bandwidth) in communications, content-rich mobile libraries, early disease diagnosis, DNA sequencing, immersive teaching software, online learning for all, advanced super computers, advanced transportation systems (e.g. high speed rail, reusable hypersonic vehicles), vaccines for every flu strain, advanced prosthetics and robotic systems, personalized medicine, real-time language translation, regenerative medicine (organ growth), air traffic control, advanced armor, smart robust energy grid, nanotechnology.

  http://aar.faculty.asu.edu/growth.html

  Students have worked on projects in most of these areas.

(10) Importance of multidisciplinary thinking;

- As stated above, we try to show students how traditional fields overlap with one another – particularly to solve cutting-edge problems whose solutions lie at the boundaries of multiple disciplines.

(11) Developing a comprehensive career plan;

- Believing in the old adage:

  "plan your work and work your plan,"

we get our students to develop a comprehensive (10-15 year) career plan:

http://aar.faculty.asu.edu/AAR_COMPREHENSIVE-CAREER-PLAN-10_17_11.pdf

Such a plan forces students to think about future classes, summer classes, summer internships, special projects, and what they want to do with their future!

(12) Writing a technical proposal, paper, presentation, and statement of purpose.

- Each of these helps students learn how to present their work. The following documents assist students with these assignments:

  http://aar.faculty.asu.edu/AAR_RESEARCH-PROPOSAL-GUIDELINES-10_14_11.pdf

  http://aar.faculty.asu.edu/AAR_Writing_a_Technical_Paper.pdf

  http://aar.faculty.asu.edu/AAR_WRITING-A-STATEMENT-OF-PURPOSE-10_14_11.pdf

From semester to semester, we try to get students in the ASAP class to significantly improve upon what they did in the previous semester. As such, the ASAP class and the guidance we provide are very student-centered. ASAP program faculty maintain an open-door policy for program students.

V. Overview of ASAP Program Results

Some of our ASAP program results are summarized below:

- Over 85% of our scholars graduate with an engineering degree (includes computer science, not construction) - (ASU: < 50%).
- Over 50% of our lower-division scholars participate in paid REUs/internships.
- Over 90% of our upper-division scholars graduate (ASU: Male - 70%, Females - 65%).
- Over 50% of our upper-division graduates go directly on to graduate school (> twice national average).
- Over 60% of our scholars are women and/or underrepresented minorities.

Many of our scholars have gone on to win prestigious scholarships (e.g. SMART, Goldwater), fellowships (e.g. NSF, GEM, NASA), and attend top engineering programs.

The activities conducted within our ASAP class have evolved over the past decade. They have been tested and they have been found to be very successful.

A very critical issue that we continue to face is that we do not have enough financial resources to address all of the academically qualified financially needy students at ASU. This issue has been exacerbated by the recent Great Recession as well as the ongoing sequestration. Ideas for addressing this financial/sustainability issue are discussed below.

VI. Strategies Moving Forward

Recently, the ASU Fulton School of Engineering has agreed to offer a class for transfer students which adopts some of the ideas addressed within our ASAP class. We will continue to work with them in order to further institutionalize our ASAP concepts.

Moving forward, we will continue to modify/improve our ASAP classes; e.g. to offer more challenging opportunities for one-on-one student-centered mentor-guided projects. This is precisely what ASU's Fulton Undergraduate Research Initiative (FURI) attempts to do:

http://more.engineering.asu.edu/furi/program-requirements/

A critical issue here, is having financial support for academically-qualified financially-needy students. Without the financial support, we may lose very capable students to low-paying time-consuming jobs that detract from more fruitful academic and scholarly activities. As stated earlier, this is also the case for our ASAP activities.

To address this critical financial issue, we plan to move forward with strategies that permit us to maximally expand our ASAP activities to non-scholarship students. This is approach, while welcomed by the federal government (NSF) and state governments (many operating with unsustainable debt because of future outlays; e.g. benefits), is very difficult. In view of this, we plan to expand providing small ($300) incentives for students to pursue our ASAP activities. We also plan to seek a partnership that involves federal government, the state government, and industry. This model, we think is suitable for America. The German model of government directly funding high school students interested in engineering, is probably politically untenable in the U.S. – at least until the current debt crisis is substantively addressed.

VII. Summary And Conclusions

Within this paper, we have presented a comprehensive framework for significantly increasing the number of individuals entering the engineering profession. The framework is based on a 2 credit ASAP class that students take each semester. While we have seen our ASAP concepts being adopted across the nation, financial sustainability of a scholarship program to attract academically-qualified financially-needy students requires a new approach in order to be scalable. Toward this end, we have proposed a partnership between the federal government, the state, industry, and the student. We believe that such an approach will permit the nation to produce the engineers it needs without unduly relying on external engineering talent.

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Accelerating Engineering Degree Completion for Military Veterans

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***Abstract* - This paper addresses an accelerated track for military veterans into bachelor's degrees in engineering. It is an update on a project that was first reported at FIE 2011. An initial thorough evaluation of the veterans' training, experiences, and expertise has been conducted with the option of granting academic credit where appropriate. Therefore, it is important to have contact with the military veteran prior to their arriving on campus to begin their schooling. Current policies give little credit for military experience or training. The development of on-line pre and post assessments and subject based tutorials are being used to accelerate the veteran's entry into the traditional math sequence. Veterans may have a base of technical knowledge acquired through the technical nature of their service posts. Assigning them to introductory level courses with traditional freshman and sophomore students does not respect their technical expertise nor challenge their capabilities and accustomed pace.**

Keywords – Veterans; accelerated programs; electric energy systems

I. MOTIVATION

This work-in-progress paper is an update on a project that was first reported at FIE 2011. It addresses curricular issues involved in integrating post-9/11 veterans into the engineering workforce. A 2009 NSF Workshop on Enhancing the Post-9/11 Veterans Educational Benefit [1] indicates that new, more generous veterans' educational benefits create an opportunity to expand the technical workforce while benefitting those who have served our country. The workshop further indicates that the veterans include a diverse and qualified pool of future talent for the nation's engineering and science employers.

The main aspect of this project is an accelerated track for veterans into engineering bachelor's degrees in engineering for those with no bachelor's degree or with a non-technical degree. The initial technical focus will be in the renewable energy and energy distribution systems areas.

A focus group of veterans already in the electrical and computer engineering department identified transfer credit for military experience and in-state tuition availability as the most important issues that affect their success.

II. ACCELERATED BACHELOR'S DEGREE

This paper addresses an accelerated track for military veterans into bachelor's degrees in engineering. It is important to have contact with the military veteran prior to their arriving on campus to begin their schooling.

An initial thorough evaluation of the veterans' training, experiences, and expertise was conducted with the option of granting academic credit where appropriate. A need currently exists for increased academic recognition of military experience to increase the opportunity for student veterans to complete a degree in a timely fashion [2]. One issue with the use of military credit is that most of the academic credit is ungraded. A possible avenue to overcome these rules is the use of advanced placement exams (where they exist) and university generated quiz-out exams. Other resources such as the American Council on Education [3] directory and university credits for community college work also provide a resource to determine class equivalency.

Required courses identified for consideration of assigning experiential credit include the following: professional and leadership development courses, a social science/humanities elective and one technical elective. The program also includes development of on-line pre-assessments and linked subject based tutorials to accelerate the veteran's entry into the traditional math sequence beginning with Calculus I or higher. Lastly, the same concept of online pre-assessment and tutorials followed by a proctored final assessment is also being developed for entry level engineering courses. In the field of electrical engineering the course to be used for evaluation is Circuit Theory I and therefore its prerequisite, Introduction to Electrical Engineering. These courses present basic concepts in electrical theory, engineering applications and an introduction to circuits laboratory. As in mathematics, veterans would complete an on-line pre-test with linked subject based tutorials ahead of enrolling in the program. Then the veteran would have the option of completing a one-time proctored post-test for course credit (C or better). This approach leverages the veterans' existing technical knowledge acquired through the technical nature of their service posts and accelerates their entry to follow-on technical courses.

By taking full advantage of the program's structure of (1) advising and assessing of military experience, (2) the mathematics refreshers and (3) the post-assessments for entry level engineering course credit a veteran would be able to earn as many as 13 of the 129 credits required for a Bachelor of Science in Electrical Engineering, which is

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approximately equivalent to one semester on campus. This is in addition to the six hours of prerequisite mathematics courses that can be bypassed by proper review and performance on the mathematics placement exam. Student success in the post-test for credit and academic success (C or better) in subsequent courses will be the primary evaluation metric. The evaluation of this metric will take place when a statistically significant number of students have had access to the accelerated option and are enrolled in the program.

Additional on-line training will focus on areas related to common computer application programs such as MatLab, P-Spice, and Verilog (used in introductory course taken by all electrical engineering students).

III. Technical Focus

Energy has been identified as a critical area where there is a large projected shortage of trained technical personnel. A 2008 NSF Workshop on the Future Power Engineering Workforce [4] indicated "a serious need is emerging for more power and energy engineers to: a) replace retiring engineers so that critical expertise is maintained; b) meet rising infrastructure construction needs; c) modernize the grid as communications, computing, and electric energy technologies converge; d) help stem the tide of electric equipment manufacturing moving off-shore, and; e) solve arising engineering challenges, such as the development of advanced power electronics and energy conversion systems, new generation and storage technologies, and the integration of those technologies into the grid.." The IEEE Power and Energy Society [5] has also indicated that "Immediate action must be taken to avoid letting a growing shortage of well-qualified electric power engineers slow progress in meeting critical national objectives."

In 2008 an industry consortium called the Kansas State University Electrical Power Affiliates Program (EPAP) was formed. EPAP is a consortium of industry leaders committed to the continued excellence of engineering education in the area of electrical power and energy systems. The program can be leveraged to help with various aspects of this proposed work, including the recruitment seminar, internships, and research projects. [6,7]

The energy systems emphasis builds on the existing expertise of the faculty at Kansas State University. Energy systems is one of the five areas of specialization in the electrical engineering program and attracts about 50 percent of the undergraduate students. In addition, the department offers a master's degree with an energy systems emphasis. This master's program has been offered via distance education since 1992, and has approximately 25 off-campus students per semester.

Another aspect of this project is the inclusion of summer internships for participants. These will be provided by members of EPAP and by funded research projects at the university.

IV. KSU and the Military Environment

Kansas State University is near a major U.S. military installation, Fort Riley, and has more than 60 years of experience providing educational opportunities to military personnel and their families. The university provides academics, activities, services and support for military families. Kansas State University has been ranked among the most military-friendly universities in the country by *Military Advanced Education* magazine and by *G.I. Jobs* magazine. Fort Riley is a 15 minute drive from campus. In addition courses are offered on post and via the Internet.

A model partnership between Kansas State and Fort Riley was recently renewed. The agreement was designed to serve as a model military-to-university-community partnership. The agreement sets the following objectives: enhancing each institution's ability to accomplish its mission through collaboration; enhancing the professional and personal quality of life for each institution's constituent communities; creating new and innovative opportunities and programs that add great value to each institution through partnership; and increasing capacity at each institution to steward, manage and sustain major resources through collaboration, innovation and partnership.

Programs between Kansas State University and the First Infantry Division and Fort Riley today aim to create new relationships; offer a diverse experience and perspective; build a stronger academic-military community; improve quality of life; and enhance education and professional development. Increasing the attractiveness of Kansas State University's engineering programs to veterans through the acceleration of degree completion times will add to the partnership between Kansas State and the U.S. military.

V. Future Plans

The major activity will be the continuation of tutorial development. The creation of accelerated courses specifically for veterans enrolled in the program will be another aspect used to accelerate degree completion.

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The TIES Program: A Transfer Initiative for Engineering Students

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***Abstract*—Strategies to recruit and retain underrepresented students in the STEM fields are as diverse as the students they seek to engage. The community college pipeline is well recognized as a source for both nontraditional and underrepresented students for engineering programs. The Transfer Initiative for Engineering Scholars (TIES) addresses the unique needs of this cohort who transfer as juniors from the community college environment. TIES is currently in the fourth year of receiving funding from NSF's S-STEM program and providing financial support to eligible students in an environment committed to smooth transitions, multiple options for student support services, community building with peers and faculty, leadership development, and mentor relationships. Many of the support activities build upon previously existing retention programs, but new components, such as leadership seminars, community building, and industry mentoring, were developed specifically for TIES participants. Among the several components of the program, those that contribute to a supportive community environment were seen by the students as extremely important for a successful transition to Georgia Tech's undergraduate electrical engineering and computer engineering programs.**

Keywords—transfer initiative; community college pipeline

I. Introduction

The overall objective of the TIES program is to increase access to Georgia Tech's School of Electrical and Computer Engineering (ECE) for students transferring from community college who demonstrate financial need. The program is designed to enhance their ability to graduate with the strong academic records that afford students rich opportunities for career and/or future education choices. This objective is achieved through the following goals:

- Increase the number of competitive community college transfer applicants applying to Georgia Tech;
- Award TIES scholarships to newly admitted students with financial need and academic commitment;
- Implement strategies to minimize the challenges of transferring from two-year to four-year institutions, and retain and successfully graduate TIES scholars;
- Provide opportunities to expose TIES scholars to experiences that will enhance their options for post-graduation opportunities; and
- Structure the TIES enrichment program so that other transfer students can benefit from the activities.

The special challenges faced by students who take this "non-traditional path" to engineering are formidable for even the most academically talented students. Using a management and support team that has had success with a variety of outreach and retention efforts, TIES has built and expanded upon these strategies to offer multiple novel support program options specifically for non-traditional junior-level transfers. Several program elements, such as active involvement with a cohesive student cohort and mentoring activities focused on research and career development, help to keep students motivated to succeed without premature feelings of defeat.

II. Program Framework

A noteworthy feature of TIES is that the program is implemented at the departmental level and builds upon the conceptual framework of student persistence developed by Vincent Tinto [1,2]. According to Tinto, when students enter the college or university environment, they bring with them attributes that will influence their academic goals and commitments. Once in college, other factors associated with the institutional experience, which consists of both academic and social factors, will also influence student persistence. The likelihood that students will persist is driven by the extent to which students are integrated, both academically and socially, into the college environment. Tinto's model remains essential to understanding the complex nature of student retention and is the conceptual framework for the extensive body of research that examines the effectiveness of various strategies used to engage students successfully [3,4].

Retention of students who transfer from the community college to research institution environment presents particular challenges. Institutional impact on community college students who do transfer has been established in the context of Tinto's model. Moreover, both the community college and the university are responsible for identifying the challenges of transferring and offering strategies to address those challenges [5]. Orientation sessions that target transfer students specifically for early help with services such as advising are important for the initial transition, but Townsend and Wilson provide evidence that formal orientations may need to provide

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more "hand holding" [6]. Furthermore, Townsend and Wilson suggest that resources expended by universities to increase academic engagement are disproportionately targeted at first-time freshman students. Even undergraduate research, which typically is geared for juniors and seniors, is more likely a feature of the non-transfer student academic experience. According to a 2010 study of 404 institutions by the Institute for Excellence, 12.1% of transfer students participate in undergraduate research, compared to 34.0% of seniors [7]. Not only is undergraduate research regarded as an effective way to achieve academic engagement and, thus, positively impact retention, findings from a recent study suggest that undergraduate research may help underrepresented minority students more fully integrate into the institution [8].

While retention models have evolved to reflect larger societal changes and research identifies effective intervention actions, Tinto points out that effective implementation remains a major challenge [9]. Thus, program elements from two existing, successful School of ECE programs contributed to the successful implementation of the TIES program. One of those program components centers on undergraduate research and engagement with other students, including graduate students. Another major program component ensures regular contact with faculty, which Tinto argues is critical to successful institutional retention programs.

III. BUILDING ON PAST ACTIVITIES

A. Partners in Transitioning to Tech

Partners in Transitioning to Tech (PITT), a retention program aimed at dual degree transfer students from historically black colleges majoring in ECE, was first implemented in 2004 with seed funding for five-years from Georgia Tech's College of Engineering. Like most community college transfers, dual degree students transfer in at the junior level. Of the several program elements used for PITT's nontraditional student cohort, two were identified by participants as particularly helpful [10]. First was the use of "Super TAs," who were ECE majors with dedicated time each month for PITT students. The Super TAs had a variety of roles, such as mentor, tutor, and friend, and, moreover, they regularly checked-in with students to show interest and concern, often heading off problems before they became serious. Second was the practice of holding small group course planning and advisement sessions run by the PITT faculty program directors. The small group dynamic encouraged interaction among students, sharing advice regarding courses, instructors, and study strategies. Having these same faculty advisors facilitate these sessions helped create a sense of ease with faculty, an environment that many of the students had at their previous home institutions. Both of these program components have been highly successful for the TIES program.

B. Opportunity Research Scholars

Opportunity Research Scholars (ORS) is a highly successful, innovative program designed to increase retention and promote the academic success of ECE students [11]. The model for ORS is based on studies on student retention and success that consistently confirm the relationship between student "engagement" and academic success. As a team-based undergraduate research program, 3-4 undergraduate students are matched with a PhD student mentor and work on specific research projects, attend monthly workshops, complete technical communication assignments, and interact with faculty in the research laboratories. The effectiveness of this program to fully "engage" traditional students in the academic environment was the impetus to adapt the program for community college transfer students.

ORS provides two options for TIES scholars. The greater time commitment involves joining a research group, which requires weekly hours in the lab, developing a research poster, and presenting at department competitions. TIES scholars, in good academic standing, may apply for an ORS slot during their second semester at Georgia Tech. The academic progress of TIES scholars who do participate in ORS is closely monitored to ensure that the demands of the research experience do not conflict with progress toward degree. The alternative is to participate only in the monthly workshop series. These workshops are designed specifically for electrical and computer engineering students tend to be interactive, and engage students with their peers in the school. Examples of monthly workshops include:

- A Glimpse into Industry: Working in industry and life after graduation (past presenters include representatives from Rockwell Collins and Texas Instruments)
- Developing a Scientific Research Poster: Conducted through ECE's Undergraduate Professional Communication Program.
- Georgia Tech Research Option Program: Conducted by ECE faculty members, this interactive discussion focuses on research for credit, Georgia Tech's Research Option, and other options for maximizing the research experience.

Since undergraduate research is a successful strategy for increasing student retention, keeping students motivated to do well in school, and helping students understand how coursework translates to real world application, ORS has been a valuable option for TIES scholars.

IV. PROJECT STATUS

These ECE programs constitute the basis for many of the strategies that have been used for the TIES scholars. Eligible students have been invited to apply for participation in ORS, and many of the successes and lessons from PITT form the foundation of the TIES support system.

At the end of the fourth year, 31 students have participated in the TIES program. From that group, 21 have successfully graduated, 8 students remain active and in good academic standing and 2 students have not been retained at the institution. At the end of the third year, the decision was made to close enrollment for the TIES scholarship in order to reserve enough funding for all 29 students retained in TIES to graduate. Of these 29 students, 27 students regularly attended TIES functions and utilized the support services offered through the program. Non-scholarship students who have also transferred from community colleges are invited to TIES programming, although few attend. Some TIES students were non-scholarship eligible for specific semesters because they fell below the required minimum course credits. These students however remained active in the program during those semesters as part of the TIES community.

Given that a major purpose of TIES is to minimize the challenges of transferring from two-year to four-year institutions in order to retain and graduate students, building a support system among students was a top priority. In the first year of the program, this process was challenging because of the lack of a critical mass of students. Only four TIES scholars were in the program for the first semester. To compensate, the TIES program staff met frequently with the students to establish a connection between them and the program directors. This first group of students formed a tight-knit group and a solid foundation for the next year when the program increased to 20 active TIES scholars.

The community-building activities fall into three basic categories:

- Informal meetings with TIES program staff
- Workshops conducted by non-TIES staff
- Events hosted by the department's undergraduate research program (ORS)

The informal meetings with TIES program staff have consistently been successful in terms of creating connections both among the students and with TIES staff. These meetings, held at the beginning and mid-point of the semester, focus on individual student questions. The culture during the meetings is very informal and interactive, where students answer each other's questions and offer advice. During the meetings, TIES staff responds to student questions regarding course planning and selection, as other students feel comfortable chiming in about their own experiences. Study partners and tutoring have resulted from the interactions at these gatherings. The supportive atmosphere has also encouraged students to take advantage of the open-door policy of the TIES staff, which contributes to an overall comfort-level within the Georgia Tech environment. Each semester, a growing number of TIES students take advantage of the opportunity to meet one-on-one with TIES staff – an offer that is reinforced during the meetings.

The workshops conducted by non-TIES staff have been well attended and appreciated, based on feedback from the TIES students. While these sessions may not be as effective for community building as the informal meetings, they provide students with critical information and materials in a small group setting. Each year, workshops are offered that focus on career-related topics, which have been extremely well received by the TIES students. Even though all of these workshop topics can be found in other venues at Georgia Tech, the TIES students appear to benefit more from the dedicated events. For students who are relatively new to Georgia Tech and who enter as juniors, the larger workshops held in lecture halls can be intimidating.

Taken together, these program components are intended to enhance options for post-graduation opportunities and promote graduate school attendance. Based on survey data from the 2012-13 TIES cohort of 19 students receiving TIES funding who were asked if their plans or goals for after graduation had changed since transferring to Georgia Tech, eight reported that their plans had changed and that they now plan to go to graduate school. In addition two students said that they had always planned to attend graduate school. While these data do not show that TIES actually caused the change, the programming is geared at retaining these students and creating a positive academic experience. The survey data thus far confirm that these goals have been achieved.

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Investigating How Service-Learning Alumni Construct their Engineering Selves

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Abstract– **Prior research has demonstrated that traditional academic pathways tend to provide engineering students with a predominantly technical sense of professional identity. We respond to this research by investigating how a non-traditional pathway, marked by a large service-learning program, engenders a sense of engineering identity. We approach this investigation using a thematic analysis and are currently developing themes related to how alumni/ae of this program construct their engineering selves. We are currently in the early stages of analysis and will present the elaborated themes at the conference.**

Keywords- engineering identity, non-traditional pathways, mixed methods, sociotechnical

I. Overview

Leading voices in the engineering community, such as ABET [1], the NAE [2], the ASCE [3], and the ASME [4], have established criteria that articulate the desired characteristics of an engineer. However, such visions of engineers do not always align with the reality of how engineering is understood and practiced, as demonstrated by several key findings from engineering studies and engineering education literature (e.g., [5-12]). Indeed, many studies reveal that professionals tend to construe their engineering identity as one that is purely technical, even if most workplace activity is non-technical in character. Additionally, they suggest that the academic pathways and undergraduate experiences of pre-professional engineers play a substantial role in constructing how they understand their engineering abilities and identities [6-12], even if this role is unintended [10].

This particular study extends prior research by investigating how alumni/ae of Engineering Projects in Community Service (EPICS), a multidisciplinary, service-learning program, make sense of their engineering identities and then connect these identity constructions to their undergraduate experiences. Unlike the earlier cited studies, this investigation examines sense-making in professionals with *non-traditional* academic pathways, specifically participation in EPICS.

II. Conceptual Framework

We place this particular investigation among other core theoretical concepts found in other studies. We especially attend to how the participants in our study understand technical and non-technical characteristics of their engineering ability and identity. Previous social science research on engineers, including those already cited, have responded to examining how engineers understand technical and non-technical nature of their work. Notably, Faulkner has posited that a social/technical dualism, or "a strong sense of the technical which specifically excludes the social", permeates "engineering professional training, identities, and practice" (p. 764 in [5]). Other engineering studies research provides further evidence for this social/technical dualism (e.g., [11, 14]), although some studies have found that this dualism may be somewhat more nuanced than originally understood by Faulkner ([9, 13]).

Additionally, we attend to the intentional and unintentional role of engineering education in *professionally socializing* the participants of this study. In other words, we especially examine how the experiences of engineering education, including EPICS, have influenced the participants' thinking about "what it means to be a 'good' engineer" [11]. Although sociological studies, including those done on engineers, name this dimension of education as *professional socialization* (e.g., [5, 11], several investigations of engineering education have recognized how undergraduate engineering degree programs play a critical role in the ways that their students construct understandings of their "engineering selves" (p. 117 in [12]; see also [8, 15-18]).

III. Methods

This study is part of a larger embedded, mixed-methods investigation [19, 20], specifically QUAL(quan), which probed how EPICS alumni/ae relate their experiences in the program to their professional preparation (for more on this study and EPICS itself, see [21-23]). In this larger study, a diverse range of participants (n = 27) were purposefully sampled from respondents to a previous survey (n = 523). We conducted semi-structured, in-depth interviews with these 27 participants via Skype and telephone calls. The interview protocol was informed by both the individual survey responses the objectives of our larger investigation.

Though the explicit focus of the larger study was on their experiences in EPICS, as we analyzed the transcripts we were surprised to discover the richness in how interview participants articulated their own engineering identities and abilities. While such discussion might be expected from participants that practiced engineering (n = 18), we found that even participants with non-engineering occupational roles (n = 9) had profound ways of discussing how they identified as engineers. Participants often connected these descriptions of their engineering identities to EPICS and other experiences.

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Consequently, we are conducting a separate analysis of the transcripts with the objective of thematically organizing the participants' articulations of how they understand their engineering selves. The methodology of this particular investigation is considerably influenced by how Braun & Clark describe *thematic analysis* [24]. That is, we are following a systematic process that involves multiple iterations of studying the participants' interview transcripts in order to organize thematic descriptions of how service-learning alums understand their engineering selves. As we have described elsewhere [22], we have analyzed the transcripts for in-depth understanding of *individual* participants' accounts as well as thematic patterns that describe the *collective* set of accounts.

IV. Preliminary Analysis

Although we are in the early stages of organizing and describing patterns of how study participants describe their engineering selves, we have already seen some broad themes in their accounts. More specifically, we note that the participants employ a variety of strategies for reconciling technical and non-technical characteristics of their practice and identities. They often distinguished between technical and non-technical characteristics of their professional identities, practice, or training. Such perspectives did not completely align with Faulkner's social/technical dualism [5], at least in the purest sense. Even among those alums that demonstrate some evidence of such dualistic thinking, they seem to at least consciously value the non-technical dimensions of their work.

Additionally, we recognize through their accounts that EPICS and other undergraduate experiences played a critical role in helping them understand what it was to *be* or *become* an engineer. This socialization effect of their education seems so pervasive that even some participants *without* engineering jobs discussed how they saw themselves as engineers. With some exceptions, participants typically expressed how EPICS interacted with other undergraduate experiences to show them "what it means to be a 'good' engineer" [11].

At the conference session, we will elaborate on these themes to further describe how EPICS alums make sense of their engineering selves. We will also discuss how these identity constructions connect to their experiences in EPICS and other undergraduate experiences and what these findings suggest for future engineering education research and practice.

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Lesbian, Gay, Bisexual, and Transgender Students in Engineering: Climate and Perceptions

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***Abstract*—Few studies of the climate in engineering for lesbian, gay, bisexual and transgender (LGBT) students have been conducted. According to these studies, LGBT students are often forced to cope with hostile climates in engineering. To address the question of how LGBT students experience the climate in engineering, we interviewed a total of 16 students at two institutions in the Midwest. We analyzed the interview transcripts using open coding based on a combination of Meyer's Minority Stress Theory and Tinto's Theory of Student Departure. Preliminary results indicate that LGBT students experience more situations of exclusion within engineering than in other areas of their campuses. Based on their experiences, students advocate increased visibility for LGBT students in engineering and a mentoring program to provide support from engineering faculty and graduate students who also identify as LGBT.**

Keywords*—LGBT, engineering, undergraduate, climate study, student interviews, mentoring program

I. Background and Significance

"While much is known about the experiences of women and racial/ethnic minorities in male-dominated fields such as engineering, the experience of lesbian, gay, and bisexual (LGB) indentifying individuals remains unstudied" [1]. Cech and Waidzunas [1] broke new ground in 2011 with the first study to specifically investigate the experiences of LGBT students in engineering. Interviewed LGBT students reported feeling "tolerated" rather than seeing engineering as tolerant or accepting. They were forced to employ a variety of emotionally exhausting coping mechanisms to persist in their engineering programs.

While Cech and Waidzunas were the first and only scholars to consider LGBT students in engineering [1], others have studied LGBT college students in general. In the typical college classroom, a significant percentage of students are LGBT with reported proportions up to ten percent [2]. Surveyed LGBT students report experiencing verbal and physical abuse, mainly from other students [3][4], and are at higher risk of encountering sexual prejudice in male dominated majors [5]. There is a need, in both engineering and LGBT research, to address the issues raised by Cech and Waidzunas and to better understand the unique difficulties faced by LGBT students in engineering.

This study builds on the work of Cech and Waidzunas by expanding on the experiences of LGB students in engineering at two different institutions as well as including the perspective of a transgender student, making it truly a study of LGBT students in engineering.

II. Methods

Interviews were carried out at two different institutions, Lavender University and Teal University (pseudonyms). Of the 16 undergraduate students interviewed, three self-identified as lesbian, 10 as gay, two as bisexual, and one as transgender (specifically genderfluid).

A. Lavender University

Near the beginning of the Fall 2012 semester, we interviewed 13 LGBT undergraduates in engineering at Lavender University, a rural, public institution in the Midwest. Interviews were semi-structured and focused on several themes, including overall campus climate, the climate in engineering, interactions with others related to LGBT issues, and recommendations for improving the climate in engineering. These themes were based on interview protocols used previously by Cech and Waidzunas [1]. Interview transcripts from Lavender University were coded using open coding based on a combination of Meyer's Minority Stress Theory [6] and Tinto's Theory of Student Departure [7]. Minority Stress Theory emphasizes the unique stresses minority individuals face stemming from the conflict between their own values and those of the dominant culture around them [6]. These stresses reduce the sense of social integration students feel within the academic culture around them, resulting in a lack of overall academic integration and possibly the decision to drop out of college [7]. Analysis is currently ongoing to fully develop themes.

B. Teal University

Near the middle of the Spring 2013 semester, we interviewed three LGBT undergraduates in engineering at Teal University, an urban, private institution in the Midwest. In addition to the content of the Lavender University interviews, Teal University interviews included themes of family background and high school experiences. Open coding of the Teal University interview transcripts is currently ongoing.

III. Preliminary Findings

We developed four preliminary themes from the Lavender University interviews which include the minority stresses

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expressed by interviewees and suggested interventions to improve their academic integration: 1) engineering is heteronormative, 2) engineering is forgotten by the LGBT community, 3) engineering is exclusionary, and 4) LGBT engineering students need support. The lack of engagement between engineering and the larger LGBT community leaves students caught in the middle with few places to turn for support, either academic or personal.

A. Engineering is Heteronormative

The interviewees perceived engineering as heteronormative both from a lack of conversation about diversity in their courses and from a lack of personal life discussions between engineering students in general. This focus on strictly technical activities and "taboo" against sharing personal stories in engineering indicated to LGBT students that their perspectives were not desired or valued within the normative expectations of heterosexual engineers. Representative quotations from interviewees are below (names replaced by pseudonyms):

> I think that [Lavender University] as a whole is very, very open minded and accepting, but I think in the [engineering school] it's a little bit different just because it's totally a straight male dominated world. … I don't feel necessarily discriminated against, but I don't feel like overly accepted either … [Elsewhere on campus] we're constantly bombarded with, "Keep an open mind. Be accepting," which I think is totally great, obviously, but I don't necessarily hear that message in the College of Engineering. – William

> I wanna talk about my girlfriend without having to blurt it out and like I want it to just be okay. I want to know [engineers are] okay with it because even though it doesn't define me, it's part of who I am, so it's just easier. – Mary

> My professor … whenever he's describing charges of atoms, positive and negative … he's always like, "The girl will be here and the guy will be here and you are very attracted to the girl," and he's asking all the guys … and I'm just thinking, "Well, I mean, yeah, most of these guys are, but I'm not going to be! This example doesn't pertain to me!" – Josh

B. Engineering is Forgotten by the LGBT Community

LGBT students in engineering perceived a lack of support from the general LGBT community on campus specifically for engineering. Engineering buildings often lacked visibility for LGBT organizations or events as if they had been neglected deliberately. Some non-engineers in the LGBT community also expressed surprise or confusion upon discovering that LGBT students were pursuing engineering majors. Representative quotations from interviewees are shown below:

> We should post more fliers and stuff around the actual engineering buildings…. There are people who are in that building … who might want to join the group … but they just don't have the access to it on their own because they're not searching or some reason like that and it would be good if it was available for them to see. – Josh

> [Non-engineers in the LGBT community], typically they say, "[Engineering] doesn't really seem like a field that you'd be interested in," like "you" connotation with, "because you're gay." – Josh

C. Engineering is Exclusionary

Fundamental aspects of engineering as a discipline, such as male dominated majors, frequent team projects, packed academic schedules, and constant competition create an indirectly exclusionary climate for LGBT students. LGBT students described anxiety with disclosing in mostly male engineering teams because of the reactions of their teammates, but lacked the free time outside of class to pursue other activities or find community outside engineering. Situations of exclusion were described most often within the engineering classroom or during casual conversation with other engineering students. Representative quotations from interviewees are shown below:

> I'll just not disclose [my sexual identity] if I have a group thing just because things tend to go a lot smoother if I don't bring something like that up. – Alan

> I think I'd like to go to some of the [LGBT student organization] stuff, but, yeah, that's it. I really haven't had time to do anything else. – Sarah

D. LGBT Engineering Students Need Support

To improve the climate in engineering for LGBT students, the interviewees commonly recommended increased visibility of LGBT organizations on the engineering campus as well as incorporation of LGBT issues into engineering courses. Every interviewed student responded positively to the idea of implementing of a mentoring program for LGBT students in engineering with LGBT faculty and graduate students or allies. In general, the interviewees' suggestions would increase visibility and support for LGBT students in engineering.

IV. FUTURE DIRECTIONS

To further explore the climate for LGBT students in engineering at Midwestern institutions, we will finish analysis of interviews at both Lavender and Teal University and triangulate with secondary data from climate surveys taken in 2011 at a rural, public institution, an urban, public institution, and a rural, public institution without an engineering program. We will also compare the climates of rural and urban institutions. This analysis is currently ongoing.

Since interviewees responded positively to providing an LGBT mentoring program in engineering, we hope to start such a program at one of the institutions studied with interested LGBT faculty and graduate student mentors during the Fall 2013 semester.

While these exploratory interviews give a window into the climate experienced by LGBT students in engineering at two Midwestern institutions, we hope to extend the study nationwide to reveal the similarities and differences in the climate in engineering for LGBT students in various regions across the country. Collaborations with institutions on the East Coast are currently underway.

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Providing a Holistic Educational Environment for the whole Family

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***Abstract*—This paper describes a multi-device Learning Management System based on Moodle with alternative interfaces providing accessibility for people with disabilities. The software architecture built over Moodle is described as well as the interface created to offer access through a TV. An initial user focus group has been used to test and get feedback for further developments of the system.**

Keywords——Adapted Interfaces; Educational Environment; e-learning; accessibility; disabled people

I. Introduction

In parallel to the technological advances in the world of the Internet and the Web we have witnessed a quantitative and qualitative increase in the amount of educational content and supporting platforms for distance learning and e-learning. E-learning environments are usually based on a desktop or laptop to support users' interactions, so the introduction of mobile devices like smartphones or tablets provides the missing element to foster enriching ubiquitous learning, that is, the possibility to learn everywhere anytime. Besides, some of these paradigms support group interaction, thus facilitating collaborative learning among peers or between learners and educators. This represents an ultimate contribution to bring education closer to the citizen, regardless of their initial education level or their intellectual and physical abilities. Specifically, groups of people with some degree of dependence and people with disabilities in particular, would dramatically benefit from these new technologies to increase their training and education opportunities. For example, elder people or wheelchair users may encounter difficulties to access conventional educational facilities.

The Foundation Vodafone-CERMI/Spain Observatory 2011, through its report on the current state of accessibility in Information and Communication Technologies (ICT) [1] stresses the need to implement strategies to promote the digital inclusion of people with disabilities, focusing on overcoming barriers and promoting their skills and motivation, as people with disabilities still face many barriers to the use of ICT products and services, which in turn are essential elements of social and economic life.

Nevertheless, technological solutions to provide distance education to these groups are still inadequate, so the aim of the research work discussed in this paper is to provide a supervised learning and self-adaptable environment for people with disabilities, focusing on the specific training-related needs of our target group, who in many cases also need direct and continuous assistance by a teacher or relative. Therefore, two main aspects guided the development of this platform, namely (1) the need for adapted peripheral and control devices, and (2) the need to create an environment in which several people can interact at the same learning scenario.

First, we have analyzed the daily behavior of our target group with the aim of e-learning to move closer to them and not the other way around. Recent studies [2][3] show that a high percentage of people with special needs spend many hours at home, in the company of family members and/or caregivers in physical spaces typically known as living rooms or TV rooms. That is the reason why this device will be used as the central element around which to build our proposal. Note that the TV set is the electronic appliance with the greatest presence in homes around the developed world, and with which target users are more familiar. In addition, we introduce the Home Theatre Personal Computer as the binding element between the TV world and the Internet. The hardware platform eventually developed will also integrate different control devices and peripherals tailored to these groups, ranging from gesture-based remotes to touch screens in smartphones and tablet computers.

On the other side, we have tried to adapt available e-learning services rather than to develop new ones from scratch. The real challenge lies in providing convenient access to these tools, that is, to adapt them to be used by an individual with some degree of disability. For this reason, we developed a Moodle client specifically tailored to a TV environment, as it is one of the most popular and widespread Learning Management System (LMS), with over 72,000 instances in 223 countries worldwide [4]. This makes it possible to reuse the management engine in any existing Moodle instance, and therefore to gain access to wealth of pre-existing content and courses. This adapted LMS is completed with a self-configurable environment based on the target users' profiles, which include an accessible TV viewer application to gain access to resources such us Wikipedia, YouTube, email, social

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network platforms, and a portfolio of educational, rehabilitation, and cognitive training games specifically tailored to people with special needs.

The rest of the paper is organized as follows: the next section discusses the technological proposal selected to provide our target holistic educational environment for people with disabilities. Then, Section III introduces the platform developed from the target user's perspective, that is, the TV-integrated Moodle client and its functionalities, together with the collection of interfacing and control devices that provide full accessibility to the platform. Section IV outlines the pilot carried out with real users intended to assess the usability and usefulness of this proposal. Finally, we provide some conclusions on the design, development and testing of the developed system.

II. Technological proposal

Typically, people with disabilities require devices specifically adapted to their particular needs. They are even part of their personal spaces. In many cases, the adaptation of these devices has a much higher cost than the one these individuals can afford. As a consequence, in many cases performing certain common daily tasks or activities is not possible to all.

In the world of education, and more specifically in the world of distance learning, the above mentioned adaptation requirement is still present. People with mobility impairments, people with cerebral palsy, the visually impaired or the Deaf will definitely have different needs when facing the adaptation of an LMS.

There are some initiatives for the development of platforms following accessibility standards set by the World Wide Web Consortium (W3C). In these cases, the accessibility issues are focused on the platform itself, and not on providing a suitable access model to the platform. Thus, although the platform may meet W3C the accessibility requirements, if users with certain limitations (e.g. mobility impaired users) cannot interact with it, the platform is no longer universally accessible in a strict sense.

On the other hand, if we focus on the content hosted by any distance learning platform and the functionality provided to interact with that content, we can see a tool with enormous potential to support most educational scenarios.

According to this premise, this project extends the access mode of an LMS so that for it to be accessible not only through its default interface (i.e., a web browser), but also through any other device capable of processing the information provided by web services.

Another important feature of the proposed model of operation is the graphical user interface not being unique and not being dependent on the specific LMS, but on the eventual device utilized to display the data obtained via web services. Therefore, the client device is the one responsible for graphical user interfacing, that is, to provide the same content in an accessible way according to the specific characteristics of individual target users.

Among the LMSs currently available, Moodle 2.0 has been chosen for this project. This decision is based on three main reasons:

- Its enormous popularity.
- Not being a particularly accessible LMS. A side objective of this research is to study how a non-accessible platform can be converted into an accessible one.
- The specific version chosen supports web services. Web services support the communication among software applications and components thereof in a standard way, independent of the select programming language or software development platform, both at client and server sides.

An important point to consider is that the support for web services offered by this platform is intended primarily for platform administration (e.g., user management). For this, Moodle 2.0 provides support for creating applications via Remote call Procedure based on Extensible Markup Language) XML-RPC, Action message Format (AMF), Representational state transfer (REST) or Simple Object Access Protocol (SOAP). In our case, we will rely on the XML-RPC technology to extend the functionality of the platform. This decision is based on its dynamic characteristics to support the introduction of new parameters for already existing functions. With this, new functions are not needed in the client side to interact with new features introduced at the server.

Fig. 1 illustrates the internal workings of web services in Moodle. As depicted by the figure, have defined an intermediate layer within the Moodle's core to serve as a middleware between requests from the web service layer and each of the modules that provide LMS features, including user management, course management, questionnaire management, or multimedia content management.

A. User authentication

The authentication requirements of the developed platform go beyond the Moodle authentication model. The need to provide additional services to those provided by the LMS requires a centralized authentication service. All services defined in the platform, including tele-education, should interact with this centralized authentication service to check users' credentials.

Authentication is also based on the web services architecture [5]. This architectural model enables the platform to be fully scalable, supporting the introduction of new services in a fast and flexible way.

For user authentication, SOAP was the selected web services technology. In a user authentication system, security is a most relevant aspect. This technology supports channel encryption (SSL) through WS-Security [6]. With this, all communications with the authentication service will always be encrypted, thus adding a layer of security to the transmission of user-password pairs.

Fig. 2 depicts the flowchart for user authentication. To provide greater security to information exchange, the user-password pair is sent only once. Upon receipt of both elements, user and password, the authentication service verifies that these credentials are correct and generates a session token to be returned to the user. This token is unique for each user currently logged in the platform. When users interact with any of the services defined, they send their session token, and the service requested will be responsible for validating the token with the authentication service. This operation mode supports all users to be collected in a single centralized service, which in turn facilitates user administration and efficient access of each user to each of the services offered.

To access the features provided by Moodle from the new adapted client devices, an additional software layer has been added to the server including different web services to support (adapted) access to the main features of the LMS (cf., Fig. 1). The process for invoking this new layer of services is as follows:

1) Once the user has been authenticated, the client application gets the corresponding session token for that user.
2) The authentication service interacts with Moodle's back-end to report about the new user. Moodle creates an association between the user and the session token.
3) The client application includes the session token in all requests performed to Moodle's web services.
4) The new web service layer checks that the received token is valid, and identifies the accessing user.
5) Moodle returns through web services all the information requested through the client application.

As can be inferred from the description above, information kept by Moodle is no transferred directly to the user, but it is packed to be sent through XML-RPC protocol to the client application. This application will display the information once conditioned according to the specific user's profile, and will collect user actions and send them back to Moodle for her to browse across the desired educational content.

B. Communication

In a system of this kind, communications are an essential part of it. When we talk about communication, we are referring to the ability of the system in establishing a communication channel among users.

To implement the initial idea to provide a system capable of adapting to different client devices requires establishing a versatile and extensible communication service. Presently, a communications protocol both popular and having the required functionality is the Extensible Messaging and Presence Protocol (XMPP) [7]. Among other popular services on the Internet, this protocol is used by both Google (i.e., GTalk) and Facebook messaging services. Its potential to be adapted to the particular needs of most messaging projects makes it a very interesting solution for almost any messaging or conference service. Another major advantage of this protocol is its support for user presence control. This feature facilitates not just knowing when a user signs in and off a system, but also identifying the actual device that completed the connection. Thus, applications using this protocol will be able to route all messages in a simple way to the actual (mobile) device where the user is located.

The platform discussed in this paper uses an Openfire [8] communications server, distributed under the General Public License (GPL). With it, the platform is fully autonomous to manage all communications required by users without having to resort to third-party communication and presence control services.

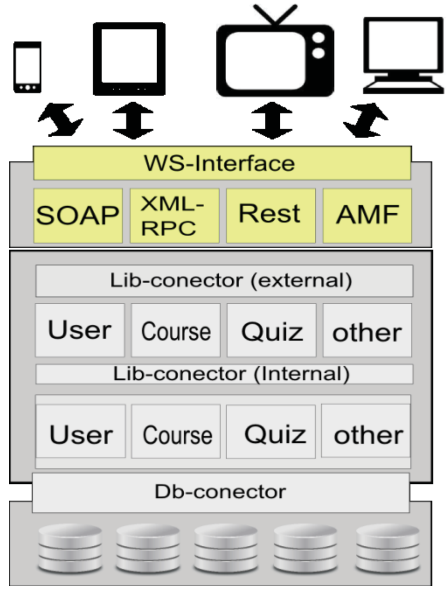

Fig. 1. Web services developed at Moodle

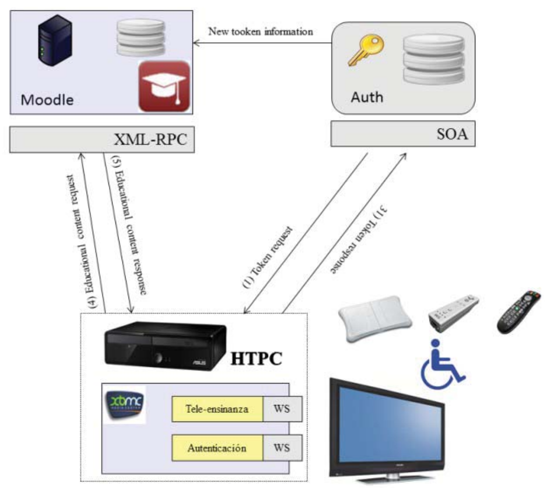

Fig. 2. T-learning system's architecture

Communications become a means through which both students and teachers can easily stay in touch. For example, a student may ask a question through the chat facility using her adapted device, and teachers may answer it via any instant messaging program that supports XMPP protocol.

III. Holistic Educational Platform

The aim of the platform discussed here is to implement a tele-education system accessible through different devices to facilitate and / or provide access to any individual independently of her personal dependence situation. In this section we outline the adaptations performed to Moodle to be used from a television environment based on a Home Theater Personal Computer (HTPC). The implementation of this client environment has did not only addressed the technical developments needed to use a Moodle front-end from this environment, but also, and above all, to facilitate its usage by people with a broad range of disabilities. For that, various interaction mechanisms have also been integrated.

As discussed above, the design of this system is based on a client using an HTPC. This device implements all the business logic required to interact with Moodle and to display educational content on a TV screen. All information transmitted between Moodle and the client is packed into XML-RPC frames to be processed and conditioned to be shown on the TV.

It is important to recall at this point that the client application will be in permanent contact with the web services developed at the server side to post back all the actions performed by the user. In the case of the previous figure, when the user answers a question in the questionnaire, the client application will send this information to Moodle, so that it can perform the same operations as if the accessing client were following the course from the standard web browser interface. Insofar Moodle is concerned, the student will be following the course in exactly the same way as if she were accessing it from any web browser. Thus, all features available in Moodle (e.g., to track user actions across courses) are still available for courses followed through adapted client devices.

A. TV-integrated functionalities

Once signed in, the student has access to both Moodle courses and the communication facilities introduced above. Through the communication service, students may establish communication with the teacher directly from their TVs and the adapted control devices adapted discussed below. Thus, as students progress along their courses direct assistance from teachers or peers in their address books can be obtained in a much more agile way.

To carry out the courses in which a given student is enrolled, the client application communicates with Moodle through the implemented web services according to the communication mechanism discussed in Sect. II. All information received by the client, (e.g., the lessons in a course or specific educational resources) are displayed on the TV screen in a way accessible to the user's needs. In turn, the student will use the TV remote or any other adapted control device to navigate through the options displayed on screen and interact with them. Each of these actions will be captured and sent back to Moodle for it to perform the required operations to support course interactions. Among the actions a user may perform are:

1) Access to the course list: a student may access all courses in which he is currently enrolled.

2) Access to a specific course: a student may follow any of these courses.

3) Score/marks visualization: a student may view the scores and marks obtained on her courses.

4) *Testing:* a student may complete any evaluation questionnaire associated to any of her courses.

Note that all Moodle logic related to course access is implemented in the new scenario. For example, course completion criteria are strictly followed by this platform. As discussed above, the developed web services act as a middleware to isolate the underlying Moodle business logic while allowing a user to follow a course from any supported client device. In other words, the client is responsible for establishing and maintaining the exchange of information between the user and Moodle, while Moodle is responsible for all the business logic of the courses. For example, when a teacher establishes that a course has certain completeness conditions, these conditions will still be present no matter the actual access device or student profile. If certain conditions are defined for evaluation questionnaires, these conditions will be followed by all client instances. As in the standard Web version, the student receives information on the completion conditions when accessing a questionnaire (e.g., number of remaining attempts, evaluation methods, scores obtained in previous attempts, etc.), the only difference being that this information and the actions triggered thereof are handled in a way adapted to each specific student.

Fig. 3. Control Platform through several dispositives

Fig. 4. Control Platform through Kinect

B. TV Adaptation

One of the advantages discussed earlier corresponds to the possibility for users to access and interact with Moodle courses using adapted devices according to their personal requirements and needs. To provide fully adapted control to different types of users with different disabilities several control peripherals were integrated. We enumerate below the ones currently available.

1) Conventional remote (cf. Fig. 3).
2) Nintendo's WiiMotes [9] (cf. Fig. 3).
3) Microsoft's Kinect [10] (cf. Fig. 4).
4) Tablet and smart-phones (cf. Fig. 3).
5) Additional devices connected by USB, infrared, WiFi or Bluetooth.

IV. Holistic Educational Platform Validation

The platform presented in this paper has been validated, from a technical and functional the standpoint, through a pilot project with real users (cf. Fig. 5) with disabilities. This pilot was performed with the collaboration of the Galician Confederation of People with Disabilities (COGAMI) [11], an organization with more than 20,000 associated people with different types of disabilities. This collaboration was orchestrated as part of a research project funded by the department responsible for social policies at the autonomous government of Galicia (Spain).

Fig. 5. User at home

This association, COGAMI, is a confederation created in 1990 with the aim of strengthening the member associations and to provide solutions to the isolation in which most people with disabilities in Galicia lived. Collaboration with COGAMI arises from the adequacy of the developed system to the profile of this confederation's users. COGAMI's fundamental mission is to achieve full inclusion of people with disabilities in all areas of society, through the defense and promotion of their rights, and fostering through partnerships and coordination with other stakeholders the delivery of services meeting their needs and expectations. Therefore, they proposed University of Vigo in Spain and the researchers involved in this project to provide technological solutions as the ones presented in this article.

Among the most important services provided by COGAMI, are the ones related to training and employment promotion. The testing of the platform discussed in this paper was performed in this scenario. COGAMI already had some expertise on computer-mediated education, as it has already been utilizing a PC-based e-learning platform named Delphi.

For the realization of the pilot project, COGAMI selected 15 users, with degrees of disability between 33% and 95%, with more than half of participants (53.33%) experiencing an average degree of disability around 70%. Note that all pilot participants were familiar with the use of tele-education systems in traditional environments (Web and PC-based Delphi).

A. Results

We discuss below the main results of the validation of the use of the platform by the users selected. In relation to the methodology implemented for the pilot experience, it was organized along two phases. First, COGAMI staff made a presentation of the platform at each participant user's premises. This presentation consisted on a single brief introductory training session lasting 15 minutes. Then, at the beginning of the training course through the platform, users were given two questionnaires [12] together with specific instructions to complete them. The first questionnaire had a series of questions about participants' previous experiences with PC platform and the TV, which was intended to be complete prior to interacting with the platform. The second questionnaire, intended to be completed after the completion of the course through the platform, focused on evaluating the usability of the system, the different services offered, and the course content.

4) Results on content assessment.

User feedback was collected on the degree of accessibility of content and its presentation through the Moodle client for the TV set. Questions tackled the readability of textual content, the display of different types of multimedia content, the information provided to track courses, the quality of video assets, and accessibility and ease of use of self-assessment instruments (i.e., adapted Moodle questionnaires).

Regarding the participants' responses to these five items, we would like to point out that results show an average user satisfaction level above 70% in relation to reading and watching course content on the TV set, and in relation to the quality of the information (cf. Fig. 6).

5) Results on platform assessment.

At the technical level, and specifically regarding its degree of usability, the questionnaire included questions designed to assess general usability and accessibility aspects of the platform. These questions were proposed by COGAMI, an institution that collects ample experience on providing services to people with disability, and they addressed the control peripherals used, the information provided on the use of the platform's features, the quality of the content displayed on the TV screen, whether it was possible to intuitively understand the use of the platform, the communication channels with the caregivers and relatives, the degree of interactivity offered by the platform, and its overall accessibility. Fig. 7 provides some figures about the users' feedback on these aspects. In general, feedback from users was completely satisfactory, as most aspects achieved a 100% degree of perceived usability and accessibility, beyond our initial expectations when designing the pilot.

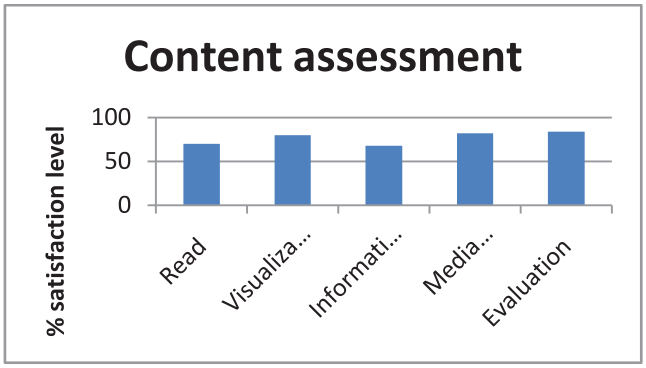

Fig. 6. Main Results on content assessment

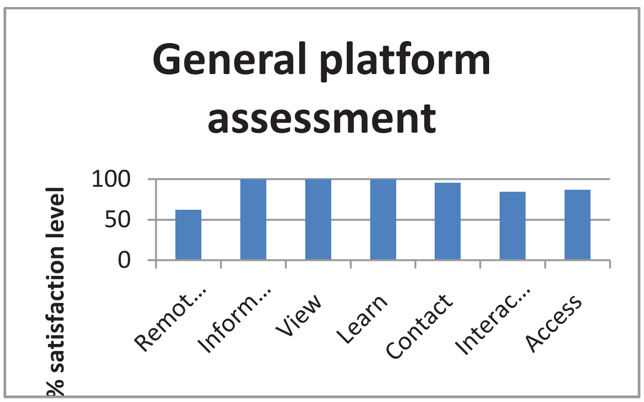

Fig. 7. Main Results on platform assessment

One of the outcomes that deserve special attention, as it was the aspect getting lower user scores (i.e, satisfaction levels), is the feedback on the remote control used to control the platform. Both the conventional TV remote and the Wiimote were not perceived in many cases as the most suitable solution for people with a very high degree of disability. However, as the open nature of the HTPC supports the integration of any input device with a USB connection, it would be possible to integrate specific custom devices to access to the platform. Nevertheless, the achieved average satisfaction rate was around 60%, which in any case is higher than the average satisfaction rate of other solutions.

V. CONCLUSION

This paper discussed an e-learning platform designed for the whole family, and especially adapted for people with some degree of disability or dependence. It described the technological solution adopted, based on open systems, and more specifically on the Moodle LMS and the HTPC platform, facilitating its maintenance and future upgrades sustainable development. The paper also introduced the architectural solution addressing the integration of different control systems and devices that complete the final accessible platform. Then, we have described the development and integration of a Moodle client tailored to a TV environment and how access to the services offered by this LMS is provided through a TV appliance. This adaptation is performed considering that our target audience may include people with disabilities or experiencing some degree of dependence (e.g., the elder), so both the graphical and integrated control peripherals have been integrated taking into account the general requirement of universal accessibility.

Besides, this work included its validation with actual users with disabilities through a pilot project whose results are fairly satisfactory. For example, content accessibility, platform's simplicity and ease of use, or the ability to interact with others have been perceived as very positive. However, the developed platform is still open to further improvements. More specifically, the pilot process served to identify the need to improve the integrated control peripherals by paying particular attention to the possibilities offered by tablets and smartphones, the need to improve the navigation sequences in courses, and the need to pay additional attention to course content accessibility. However, results demonstrate the feasibility of this approach for the education and training of people with disabilities based on an open t-learning environment, which offers new possibilities to provide education to these collectives, and therefore to achieve their complete integration into society and the workplace.

Finally, the research team is presently focused on the improvement of the discussed platform with the integration of new multimedia solutions, the improvement of the features presently available at the TV client to foster social learning (e.g., blogs, tools for local and remote collaboration, etc.), the development of new adapted content, the integration of additional control peripherals for people with very severe motor disabilities, and to develop a new pilot project targeted to assess the introduction of this platform for the training of persons with disabilities in the framework of employment promotion, which is a most relevant aspect to be tackled according to our partner associations.

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Online Course Advising: Differences in Student Response by Gender and Ethnicity

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***Abstract*—Previous research suggests that effective academic advising can lead to better academic outcomes among undergraduate students. This study examines patterns between the use of an online advising tool, Course Signals, and course performance among students in engineering and technology. The number of advising interventions distributed through Course Signals tends to be positively associated with improved student course performance, particularly among female students. Findings suggest that online advising has the potential to be an effective method to improve student academic performance.**

Keywords—online advising; course performance; gender

I. INTRODUCTION

Although the participation of women and minorities in engineering has increased over time, they still constitute a lower share of engineering undergraduates. Women in engineering earned only 18% of the engineering bachelor's degrees in 2010 [1]. Meanwhile, among those who received bachelor's degrees in science and engineering in 2009, 10% were Asian/Pacific Islanders, 8% African Americans, 9% Hispanic, and 0.7% American Indian/Alaska Native [2]. As the United States faces a shortage of high-tech workers, attracting more women and minorities into engineering would help fill the gap [3]. Therefore, developing strategies to effectively recruit and retain female and minority students is one of the top priorities for engineering educators.

One potential solution to improve student retention in engineering is academic advising. Previous research indicates that high quality academic advising is a key factor in engineering students' academic success and retention [4-5]. Engineering programs are encouraged to "evaluate student performance, advise students regarding curricular and career matters, and monitor students' progress to foster their success in achieving program outcomes" (p.1) [6]. Research also suggests that women may be more responsive to advising interventions and signals that grades may provide [7-8]. Many computer tools and systems have been invented to facilitate the advising process [9]. Among these tools is Course Signals, which uses real-time data pertaining to student performance and other indicators to provide up-to-date feedback to students. Course Signals can also be used to deliver advising interventions aimed at promoting more effective study strategies and other changes that can lead to better outcomes [10].

In this study, we ask: is the frequency of advising interventions delivered through Course Signals associated with improved academic performance? Are there variations in student response to Course Signals by gender or race/ethnicity?

II. LITERATURE REVIEW

A. Advising

Successful academic advising requires an investment of time and effort from both advisor and advisee. In order to assist and facilitate the advising process, various computer tools have been invented to provide student information, academic records and advising resources to both advisors and students in a timely manner [9]. Some advanced tools can further process information and offer basic suggestions to students, such as selection of potential courses [9]. Research shows that these tools can provide effective assistance to advisors and students, especially at the beginning of the semester, when students need help to register courses [11-12], and at the end of the semester when advisors need students' grade point averages (GPA) to identify students who may have some difficulty with course progress [13].

While these methods and tools can help students with course selection and overall academic progress, there are also online advising systems that provide real-time feedback regarding course performance. Campbell, Collins, Finnegan & Gage (2006) proposed the idea of developing an early warning system to identify students who were at risk to provide interventions in time to improve student performance during the course [14]. Similar systems have been developed and utilized in advising engineering students at several institutions. These early warning systems allow instructors to recognize and advise students who have difficulty in their courses and help those students improve their performance [15-17]. For example, at Iowa State University, first year math, chemistry and engineering instructors can inform students and advisors on students' class performance within the first four to six weeks by using an early warning system [15]. This system enables advisors to recognize and advise students who are not performing well in class, but have not yet sought advising help [15]. The early warning system used in Rochester Institute of Technology has similar functions, as it allows faculty members to send emails to students who have difficulty in their courses [16].

Although many advising tools and systems have been implemented, there are limited studies on the impact of advising on engineering students' academic performance. Existing studies on advising suggest that advising can improve students' performance. For example, Morehead and Johnson (1964) found male electrical engineering freshmen who received increased informal advising contact had a significantly higher GPA than those who were in the regular advising program [18]. Goodwin et al (2010) examined the impact of an early warning system, which was implemented in first year math, chemistry and engineering courses. In their study, engineering students who entered college as undeclared engineering major in those courses were contacted by their advisors once they received warnings while students who entered as declared were not contacted by advisors when they received warnings. The analysis showed that students who received warnings and advising had better performance, compared with those who only received warnings [15].

While literature indicates that advising helps students improve their academic performance, it is not established whether there are differences in student response to online advising by gender or race/ethnicity. Previous studies on gender issues suggest that women may be more sensitive to grades. For example, research in economics shows that female students who receive an "A" in their first economics class are more likely to choose economics as their major [7]. In physics, Ost (2010) also discovered that women were more sensitive to grades; "For females a one point increase in GPA in physical science courses improves the probability of persistence by 13.4% whereas the corresponding figure for males is only 10.7%. Similarly, a one point increase in overall GPA (holding constant science GPA) leads to a much steeper decline in persistence for females than for males" (p. 932) [8].

Research on engineering and science students further suggests that female and male students respond to classroom technology or educational strategies in different ways. For instance, King and Joshi (2008) investigated the use and effectiveness of personal response systems (clickers) in chemistry and found that female students participated more actively than male students when given the clickers [19]. Kang et al. (2012) also examined gender differences in learning biology using two types of pedagogy: traditional lecture and narrative case studies with use of clickers. They found that while women performed better or similarly in classes that utilized narrative case studies with clickers compared to traditional lecture classes, men performed better in lecture classes [20].

Strategies, such as increased mentoring and academic support, have been used to increase the academic success and retention of underrepresented students [21]. For example, underrepresented students who received additional visualization specific instructions in an engineering graphics course were more likely to persist and have higher overall GPA compared to students who did not receive the additional support [22]. It is unclear, however, whether minority students respond to those strategies differently from their white counterparts.

B. Course Signals

One advising system that incorporates the main features of an early warning system is Course Signals. A predictive algorithm is applied to estimate students' risk statuses based on factors, such as student course effort, academic performance, prior academic history, and demographic characteristics [10]. The result is then translated into a red, yellow, or green signal, which is displayed on the student's course homepage to provide the student with up-to-date feedback on his/her course performance [10]. In Course Signals, "a red light indicates a high likelihood of being unsuccessful; yellow indicates a potential problem of succeeding; and a green signal demonstrates a high likelihood of succeeding in the course" (p2) [10].

Course Signals provides instructors two ways to communicate with students about their risk status in the course: a signal and an intervention message [23]. Instructors are encouraged to reveal the signals and send personalized intervention messages to students on a regular basis in order to advise students on their progress in the course [24]. While we have data on the number of advising interventions sent by each course instructor in the sample, we do not have information on the type of messages or advising instructions sent.

Since advising is one of the major factors that affect female and minority students' satisfaction and success in studying engineering [25-26], we explore the impact of Course Signals on student course performance with a focus on potential differences by gender and ethnicity/race. Our aim is to determine whether more frequent use of Course Signals is associated with improved course performance among engineering and technology students, and if there are variations in student response by gender or race/ethnicity.

III. DATA

A. Sample

The sample includes engineering and technology students from a large research university in the Midwest who were enrolled in a course utilizing Course Signals. The sample was limited to four courses with large enrollments (n > 90) offered in 2009 and 2010. Among those four courses, the Course Signals intervention was applied twice in two of the courses and three times in the remaining two courses. The data include demographic information, such as gender, race/ethnicity, citizenship, and declared major, as well as Course Signals information. Course Signals information includes the number of interventions (signals) provided to students and the color of the signals.

In total, 951 cases were analyzed (Table I). The sample includes 808 men, 143 women, and 234 international students. Among the U.S. citizens, 582 are Caucasian whereas 135 are Black or African American, Hispanic/Latino, Asian American, Pacific Islander, Native Hawaiian, or American Indian or Alaska Native. Of the sample, 619 students were majoring in engineering and 332 were majoring in technology. The lower percentages of women and minorities in the sample are consistent with the overall university student composition. In Fall 2012, only 21.4% of engineering undergraduates were female, 15.1% of technology undergraduates were female [27], and 13.7% of the total undergraduates were minorities [28].

In the rest of our paper, we refer to the 582 domestic Caucasian students as the Caucasian group and we categorize the 135 U.S. citizens who are Black or African American, Hispanic/Latino, Asian American, Pacific Islander, Native Hawaiian, or American Indian or Alaska Native as the minorities group.

B. Distribution of First Signal

Table II provides the distribution of first signal across demographic characteristics. Among engineering and technology students, 55% of male students and 50% of female students received green initial signals. A higher percentage of international students (68%) received green initial signals, compared to domestic students.

IV. METHODS AND FINDINGS

We divided students into three groups based on the color of the first signal that the student received: 1) red, 2) yellow, and 3) green. We categorized students based on their initial signals because although all students received interventions from Course Signals, the magnitude for improvement differs among the three groups. For instance, students whose initial signals are yellow could improve their performance to green, stay at yellow, or decrease in performance to red, whereas students who receive initial green signals can only receive the same signal or lower.

Within each group, we conducted Chi-square test or Fisher's exact test on male, female, domestic (Caucasian or minority), and international students separately to determine whether there is an association between students' performance and the number of signals given. We further compared the test results between student groups to identify differences by gender or ethnicity/race.

A. Analysis of Students Whose Initial Signals Are Red

For students whose initial signals are red, their final signals can either remain the same or turn yellow or green indicating an improvement in course performance. We categorized students who remained red in their final signal into a "same" group and those who received yellow or green final signals into an "improvement" group (Table III).

We used Chi-square test to test whether there is an association between students' performance and the number of signals given to students by gender and race/ethnicity. For groups with sample sizes less than five, we used Fisher's exact test. The second column in Table VI shows that all p values are greater than 0.05 demonstrating there is no significant association between students' performance and the number of signals given.

B. Analysis of Students Whose Initial Signals Are Yellow

We categorized students with initial yellow signals into an "improvement" group if their final signal was green. We put students into a "same" group if their final signal stayed yellow and into a "deceased performance" group if their final signal turned red.

In general, students who received three Course Signals interventions were more likely to improve their performance compared to students who received two Course Signals interventions (Table IV). We used Chi-square test or Fisher's exact test to further test whether there is an association between students' performance and the number of signals given to males, females, Caucasians, minorities and internationals separately. The results (Table VI, third column) show that an association exists in each group, except among international students. Based on the statistics in both Table VI and Table IV, an additional intervention appears to be associated with improvements in course performance. Compared to students who received two signals, a higher percentage of students who received three signals demonstrated a decrease in performance.

C. Analysis of Students Whose Initial Signals Are Green

For students whose initial signals are green, their final signals will either remain the same indicating maintenance of good performance or become red or yellow indicating a decrease in course performance. For those who remained green in their final signals, we put them into a "same" group. Otherwise, they were categorized as "decreased performance" (Table V).

TABLE I. DESCRIPTIVE STATISTICS OF SAMPLE

	Percentage	Sample size
Female	15.04%	143
Male	84.96%	808
International	24.61%	234
Caucasian	61.20%	582
Minorities	14.20%	135
Engineering students	65.09%	619
Technology students	34.91%	332
Total	100%	951

TABLE II. DISTRIBUTION OF FIRST SIGNAL BY DEMOGRAPHIC CHARACTERISTICS

	Initial signal=green Percentage (sample size)	Initial signal=yellow Percentage (sample size)	Initial signal=red Percentage (sample size)	Total
Male	55% (442)	25% (198)	21% (168)	808
Female	50% (71)	34% (48)	17% (24)	143
International	68% (158)	24% (55)	9% (21)	234
Caucasian	51% (294)	25% (146)	24% (142)	582
Minorities	45% (61)	33% (45)	21% (29)	135

Again we used a Chi-square test or Fisher's exact test, and found an association between number of interventions and course performance among female students (Table VI, fourth column). Among female students who received two signals, 71% remained green in their final signals whereas 92% of students receiving three signals maintained a green signal throughout the course.

TABLE III. ANALYSIS OF STUDENTS WITH RED INITIAL SIGNALS

Two Signals				Three Signals			
Group	Improvement Percentage (sample size)	Same Percentage (sample size)	Total	Group	Improvement Percentage (sample size)	Same Percentage (sample size)	Total
Male	73% (101)	27% (37)	138	Male	67% (20)	33% (10)	30
Female	74% (14)	26% (5)	19	Female	80% (4)	20% (1)	5
International	67% (10)	33% (5)	15	International	50% (3)	50% (3)	6
Caucasian	74% (87)	26% (31)	118	Caucasian	71% (17)	29% (7)	24
Minorities	75% (18)	25% (6)	24	Minorities	80% (4)	20% (1)	5

TABLE IV. ANALYSIS OF STUDENTS WITH YELLOW INITIAL SIGNALS

Two Signals					Three Signals				
Group	Improvement Percentage (sample size)	Same Percentage (sample size)	Decreased Performance Percentage (sample size)	Total	Group	Improvement Percentage (sample size)	Same Percentage (sample size)	Decreased Performance Percentage (sample size)	Total
Male	19% (24)	72% (90)	9% (11)	125	Male	51% (37)	29% (21)	21% (15)	73
Female	11% (4)	83% (29)	6% (2)	35	Female	54% (7)	31% (4)	15% (2)	13
International	19% (10)	72% (38)	9% (5)	53	International	50% (1)	50% (1)	0% (0)	2
Caucasian	17% (13)	79% (61)	4% (3)	77	Caucasian	51% (35)	28% (19)	22% (15)	69
Minorities	17% (5)	67% (20)	17% (5)	30	Minorities	53% (8)	33% (5)	13% (2)	15

TABLE V. ANALYSIS OF STUDENTS WITH GREEN INITIAL SIGNALS

Two Signals				Three Signals			
Group	Same Percentage (sample size)	Decreased Performance Percentage (sample size)	Total	Group	Same Percentage (sample size)	Decreased Performance Percentage (sample size)	Total
Male	82% (213)	18% (46)	259	Male	80% (147)	20% (36)	183
Female	71% (32)	29% (13)	45	Female	92% (24)	8% (2)	26
International	87% (109)	13% (16)	125	International	94% (31)	6% (2)	33
Caucasian	75% (107)	25% (36)	143	Caucasian	81% (122)	19% (29)	151
Minorities	81% (29)	19% (7)	36	Minorities	72% (18)	28% (7)	25

TABLE VI. RESULTS OF CHI-SQUARE AND FISHER'S EXACT TEST

	P Value Initial Red Signal	P value Initial Yellow Signal	P value Initial Green Signal
Male	0.4708	<0.0001	0.6106
Female	1.0000	0.0020	0.0396
International	0.6311	0.5010	0.3679
Caucasian	0.7702	<0.0001	0.2176
Minorities	1.0000	0.0314	0.4345

V. DISCUSSION

In this study, we investigate whether more frequent use of Course Signals is associated with better academic performance among engineering and technology students, and if there are variations in student response by gender or race/ethnicity. In general we find that among students who have average performance (yellow signal) at the beginning of the course, receiving an additional Course Signals intervention is associated with improved course performance. This additional intervention also appears to be associated with positive academic performance among female students suggesting that women may be more responsive to advising delivered through Course Signals. This is consistent with previous literature indicating that women are more sensitive to grades and that men and women respond to educational technology in different ways [7-8, 19-20].

Although the data suggest that additional interventions are associated with improved course performance, caution should be applied in interpreting these findings. These analyses are primarily descriptive, and not causal. There are several limitations to the study including the small sample size and the variations between the courses. While all instructors utilized Course Signals, there may be differences in their pedagogical approaches and grading practices that could explain differences in the magnitude of changes in student course performance. For example, an unexpected result is that a higher percentage of male, female, and Caucasian students who were given three interventions exhibited decreased performance compared to students who received two interventions. This difference in response could stem from differences in grading practices or the type of final exams given by the instructors in the two groups.

To address these limitations, we will expand our sample size and include a control group that would enable a causal analysis. The control group would be comprised of the same courses taught by the same instructors without the application of Course Signals.

VI. CONCLUSION

This study suggests that Course Signals, an online advising tool, has the potential to help students improve or maintain their level of academic performance. The results are consistent with the general conception that academic advising can promote students' academic success. Among students who have average performance at the beginning of the course, a higher percentage of students receiving three signals instead of two demonstrated improvements in course performance. In particular, Course Signals may have a positive impact on female students' academic performance. Among female students who were likely to succeed at the beginning of the course (green signal), a higher percentage maintained the green signal compared to those who received two signals. These findings suggest that advising delivered through online methods also have the potential to help students achieve better academic outcomes.

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First-Year Engineering Students with Dyslexia: Comparison of Spatial Visualization Performance and Attitudes

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***Abstract*— Student diversity in higher education tends to focus on gender, ethnicity/race, and socio-economic status. However, these factors do not address cognitive diversity. Cognitive diversity, within the context of this study, refers to the varying ability of brain functions such as reasoning and memory, excluding persons with a developmental disability. Students with learning disabilities (LD), specifically dyslexia, contribute to this cognitive diversity. This study aims to initiate scholarly research on academic success factors for First-Year Engineering (FYE) students with dyslexia. FYE student performances on the Purdue Spatial Visualization Test-Rotations (PSVT-R) and Student Attitudinal Success Instrument (SASI) have been found to be predictors of academic success in engineering. A preliminary analysis of entering FYE student performance on the PSVT-R and SASI is conducted for three populations: students with dyslexia, students with a LD, and students without a LD. The anticipated findings will support the inclusion of cognitive ability, with an emphasis on LD and dyslexia, in FYE engineering diversity programs.**

Keywords*— *dyslexia, learning disabilities, spatial-visualization abilities, first-year engineering, academic success

I. Introduction

This work-in-progress (WIP) paper presents preliminary findings from a quantitative study designed to investigate critical factors influencing academic success of engineering students with dyslexia. "Dyslexia is a specific learning disability that is neurological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge" [1]. This study examines spatial abilities and attitudes toward formal learning experiences. Comparisons are made between First-Year Engineering (FYE) students with dyslexia, a learning disability (LD), and students without a LD on the Purdue Spatial Visualization Test-Rotations (PSVT-R) and the Student Attitudinal Success Instrument (SASI). The PSVT-R is amongst the most common instruments for assessing visual spatial skills of engineering students [2]. It requires the student to visually rotate a solid to the correct position [3]. The SASI is a 161-item survey that is composed of 13 specific attitudinal and affective constructs, which have evidence of validity and reliability for engineering students [4]. The SASI is used to assess these constructs prior to the first year of engineering study and assists with retention programs and efforts at the first-year level.

II. Dyslexia & Engineering

A. *Disabilities in Engineering*

The National Academy of Engineering (NAE) has released several reports stating the U.S. must increase the diversity of engineers to meet the competitive need in the field [5][6]. Yet, this characterization of engineering diversity must be furthered to explicitly identify persons with different cognitive abilities such as a LD. The National Science Foundation (NSF) Committee on Equal Opportunities in Science and Engineering (CEOSE) supports the advancement of people with disabilities in STEM disciplines with the purpose of supporting diversity, however, LDs are not a major focus and data is not readily available. LDs are a major component of cognitive diversity, the varying ability of brain functions, such as reasoning, memory, and perception [7][8][9], and must be included in this national dialogue. The CEOSE has recently noted a need to regularly collect data on disabilities in STEM and requested that the National Center for Science and Engineering Statistics (NCSES) move forward with this recommendation [10].

B. *Students with Dyslexia: Self Perception*

Currently, there is minimal research explicitly investigating undergraduate engineering students with dyslexia. Research has found that history of academic achievement and stress impacts the self-perceptions of students with a LD or dyslexia in higher education [11][12]. These stress factors also persist in students that have both dyslexia and gifted abilities, referred to as twice-exceptional [13]. Twice-exceptional students with dyslexia are often identified late in their academic career; these students may be of particular interest to engineering. For example, competitive

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engineering programs admit highly ranked students. If the admitted students are unidentified twice-exceptional persons with dyslexia and encounter challenges in their curriculum, anxiety and stress may be induced. Students with positive self-perceptions, supportive institutions, and a personal support network have success in higher education [14][15]. Students with LD and dyslexia in higher education attribute their success to motivation, planning, and organization. Lastly, a study of factors impacting retention found that belonging, involvement, purpose, self-determination, modeling inclusive behavior, and universal design for learning (UDL – which includes curricular and co-curricular components) were all key to retaining students [16].

C. Dyslxic Spatial and Visualization Abilities

In dyslexia research, spatial visualization ability debates have pivoted around the hypothesis of a "gift" [17][18] or a deficit [19][20]. Conflicting evidence has been presented for both [17]. The different neurological connections in the brain have led investigators to consider how those connections impact spatial visualization abilities and visual motion [21]. Studies have indicated that people with dyslexia have deficits in spatial visualization and detection of stimuli (motion) in a number of different tasks [21][22], others indicate that their was no differences between controls and persons with dyslexia in visual spatial tasks [21], and other studies suggest further spatial and visualization investigations must be conducted [19][18].

D. Research Questions

1. How do entering FYE students with dyslexia, with a LD, and without a LD perform comparatively on the PSVT-R?
2. How do entering FYE students with dyslexia, with a LD, and without a LD answer the SASI?

III. Methods

The PSVT-R and SASI was administered to all incoming FYE students at a large Midwestern public university; data was collected for fall 2010, 2011, and 2012. A matching comparison group was used for the initial statistical analysis to examine the data. From the SASI, three constructs predictive of academic success were selected: leadership, self- efficacy, and expectancy value. These constructs were selected based on key findings for student success in the dyslexia literature. It is hypothesized that students with dyslexia will perform differently than students without a LD.

IV. Preliminary findings

Institutional Review Board (IRB) approval is underway to access the necessary secondary data for this study. Data has previously been collected for entering FYE student performance on the PSVT-R and SASI. The authors have the support from the university disability offices and are seeking approval from the IRB to identify particularly students with dyslexia and LD for the analysis. Findings will be presented in a tabular format with the resulting statistical analysis based on tests of normality to determine if there is a significant difference in performance on the PSVT-R and responses on the SASI.

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Factors Influencing Participants' Selection of Individual REU Sites

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Abstract*—This study seeks to elucidate factors influencing undergraduate engineering student intent to participate in research assistantships offered through National Science Foundation (NSF) research experiences for undergraduates (REU) site programs. Understanding participant decision criteria could increase targeting of specific student populations, improve program outcomes, and increase efficiency of site directors. This ongoing study builds off previous work by the NSF [1] on REU programs to answer the following questions: (1) are participant selection criteria uniform for all STEM REU programs or do they vary by program primary discipline, (2) do additional factors not previously considered, such as geography and other offers they receive, significantly impact REU selection, and (3) do factors significantly vary by each successive student cohort. To collect data, a survey was sent to REU participants through nine participating National Science Foundation (NSF) site administrators. Geographic distributions of applications were classified based on distance and spread with respect to hometown and indicated applicant divisions. Initial results showed that twenty five percent of these participants were offered multiple positions and seven percent of respondents declined another offer before accepting their current position.

***Keywords*—Research Experiences for Undergraduates; Student Selection; Student Decision Making; Summer Programs**

I. Introduction

Significant funding is being allocated for undergraduate research programs with the expectation that these programs will help increase the number of students applying to, and succeeding in, science, technology, engineering, and mathematics (STEM) graduate programs [2]. Research opportunities for undergraduates promote the development of student scientific research identity (i.e. becoming a scientist/researcher) [3] and also help students confirm or realize graduate education aspirations [4,5,6]. One prevalent type of these undergraduate research programs are the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) sites, where student participants are recruited to academic research institutions for typically ten week mentored projects.

Initial studies of NSF REU site programs have sought to understand the factors that motivate undergraduates to apply for and select individual sites [1]. Although a previous report identified some influencing factors for NSF REU participants [1], more work is needed to identify: ***(1) if these factors are domain specific [such as materials science and engineering (MSE)] or if they are uniform for all STEM REU programs, (2) if additional factors, such as geography, are significant for impacting REU selection, and (3) if the importance of previously identified factors vary with each new student cohort.*** In this study, particpants within 2012 summer NSF REU sites were surveyed to help elucidate these aims. Another survey to be conducted of participating REU programs in the summer of 2013 will increase the number of respondents and investigate possible causal relationships for identified trends.

II. Methods

Feedback was solicited from participants within nine REU programs at eight different institutions within the U.S. A voluntary online survey was distributed via email to the REU participants through their site administrators. This survey included fourteen items to identify the aspects which students consider important when selecting research programs. It also included questions to ascertain the geographical location of where they graduated high school (hometown) and their current educational institution, which (and how many) REUs they applied to, as well as the other types of activities they pursued in addition to the REU program for summer work, and general demographic data (gender, class standing, # of years at current institution). The data collection instrument for this study was approved by each institution's Institutional Review Board.

Once results were collected, responses were stripped of any potential identifying information and specific institutional references were converted to classifications by the Carnegie Foundation for the Advancement of Teaching [7] and ZIP codes for anonymity. Statistical analysis was performed using Pearson's chi-squared tests and t-tests in order to identify statistical significance of trends observed from the survey.

III. Preliminary Results and Discussion

The REU sites participating were primarily classified as having very high and high activity research universities (RU/VH and RU/H) accounting for 44% and 40% of responses respectively; 16% of students attended an REU at an engineering special focus institution (SFI/Eng). A total of 61 participants responded with expected demographics (54%

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female, 44% male, 2% undisclosed gender, 58% rising seniors, 32% rising juniors, and 10% rising sophomores.)

A summary of factors identified by participants to their acceptance of a REU site offer is shown in Table 1. A majority of participants considered the stipend a influence (69 %), with smaller, but still significant, responses for research project focus, date of offer and housing/meal package. Factors selected by the smallest number of participants included the REU site application deadline, the distance of the REU site from the participant's hometown (close or far), and advice from advisors/professors. Eight percent of students noted other factors, such as that the participant only submitted a single REU application. The response frequencies for each decision making factor are noted in Table I.

TABLE I. STUDENT RESPONSE OF IMPORTANT FACTORS FOR ACCEPTING REU OFFER

Aspect	% Response
Stipend	69 %
Research Project Focus	64 %
Date of Offer	61 %
Housing/Meal Package	43 %
Activities Outside of Lab	38 %
Advice or Suggestions	34 %
Close to Home	26 %
Far from Home	22 %
Deadline of Application	20 %
Other	8 %

Comparing the results of this study with a previously published report [6] discussing selection criteria for REU participants notes interesting deviations. Two of the top three aspects noted in Table I (stipend and date of offer) were ranked much lower in the previous study [1]. This could be the result of a transition in student interest with more recent cohorts [8]. However, considering the limited sample size in this study, more data is needed to further confirm this finding. Additionally, the other report employed a Likert-like scale to note student importance, while our initial survey included a binary value of whether respondents considered the aspect important of not. Further scale development in successive survey iterations is desired.

The majority of students applied to two or less REUs, as seen in Fig. 1. Responses indicate that these students applied primarily to NSF sponsored REU programs as 62.3% of students did not apply for non-NSF REU positions and 52.5% of students did not apply for internships. Even though most students did not apply to many REU programs, 25% of students surveyed received two offers.

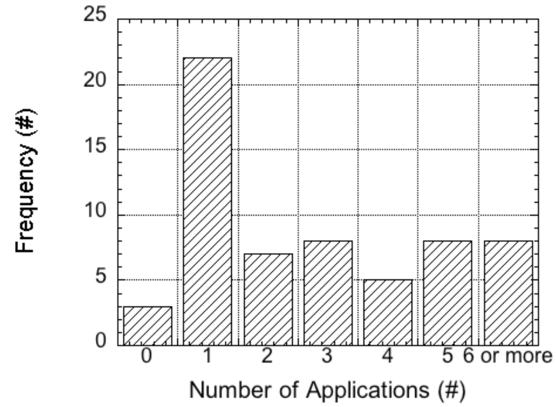

Fig. 1. Number of REU programs applied to per student applicant. The majority of students apply to 2 or less programs.

When decision factors are considered with respect to student demographics, some trends arise. The female students polled were significantly more interested in the housing/meal package (55% for females vs. 30% for males, χ^2 test, p-value: 0.068). Also, students that received two offers indicated that the date of the offer was especially important (93% for dual offers vs. 51% for single offers, χ^2 test, p-value: 0.003) and less likely to consider staying close to home important (7% for dual offers vs. 33% for single offers, χ^2 test, p-value: 0.053). When impact of Carnegie classification of REU site is considered, it appears to have affect whether students consider the application deadline to be important. Half of students responding from SFI/Eng REUs noting the importance of the deadline compared with 18% of RU/VH students and 12% of RU/H students. This could be due to the overall reputation of the schools associated, as SFI/Eng schools are by definition smaller and less research oriented than the others.

While some trends had statistical significance and could be reported, the analysis of demographic influence was limited by current sample size (61 survey responses). χ^2 tests showed that all other factors considered with respect to demographics (gender, class standing, REU institution type, and offers received) were not significant. Further work will include further development of the data measures and also an increase in the sample size to enable statistical significance.

Fig. 2 shows the distribution of distances between students' current institution and the REU that they attended. It can be seen that many students attend REU programs at their home institution and most remain within 500 miles. However, there is still a significant amount of students that travel farther distances, some even over 2500 miles. T-tests were used to determine that there was no significant deviation between the distances of schools that students applied to (total applications) compared with the REU site that they eventually chose. Similar trends were noted when viewing distance with respect to student hometown as well.

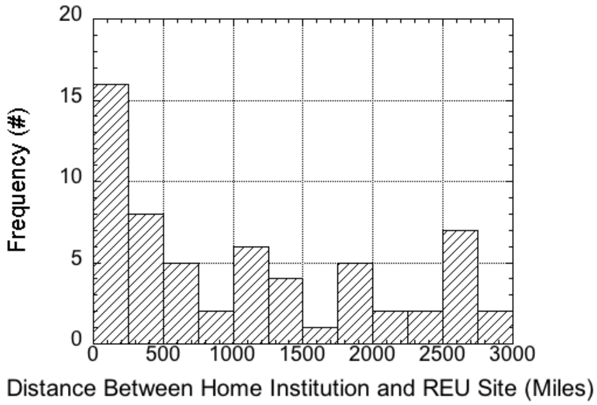

Fig. 2. Distance between the participant's home institution and the selected REU site. Some participants took part in REU programs at their home institution.

Analysis of geographic application distribution is underway to classify qualitative trends seen in student responses. Fig. 3 shows a representative participant application distribution created using the ggplot2 package in R [9,10]. Fig. 3 was created from representative data but modified in order to prevent identification of the individual. Initial classification suggests that there are multiple student application profiles such as: students who went far away from home for their education and applied to many long distance REUs, students who stayed close to home for their education and applied to many long distance REUs, students who went far away from home for their education and then applied to only that institution for an REU, and students who went far away from home for their education and then applied to a single REU that was not close to their home or their institution among other less common scenarios. Current efforts are underway to refine classification scheme and obtain inter-rater reliability measurements through the use of Fleiss' kappa calculations.

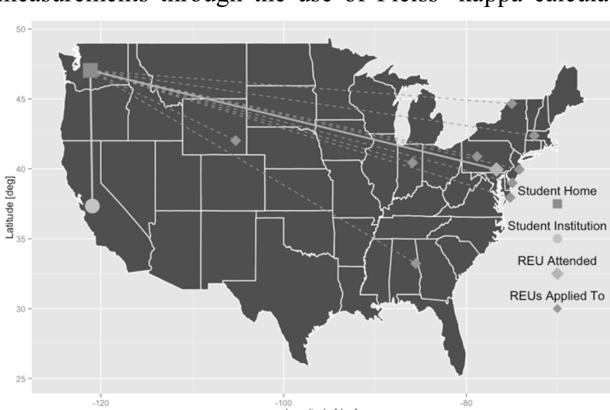

Fig. 3. Example distribution of potential application distribution to many REU programs across the USA.

IV. Conclusions and Future Work

Preliminary data from this ongoing study shows that recent REU participants consider stipend, research project focus, and date of offer to be the most important factors that influence their choice of summer program. However, when students received multiple offers, the date of offer was the primary factor. Students with multiple offers indicated that REU site location was less important than students with a single offer. When comparing with a previous report [6], it can be seen that there has been a shift from the identified motivating factors, this could be due to relatively small sample size (n = 61), or it could be due to varying student opinions in more recent cohorts [8]. Initial analysis has shown that there is no significant difference between the distance to institutions that students apply to when compared with the REU program that they finally select.

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Context and Consistency in Students' Approaches to Solving Problems in Engineering Statics

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***Abstract*—This paper examines students' responses to conceptually identical equilibrium and equivalence concept questions given in slightly different contexts, two as part of a final exam requiring explanation and the other two as part of a concept inventory. Since equivalence questions are essentially equilibrium questions from a different perspective, students were asked to apply the same concepts from two different perspectives and in two different contexts. Ideally student responses would be independent of context, but examination of students' answer selections and explanations indicates that approximately 2 in 3 students are consistent in their answers for equilibrium or equivalence questions in different contexts, but only approximately 1 in 3 students is consistent for both types of questions in both contexts. This paper builds off of previous studies of students' responses to Engineering Statics concept questions, explains the questions and methodology used in the study, and presents the results of the study.**

Keywords— Statics, Specific difficulties, Misconceptions

I. INTRODUCTION

How well do students transfer understanding from one context to another? If one asks what an expert would recognize as the same question in a different way or with additional requirements how often do students approach similar problems the same way? The traditional literature on transfer defines transfer as the ability to apply a skill learned in one context successfully in a different context. More recent work on transfer has focused more on the ability to use knowledge gained in one context to be able to learn in a new context, or the preparation for future learning (PFL), and focuses more on the student's perspective than the researcher or expert's perspective, also known as actor-oriented transfer [1]-[9]. Not all transfer, however, is related to novel situations. Sometimes the problem is only different in the details, but not in the structure or underlying model. To differentiate between these two types of transfer, Rebello et al. refer to situations where a pre-existing knowledge structure can be applied as horizontal transfer, and situations where the mental model must be created rather than referenced as vertical transfer [8]. Much of what students do on traditional end of class exercises such as final exams is an attempt to confirm students' horizontal transfer. The underlying hope is that students with sufficient horizontal transfer have a good PFL foundation and will eventually be able to apply their knowledge successfully in vertical transfer situations. Given the uncertainty that surrounds real-world engineering problems, the PFL foundation is critical to success and safety once the student becomes a practicing engineer.

In Engineering Statics equilibrium and equivalence are fundamental concepts that require students to apply the same methods. In both cases students must consider linear and rotational acceleration (or lack thereof) in order to guarantee that conditions are satisfied; in essence an equivalence problem is an equilibrium problem from a different perspective, so the tools and methods for solving equilibrium and equivalence problems are the same. From the perspective of transfer, for an expert equilibrium and equivalence problems represent horizontal transfer, but that may not be the case for students at the end of Statics. Many studies have shown that students either conflate linear and rotational acceleration or consider only one of them in many cases [10]-[17]. Previous work has also shown that students are not consistent in their approaches to equilibrium and equivalence problems when responses on those two types of questions are compared to each other [16].

One of the questions left open by previous studies is how much variation there is in students' responses to questions when the same type of question is asked in a different context. To test this notion of consistent student responses, three groups of students at Western Washington University (WWU) were asked to solve and explain a concept question on the final exam, a traditional on-paper exercise, and then asked to answer but not explain a conceptually identical question as part of the Concept Assessment Tool for Statics (CATS) concept inventory (formerly known as the Statics Concept Inventory or SCI), an on-line multiple choice assessment, for both an equilibrium question and an equivalence question [18]. The comparison of students' performance on the two equilibrium questions is an assessment of students' horizontal transfer, as is the comparison of the two equivalence questions. If the students have a stable model for both equilibrium and equivalence, then they should exhibit consistency on those questions on CATS and the final exam. Comparison of students' performance on the equilibrium and equivalence questions to each other represents a situation that is horizontal transfer to the expert, but might have some elements of vertical transfer for the students. A decline in performance across the two types of problems is an indicator that students do not recognize that equilibrium and equivalence problems represent the application

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of the same concepts even though the problems are phrased differently. Ideally context, here meaning both the different formats and the different phrasings, would not have significant influence on students' responses, and students would be consistent in their responses, whether those responses are correct or exhibit specific difficulties.

The term 'misconception' is commonly used in engineering education to describe an incorrect understanding that must be unseated and replaced with a correct understanding, but there is an alternative theory in Physics Education Research that student difficulties are influenced by context if not outright context dependent [19]-[24]. In this view students' incoming understanding is made up of bits of loosely connected knowledge referred to as phenomenological primitives (p-prims) [19]-[23] or facets of thinking [24]. These p-prims, or knowledge elements, are triggered by context; while they may individually be correct in some circumstances, they may be applied in the wrong circumstances or combined improperly to form incorrect conclusions. According to this view, students do not need to have misconceptions unseated; instead they must learn which elements are correct in which contexts. These elements provide building blocks for reaching the desired mode of thinking. In this terminology, instead of misconceptions, students exhibit "specific difficulties" [25] – some more commonly than others. In order to design effective instructional material and techniques, one should take students' specific difficulties into account [26],[27].

One could argue that these two perspectives are not mutually exclusive. A student can have a fundamental misconception regarding a certain type of situation or problem, and this should manifest itself in a consistently incorrect approach to that situation or problem. If, however, the student has an inconsistent approach or unstable model, then it is possible that there is something discernable about the context that may be influencing the student's approach. This situation highlights some of the challenges that engineering education faces as we begin to acknowledge the contextual influence of students' specific difficulties.

A. Inconsistency

Since inconsistency is an important component of this study, it is necessary to be specific about how student consistency and inconsistency are defined. Quite simply, consistency is defined as using the same approach to the same type of problem in different situations, and inconsistency therefore is a lack of consistency. When looking at consistency in the context of assessing equilibrium questions, there are four ways in which a student could display consistent behavior: 1) always assess force and moment equilibrium; 2) always assess force, but never assess moment equilibrium; 3) never assess force, but always assess moment equilibrium; and 4) never assess force or moment equilibrium. Of the four it is obvious that the first is the desired behavior, but the other three also represent a consistent, if incorrect, approach. All other behaviors for assessing equilibrium on multiple problems are therefore labeled as inconsistent. The four consistent approaches represent good horizontal transfer, although the three consistent but incorrect approaches may be the sign of a misconception, and while the horizontal transfer may be good, these outcomes do not indicate good preparation for future learning. The inconsistent approaches not only are a sign of poor horizontal transfer, but also are indications that something in the context of the problem may be influencing a student's approaches to these problems.

Because the questions used in this study have also been used in previous studies [11]-[16], the correlations between students' answer selections and specific difficulties are known for these problems. Unfortunately, however, because the current version of CATS, run through the ciHUB, does not provide which incorrect answer a student has selected when the answer is incorrect, that information was not available for the spring 2012 group of students in this study. As a result, a simpler and slightly less informative definition of inconsistency needs to be used. For the purposes of this study, consistency is defined as answering the conceptually identical problems given in different contexts both correctly or both incorrectly. Unfortunately this conflates those students who are consistent and incorrect, and therefore may have a misconception, with those students who are inconsistent and incorrect, and may be influenced by context. What is important to note then is that results given here represent the best case scenario or upper bound of student consistency. While correct answers in both contexts are truly a sign of consistency, incorrect answers in both contexts might not be, because a student may select different incorrect answers in the different contexts, and those answer selections correlate to different specific difficulties.

Given that some of the information that would be desirable to have to discern what specific difficulties students are displaying is not available, there is still useful information in the conservative estimate that is available. There is also a clear correlation between doing poorly on the equilibrium and equivalence sections of CATS, especially the equivalence section, and making errors on traditional statics problems [28],[29]. As such, in addition to the consistency issue being examined here, the incorrect answers on these concept questions, whether consistent or not, are indicators of a likelihood that those students will also make more errors on traditional statics problems.

B. Statics at WWU

This study is based upon student response to concept questions given in Statics classes at WWU during the spring 2010, 2011, and 2012 academic terms. During this period 130 students were enrolled in these Statics classes, but not every student completed every assignment, so the analysis is based upon 109 student responses to the four concept questions. The Statics course at WWU, which has a pre-requisite of one quarter of physics (mechanics), is organized around six topics: free body diagrams, equilibrium, equivalence, separation of rigid bodies, friction, and linear algebra solution techniques, without differentiation between two vs. three dimensional cases, concurrent vs. non-concurrent force systems, and single bodies vs. frames and trusses [30]. These situations are all addressed in the course, but not in the order of traditional textbooks. Otherwise the course is a standard lecture-based course with homework, midterms, projects, a final exam, a limited number of think-pair-share exercises, and weekly Warm Up exercises for the first eight weeks of the quarter [31]. During this period students in Statics at WWU also were asked

(2010 and 2011) or required (2012), depending upon the term, to enroll in the OLI Statics class, which was used in lieu of a textbook [32]. The 2010 students had a lower average on the final exam than the 2011 and 2012 students, who had virtually identical average scores. The 2011 students had a lower average on CATS than the 2010 or 2012 students.

The final exam for the Statics class at WWU contains two concept questions derived from CATS questions in addition to five traditional problems. For the concept questions students are required to explain why the answer they have selected is correct or why the other answers are incorrect. This structure allows the instructor some insight into students' thinking on these questions.

II. The Questions

This study is based upon two pairs of conceptual questions. Each pair includes one question on CATS and one question on the final exam that is a modified version of the question from CATS. Figures 1 and 2 show the CATS and final exam versions of the equilibrium questions respectively.

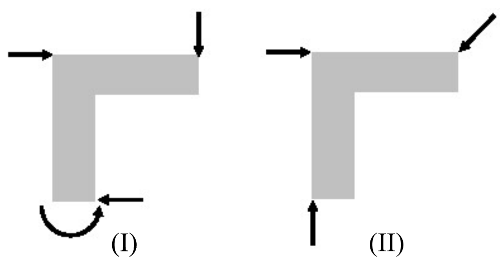

Fig. 1. CATS Version of the Equilibrium Question

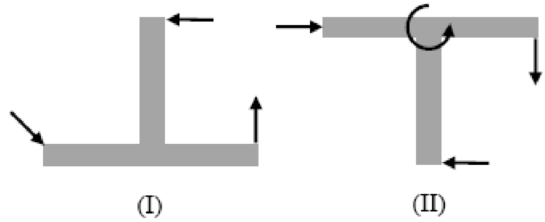

Fig. 2. Final Exam Version of the Equilibrium Question

The equilibrium questions ask students to consider the two bodies shown in Figures 1 and 2, and in both cases to determine which of the following statements is correct:

(a) I could be in equilibrium; II could be in equilibrium.
(b) I could never be in equilibrium; II could never be in equilibrium.
(c) I could be in equilibrium; II could never be in equilibrium.
(d) I could never be in equilibrium; II could be in equilibrium.
(e) Cannot say without more information.

The correct answer is (b); it is not possible for either system to be in equilibrium. One body has an unbalanced vertical force, which means force equilibrium is impossible; the other body has balanced linear forces, but they are arranged in a manner that guarantees an unbalanced moment. This is the most difficult question on CATS. Student responses to it have been extensively studied [11]-[13],[15], and those papers provide extra information, including what specific difficulties are associated with which answers.

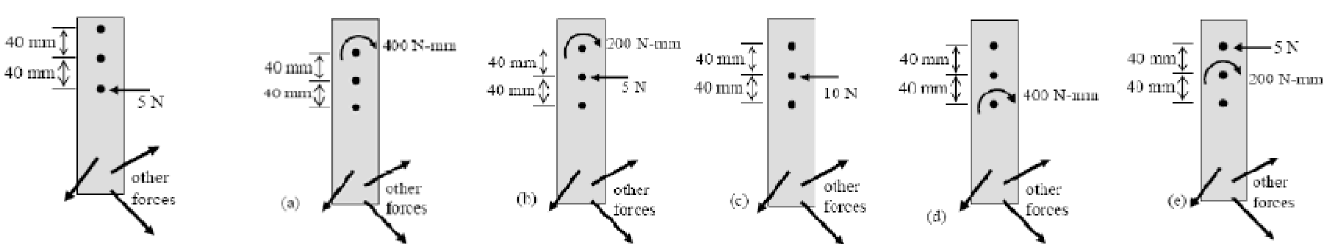

Fig. 3. Original System (left) and Answers for CATS Version of the Equivalence Question

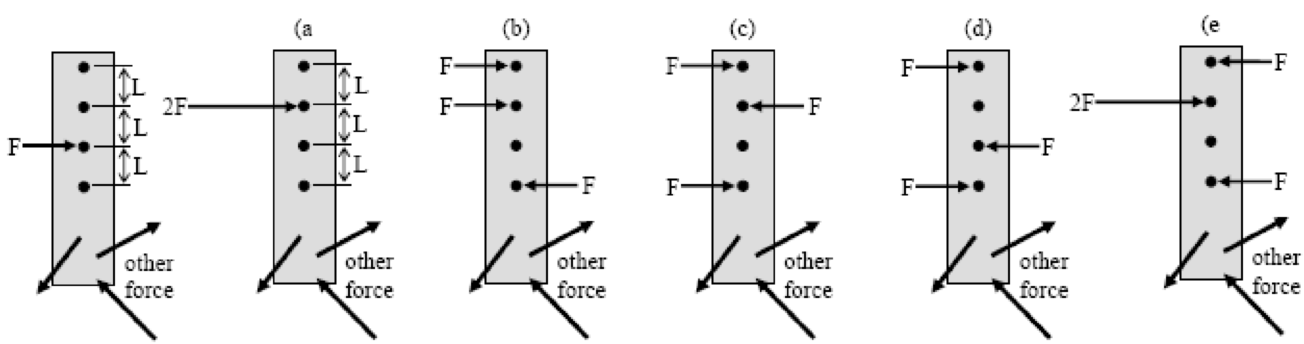

Fig. 4. Original System (left) and Answers for Final Exam Version of the Equivalence Question

The equivalence questions ask students to find an equivalent system to the one shown on the left-hand side of Figures 3 and 4. The question states that the body is subject to "other forces" on its lower portion, and it is kept in equilibrium by the additional force near the top. Students are then asked which of the other five systems shown would be able to maintain equilibrium if the "other forces" remain the same. For the CATS question, the correct answer is (b). Only systems (b) and (e) maintain force equilibrium, and of those two only system (b) maintains moment equilibrium. However, answer (a)-(d) all appear to maintain moment equilibrium if one only considers the top point. For the final exam question the correct answer is (c). Only systems (b)-(d) maintain force equilibrium, and of those three only system (c) also maintains moment equilibrium.

One of the observations from studying student explanations to the CATS problem in Figure 3 is that students who exhibit specific difficulties on this problem are much more likely to ignore force equilibrium than moment equilibrium. As a result of this observation, the final exam problem in Figure 4 was designed to be conceptually equivalent, but to not include any applied couples to see if that made any difference in students' approaches to the problem. It does, but only in a limited way. Students are still more likely to ignore force equilibrium than moment equilibrium when completing the problem shown in Figure 4, but they are also more likely to ignore moment equilibrium than with the problem in Figure 3. The question in Figure 4 does not, however, appear to be easier in the context of the final exam than the one in Figure 3. When the version in Figure 3 was used on the final exam for three classes in 2006 and 2007, the rate of correct responses was 73% (n = 140). When the version in Figure 4 was used in 2010, 2011, and 2012, the rate of correct responses was 64% (n = 129).

Table I gives the correct response rate for each of the four questions for the 109 students who completed all four questions. In both cases the rate of correct responses is higher for the final exam question, which also requires an explanation to accompany the multiple choice selection. What is interesting, however, is that the success rate is very similar for the equilibrium question, but notably higher for the equivalence question. The 2006 and 2007 students mentioned above had a correct response rate on the equilibrium question of only 45%. Those students did not take CATS, so there are no comparable data for the correct response rates on the CATS questions.

TABLE I. RATE OF CORRECT RESPONSES

Question	n	Rate of Correct Responses
CATS Equilibrirum	109	58%
Final Exam Equilibrium	109	61%
CATS Equivalence	109	44%
Final Exam Equivalence	109	64%

While there is nothing impressive about these results based on the numbers alone, the national averages on CATS for correct responses are 16% for the equilibrium question and 35% for the equivalence question [16].

III. CONSISTENCY ANALYSIS

Four aspects of consistency were considered for these student responses: 1) consistency on the equilibrium question, 2) consistency on the equivalence question, 3) consistency on all four questions, and 4) incorrect answer consistency on the equilibrium question for students in the 2010 and 2011 sections. Table II summarizes the results of the first three; the fourth is discussed below.

TABLE II. RATES OF CONSISTENCY IN RESPONSES

Question Type	n	Consistent		Inconsistent
		Correct	*Incorrect*	
1) Equilibrium	109	45.0%	25.7%	29.3%
2) Equilvalence	109	34.9%	26.6%	38.6%
3) Both	109	23.9%	9.2%	66.9%

The first two items, equilibrium and equivalence only, are the horizontal transfer situations. The distributions for the two based upon consistency v. inconsistency are not statistically different. The results are not horribly encouraging, with almost one-third of students not displaying good horizontal transfer for equilibrium, and over one-third not doing so for equivalence. When compared to other studies, however, these results are not as bad as it might seem at first, as evidence of horizontal transfer is often hard to find. In Rebello et al., for example, the researchers found no evidence of horizontal transfer from trigonometry to Physics [8].

It is also worth noting that for both the equilibrium question set and the equivalence question set that more than one-third of the students who displayed consistency were consistently wrong, which one could argue is worse than being inconsistent, and may indicate students with misconceptions. This is a virtually identical result to what was found in a study of students' consistency of assessing both force and moment equilibrium on these questions when students provided explanations to their answers [16]. In that study almost 36% of students who were consistent either selected incorrect answers or supplied incorrect explanations to these concept questions.

The third item, consideration of consistency on both equilibrium and equivalence, is a horizontal transfer situation from the perspective of the expert, but may not yet be for the students. As the data show, the consistency rate in this situation drops to roughly one-third of the students, although the rate of correct responses among the students who were consistent rises to slightly over 70%. The differences between this distribution and the first two are statistically significant ($p < 0.001$). This is an indication that students do not have strong or stable models that acknowledge equilibrium and equivalence as the same type of problem with different phrasing. These findings are also consistent with previous studies of these questions [16].

The fourth and final item, the consistency rate among those with incorrect answers can only be inferred from the student in the 2010 and 2011 classes (n = 59). Examining the incorrect answer consistency for those students for whom such information is available makes things worse. Of the 20 students who were in the 2010 and 2011 sections of statics who were consistently incorrect only 13 of them selected same answers for the equilibrium question on both the final exam and CATS. While these numbers are too small to draw any firm conclusions, it does clearly indicate that the fraction of students who are consistent while being incorrect is inflated, because their incorrect answers change with context, and on the equilibrium question each of the answers is strongly indicative of what the student actually assessed while completing the problem. If one infers that the roughly one-third of the incorrect responders are also inconsistent in all situations, the differences between the distribution for the consideration of all four questions (item 3) and the separate equilibrium and equivalence distributions (items 1 and 2) are still statistically significant ($p < 0.001$), so the implications regarding transfer remain.

A. Implications and Possible Explanations

The bottom line problem is fairly obvious, at the end of Statics, fewer than 25% of the students included in this study were able to answer four conceptually similar questions correctly, and fewer than 50% were able to answer three of the four correctly. Moreover, the national data cited in a previous study had fewer than 10% of students answering just the two CATS questions correctly [16]. This is clearly an issue that needs to be addressed.

What underlies the poor performance, however, is both less clear and integral to addressing the problem: student responses to conceptually identical problems vary with context. The immediate conclusion that can be drawn from this is that the misconception model of an incorrect understanding that must be unseated and replaced with a correct understanding is not valid for the majority of students. That is not to say that it is always invalid, but it not the proper approach to addressing students' ability to assess equilibrium at the conceptual level, whether those problems are presented directly or as equivalence problems.

The questions then become: What are the p-prims or facets of knowledge that students are using to build their approaches to equilibrium problems? What cues serve as triggers to get students to take a specific approach in a given context? The former question is not answerable from this study, but it was hoped that this study could shed some light on the latter question. Two of the possibilities that were raised earlier were 1) that including a couple symbol in the problem is more likely to invoke consideration of moment equilibrium and 2) that including numbers in the problem invokes a different approach to the problem [16]. Based upon studies of the CATS equilibrium question, the former seems to be true for students entering Statics, but does not appear to be true for many students at the end of Statics [11]-[15].

These potential cues were the impetus for the creation of the alternative version of the equivalence question used on the final exam (Fig. 4), which contains neither couple symbols nor numbers. Based upon students justifications of their answer selection, there is nothing to indicate that the lack of numbers made a difference, but there is some indication that the couple symbol may have made a difference. The rate of consideration of force equilibrium was identical for the 2006 and 2007 classes, who answered the problem in Figure 3 on their final exam, to students in the 2010, 2011, and 2012 sections, who answered the problem in Figure 4 [16]. There was, however, an 18% decline in the rate of consideration of moment equilibrium for the 2010, 2011, and 2012 group compared to the 2006 and 2007 group, and that difference is statistically significant ($p < 0.001$). This difference is reason to believe that the couple symbol does induce some students to consider moment equilibrium when they might not otherwise, but that does not appear to be true for the majority of students.

The equilibrium question responses may serve as a guide to strengthen the inference that the couple symbol is a cue. The students in the 2010, 2011, and 2012 group were slightly more likely to consider force equilibrium and significantly more likely to consider moment equilibrium on the equilibrium question than students in the 2006 and 2007 group. Since both groups of students answered what is essentially the same equilibrium question, including a couple symbol, one could surmise that the more recent group was more predisposed to consider moment equilibrium, so the fact that their rate of consideration of moment equilibrium on the equivalence question declined relative to the other group might be an indication that the couple symbol is a stronger cue for the consideration of moment equilibrium than the 18% decline implies. This is, however, not a provable supposition with these data.

These data also do not give a clear indication if the format is a factor. Students did significantly better on the equivalence problem on the final exam than on CATS, but had roughly equal performance on the equilibrium problem. The two obvious potential differences are that requiring an explanation for the answer on the final exam invokes deeper thinking on the part of the students, and that they are more motivated to do well on the final exam than on CATS. Testing whether the first one is an issue or not would require a different study, say with think-aloud reasoning on the part of the students. The second one, motivation, probably is not testable. It is true that the final exam question had slightly more potential to influence the course grade, but none of the in this study problems had a significant impact on the overall course grade. So while the data in this study show effectively that context influences students' reactions and/or approaches to problems, that transfer between equilibrium and equivalence is poor, and that the couple symbol is likely a cue for consideration of moment equilibrium for some students, but it does not shed much light on why these things are true or what the building blocks that students use for equilibrium analysis may be. That is a topic for continued exploration.

B. Future Work

The remaining tasks in this area are twofold: 1) continue to work to determine what p-prims or facets of knowledge are serving as the building blocks for student responses, and also what cues or contexts incite what modes of thinking, and 2) continue to work to develop exercises that will help reduce the contextual nature of students' responses to equilibrium questions. Simply stated, more input is needed by more researchers in this area. A deeper understanding of how students develop appropriate approaches to concepts such as assessment of equilibrium might help shed more light on how students approach more complex concepts in higher level classes.

In addition to continuing to study and develop tools to improve performance on equilibrium problems, it would be interesting to study some of the other conceptual areas of Statics in more depth to determine if student performance in those areas is also strongly influenced by context. There is no magic solution to get students to pick up concepts like equilibrium quickly and efficiently, but there may be approaches that improve the rates of learning and retention, and it may be easier to shed some light on them by broadening the scope of Statics concepts under consideration.

IV. Conclusions

This paper has examined student responses to two equilibrium and equivalence questions in two different contexts, a final exam with an explanation required and a concept inventory (CATS), to show that student approaches to equilibrium are inconsistent. The students in question completed conceptually identical equilibrium questions and equivalence questions in the two different contexts. Consistency on these pairs is an indication of good horizontal transfer. Furthermore, an equivalence question is essentially an equilibrium question from a different perspective, so in essence these students completed four different equilibrium questions with two forms of presentation in two different contexts. Consistency of all four questions is an example of horizontal transfer to an expert, but may not be so yet to the students.

Transfer on the same type of question in different contexts was relatively good based upon consistency, but was poor from the one type of question to the other. Examination of students' responses showed that roughly two-thirds of students were consistent in their approach to the same type of problem in different contexts, the final exam and CATS, but only about one-third of students were consistent in their treatment of all four problems, and roughly one-quarter of those students who were consistent were consistently incorrect. The conclusion of this study is that when it comes to equilibrium most students do not have deep-seated misconceptions that must be corrected, although some might, but that most students who are giving incorrect answers are reacting to context, including in some cases the symbol for an applied couple. Engineering education research needs to consider different models of student behavior when confronting students' specific difficulties in the area of assessment of equilibrium.

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When a testbed does more than testing

The Internet-Scale Event Attack and Generation Environment (ISEAGE) – providing learning and synthesizing experiences for cyber security students.

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Abstract— The importance of laboratory exercises for students is recognized unilaterally by engineering and technology programs. As engineering educators whose academic focus is information assurance and cyber security, we believe students in cyber security need the same type of access to hands on opportunities as their counter parts in hardware design or circuit design. Students should be able to configure and run their own networks, as well as explore the vulnerabilities, exploits, and remediatios needed in a cyber security professional's tool kit. Further, they need exposure to working in the complexity of the Internet. While some might argue that simulation software could be a solution, it often lacks realism. In this paper we show how our institution goes beyond the providing the standard, formalized laboratory activities for our cyber security students by developing a unique, highly configurable testbed called Internet-Scale Event and Attack Generation Environment (ISEAGE – pronounced "ice age") that allows us to imitate the Internet. ISEAGE provides a controlled environment that allows real attacks to be played out against the students' networks and demonstrates to them real world security concepts.

This paper provides an overview of how the ISEAGE security testbed functions, as well as illustrates how ISEAGE provides our students five different types of opportunities for real world experience: support of formalized classroom work; cyber defense competitions for high school, community college and four year students; inquiry-based learning in a playground environment for high school, as well as college students; testing environment for network devices such as firewalls, data loss protection, intrusion detection; research environment for senior and graduate student work.

Keywords—testbed, information assurance education, cyber security, laboratory exercises.

I. Introduction

Engineering and technology programs across the United States recognize the importance of laboratory exercises (or hands on experiences) for their students to truly synthesize concepts. As engineering educators whose academic focus is information assurance and cyber security, we want to provide our students with the most realistic of laboratory experiences to help them hone their skills and develop the depth of thinking needed in this complex and every changing world we live in. Students in cyber security need the same type of access to hands on opportunities as their counter parts in hardware design or circuit design. They should be able to configure and run their own networks, as well as explore the vulnerabilities, exploits, and remediations. However, putting students in labs full of physical equipment can be expensive to do, even with virtualization. And, if given an unending supply of servers, hard disk and RAM to create local networks, it is still a challenge to mimic the complexity of the Internet. Others might argue that simulation software could be a solution, but it often lacks realism. So, we are presented with a hard problem. How do we create a realistic Internet for cyber security students to use?

In this paper, we show how our institution goes beyond the providing the standard, formalized laboratory activities for our cyber security students. We have developed a unique, highly configurable testbed called Internet-Scale Event and Attack Generation Environment (ISEAGE – pronounced "ice age") that allows us to imitate the Internet. ISEAGE provides a controlled environment that allows real attacks to be played out against the students' networks and demonstrates real world security concepts. The ISEAGE security testbed has an air gap proxy server through which students can connect to the Internet to download operating systems and patches or search for additional information about configuration problems, but no other traffic can escape. While ISEAGE can follow all TCP/IP protocols, it also allows manipulation of those protocols and traffic capture to demonstrate specific types of attacks such as Distributed Denial of Service.

This paper will provide an overview of how the ISEAGE security testbed was developed and functions, as well as future work underway with the testbed. However, the major focus of the paper is to illustrate how ISEAGE provides the environment so that our students have five different types of opportunities for real world experience. It is divided into four sections. Section II provides a technical overview of ISEAGE and how it is configured. Section III enumerates the five different types of experiences our students are provided by the ISEAGE security testbed: A) support of formalized classroom work; B) cyber defense competitions for high school, community college and four year students; C) inquiry-based learning in a playground environment for high school, as well as college students; D) testing environment for network

The ISEASGE security testbed was developed through Department of Justice funding.

devices such as firewalls, data loss protection, intrusion detection; E) research environment for senior and graduate student work. Section IV provides the conclusions and future work.

II. Overview of ISEAGE

There have been several successful network testbeds, the most widely recognized name in this area is DeterLabs [1], but ISEAGE is designed specifically for use in security research and offers several advantages over a conventional network testbed. It has four unique features as part of its highly reconfigurable architecture which allows for very small or very large network testing and rapid setup. Each of ISEAGE's features (architecture, tool set, data collection availability, and scalability) are described in the following sections.

A. Architecture

As shown in Fig. 1, the core of the ISEAGE security testbed is a routable IP network that supports the traffic to and from the networks and systems under test. Because of ISEAGE's internal programming, called ISEFlow, the architecture simulates the cloud environment of the Internet with multihops, but the traffic all stays contained within the security testbed. However, ISEFlow makes traffic appear as if it has routed through the Internet. ISEAGE is unlike conventional testbeds where each router represented by either a real router or a software router running on a computer. ISEFlow creates the external subnets as well as a large number of internal networks without needing to instantiate a separate router for each network. This internal cloud network represents a cluster of routers. If an external computer performed a traceroute to a server in a different network, it would see a number of hops between itself and server as if there were real routers between it and the server. The TTL field in the IP header would also indicate the traffic traversed multiple routers just as it would if it were traveling via the Internet.

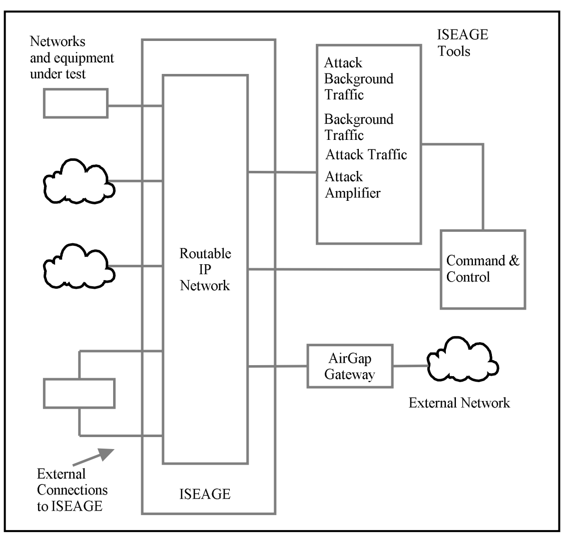

Figure 1. ISEAGE Architecture

As is also shown in Fig. 1, the networks and equipment under test are directly connected into the ISEAGE's routable network. Generally, this equipment is considered to be servers and end user machines. These types of devices are end points and view ISEAGE as an Internet connection. However, there is also the ability to connect external devices to insert additional routing infrastructure. These types of devices can use the data flow through ISEAGE and can be used to test routers, firewalls and other devices that interconnect multiple networks.

As was discussed in the introduction, the ISEAGE security testbed was created to allow work conducted in a secure environment. As shown in Fig. 1, there is a separate command and control network for configuring both the ISEAGE routable network and the networks and equipment under test. Further, Fig. 1 also shows the air gap proxy which is the only egress point for traffic leaving the ISEAGE security testbed. It allows web and ftp traffic to pass out of the networks attached to it, but restricts all other traffic. This configuration provides an isolated network environment in which the networks can run. It was intentionally developed to avoid the inevitable misconfiguration or unwanted attacks on the real world network by a student learning about or incorrectly configuring a device. Finally, the tool repository is shown in Fig. 1 and is discussed in Section B below.

ISEAGE is highly configurable and highly scalable. The authors have copies running on computers ranging in size from modest laptops to multi-machine installations. One of ISEAGE's unique features is the ability to have an unlimited number of routers connected. The only limitation is the size of the computer or server on which the framework is running. ISEAGE is currently built on ESXi servers allowing for the quick addition of additional resources for any project.

As a simple network configuration example for this paper, Fig. 2 is provided. For the sake of this discussion, it will be assumed the entire ISEAGE testbed is installed on one ESXi server. However, there are many different configurations that could occur in ISEAGE, depending upon the complexity required. Fig. 2 shows the network using five copies of ISEFlow which is depicted as a red box. Again, the number of ISEFlows can vary with the complexity of the installation. In this simple configuration between one and three routers are configured in each ISEFlow. Each of the numbered routers within the ISEFlow has an ingress and an egress address in public IP space. Again, because the traffic doesn't escape the ISEAGE security testbed, ISEAGE can use public IP address space.

The red boxes labeled B1, B2, and B3 are the ISEFlows that allow systems to be attached into the ISEAGE network. Outside of the red boxes at the top of Fig. 2 are five additional IP address ranges. Again, these are in the public space. The systems under test use these additional IP ranges. The devices are either attached as endpoints and view ISEAGE as an Internet connection or they are inline devices that use ISEAGE to test the data flow through multiple networks. In either case, the systems under test point their outbound traffic to the outermost router interface in the ISEFlow configuration to which they are attached. When traffic leaves the devices of interest, the cluster of routers in ISEFlow will alter the traffic as if the traffic traversed each router in turn.

The red box labeled B4 exists to connect the ISEAGE network to the real outside Internet through an air gap proxy that allows only web and ftp traffic out. Air Gap 1 also functions as an internal DNS server so all systems under test can have name resolution. The red box labeled B5 is a data collection port and can record all traffic in the ISEAGE network. The green box labeled Backplane allows ISEFlows to communicate with each other.

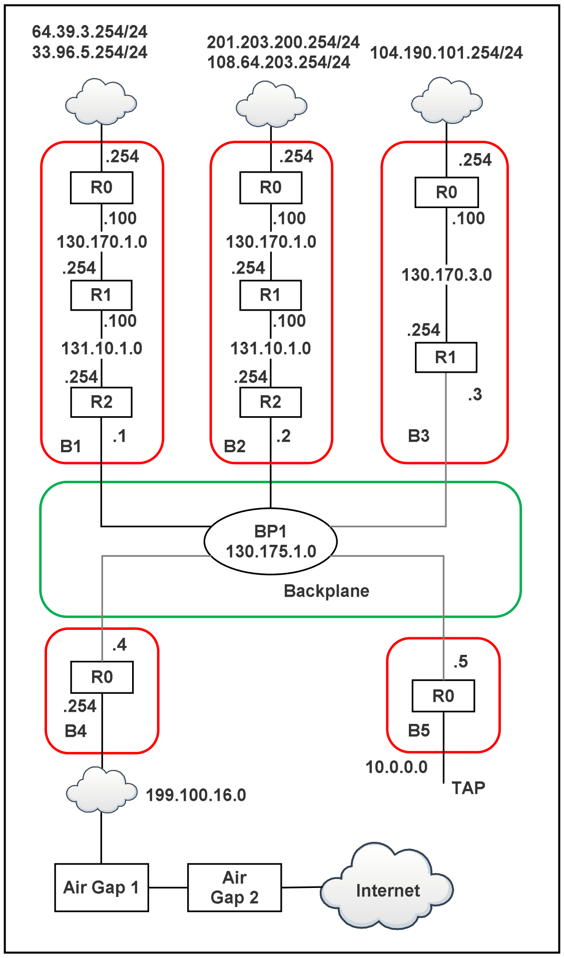

Figure 2. Simple network

B. *Tool Set*

There are multiple tools designed to support ISEAGE. The tools use a common command and control protocol to allow easy integration into the ISEAGE command and control network. Below is a brief description of the tool set.

1) Attack Amplifier & Condenser

The attack amplifier is used to convert an attack launched from a single computer into an attack that appears to be launched from multiple computers. This tool allows researchers to study distributed and flooding based attacks. With this tool researchers can create attacks that appear to come from thousands or even tens of thousands of computers.

The attack condenser works with the attack amplifier. Often distributed attacks create a large number of responses back to the attacker or responses that have been redirected to another target. The attack condenser will take the responses and condense them into a small number of responses. It can also be configured to respond to the messages. For example, if there is a redirected distributed attack pointed to a machine, the attack condenser can become that machine and absorb the attack and respond when necessary.

2) Packet Changer/Responder

The packet changer/responder can be used to modify packets in real-time as they flow through the network. This tool can be used to create man-in-middle attacks or can be used to generate traffic in response to certain incoming packets.

3) Attack Collector/Watcher/Replayer

These three tools are used to collect information to be replayed within the virtual internet. The attack collector is a honey pot / honey net that is used to collect host based attacks. The attack watcher is an intrusion detection system that captures network attacks. The attack replayer replays the attack inside the virtual internet. The attack collector and watcher are connected to remote sites via the internet using encrypted connections.

4) Attack Tool Repository

An extensive library of attack tools is maintained. The library allows the launch of a wide array of attacks. By feeding the attacks through the tools described above the testbed network allows examination of and design of mechanisms for defense against real attacks

5) Traffic Collector/Replayer

This tool captures traffic patterns from the actual Internet at particular locations so they can be replayed with ISEAGE. The collector captures traffic patterns only; it does not capture the data. The replayer then reconstructs traffic from the captured data to recreate as close as possible the background traffic seen at a given location on the actual Internet.

C. *Data Collection Point*

Another interesting feature of ISEAGE is its ability to capture all traffic through what is called a tap port. This is very useful when teaching about intrusions or when wanting a log of all network traffic during a research experiment.

D. *Scalability*

In addition to the full scale ISEAGE testbed several smaller versions have been developed. ISEAGE is capable of running on a single machine running virtualization. These smaller versions of ISEAGE are used in most of the setting discussed in this paper. The full scale ISEAGE is used primarily for research and device testing. The smallest version of ISEAGE runs on a laptop. The only limiting factor for the number of routers and nodes that can be used in the ISEAGE testbed is the size of the hardware on which ISEAGE is installed.

III. ISEAGE USES

There are five different uses of the ISEAGE security testbed in which student can gain valuable, real world experience with networks and security. The first three listed below (classroom, cyber defense, and playground) are very similar, but have distinct differences based upon who builds the network that is being tested and who does the testing.

A. ISEAGE in the Classroom

The ISEAGE security testbed is used to support several classes at Iowa State University (ISU). Two of them are discussed in this paper: an undergraduate introduction to networking and graduate level capstone course. Both of these courses use the ISEAGE architecture as a connection to the Internet. Both courses allow the students to build networks by setting up servers and running services on them. However, the undergraduate course focuses on teaching basic principles such as IP address space, network connectivity, and simple protocols. This course was not taught in the engineering college, but in the business college as part of the Management Information Systems (MIS) program. The hands on activities include designing and configuring a mail server, a domain name service (DNS), a firewall, and a web server using their assigned public IP address and domain name in the ISEAGE testbed. They also had to use Windows Server 2008 as their operating system. The course was taught in the traditional lecture manner with students needing to complete the hands on exercises on a computer on their own time; no lab was associated with this course. Students self-selected into teams of four to five to complete the project. The course included a project planning phase, an implementation phase, and an evaluation phase for each team of students.

The graduate course is an information assurance course capstone course developed at ISU to enable distance education students to complete the requirements for a Master's of Engineering in Information Assurance without setting foot on campus [2]. This course is entirely lab-based and is comprised of three parts: the planning and implementing phase (six weeks); the defending and attacking phase (four weeks); and the infrastructure assessing phase (five weeks).

While the undergraduate course had the planning and assessment phases, the graduate course was more rigorous and included an attack and defend phase. Here individual students create their own networks instead of working as a team. They adhered to a provided scenario or story line of what services have to be run. The students could select any operating system as long as it was open source, had a demonstration period that lasts throughout the semester, or was site-licensed by ISU. Additionally, the graduate students had to produce their own preliminary network plan that included a diagram of their network, as well as the rationale for selecting the operating systems and applications used. Again, the graduate students were assign public IP addresses and domain names in the ISEAGE testbed which they had to implement.

During the attack and defend phase each graduate student tries to identify vulnerabilities and weaknesses in his classmates' networks. Students are allowed to exploit these vulnerabilities on others' networks, as well as capture predefined flags or planting flags. Students must document their discoveries and activities as part of their final report. Additionally, while they are trying to exploit others' networks, they must defend their own networks and protect their flags.

In summary, in the MIS class the students build their own networks as teams using a Microsoft environment, but the networks were only tested by the faculty member to verify the systems were working. In the graduate course, a single student built his entire network using any operating system and then attacked other students' networks. In both cases the requirements for building the network were specified ahead of time and did not change during the semester.

B. ISEAGE as a Cyber Defense Environment

The goal of a cyber defense competition (CDC) is to have students design, and configure a set of servers and a network in a secure manner and in a relatively short, one-month period of time [3, 4]. Then, the students attend a two-day competition to defend their network from attackers. During the two-day competition, their goal is to prevent, if possible, any security violations or attacks on their network, as well as report and correct any problems that arise. They also must maintain full functionality of their systems for the end users. Students in ISU competitions are required to configure their networks as described by a scenario that details the services that they have to implement in a short story format, as well as their network address space. They are told they are the IT support staff for a company or school and have to implement services such as email, web mail, remote programming, file sharing, and web hosting. They are also told they are responsible for their own Domain Name Service (DNS) and it would be wise to implement a firewall to help protect their networks. They are also given some service, generally a web server, that is a legacy installation which must be supported in a present state. The legacy system provides some inherent security vulnerabilities that they have to protect against. Teams also have to protect flags from being captured by the attackers. These flags are encrypted files which contain a unique string and are required to be stored in a specific directory location on specific servers the teams are running. In our competitions, these student teams are known as the Blue Team. Depending upon the competition, the Blue Team may be comprised of high school students, community college students, four-year institution students or IT professionals/faculty members.

In addition to defending their network, the students also participate in numerous activities (called anomalies) throughout the competition which are designed to keep them engaged and slightly off balance just as real IT staffs get engaged in new projects and may overlook intrusions or security risks in new implementations. The people who activate these anomalies are the Green Team. This team of people are assigned to play the role of end users of the teams' networks. They can request changes to be made to the Blue Teams' networks throughout the competition. Some of these Green Team requests may run counter to the goal of having secure systems or may be to have the teams install some of the latest software that opens holes in their servers. The Blue Team must then decide how, or if, to implement the request on their network and how to implement it security.

The Green Team members are recruited from undergraduate student population, less technical corporate partners, and ISU faculty across campus. This wide variety of computer skill levels provides true tests of usability for the

Blue Teams. The addition of the Green Team is what helps keep the students focused on providing a useable network, as well as a secure one. Generally, the anomalies occur with a frequency of every 60 to 90 minutes during the competition. However, during the cyber defense competition an anomaly may be developed based upon a common characteristic found in the networks.

The group who tests each Blue Team network for vulnerabilities and plays the role of attackers in the competition are IT professionals, as well as Computer Engineering faculty and graduate students specializing in Information Assurance (IA), and are called the Red Team. The Red Team is led by an ISU IA faculty member and/or a member of industry who specializes in penetration testing. Since the competitions occur over a Friday and Saturday, their job is to conduct reconnaissance work on Friday and early Saturday morning when the teams are still setting up to determine what kinds of networks the teams are running or to carry out social engineering. Then, at the designated time on Saturday morning, the Red Team begins active network scans and active penetration testing against the Blue Teams' networks. Once vulnerabilities are found, the Red Team may act on those to gain access to the servers of interest. First, they must capture the flag on that server to prove that they have access to the box. Then, once they have the flag, they can reconfigure it, install additional software on it, install a virus on it or take any variety of steps that an attacker might take on a production server. The Blue Teams may recognize the Red Team's advances and may take actions to stop them or recover from them, as well as report the breach. However, the Blue Team may not attack or block the Red Team in an effort to protect their systems.

All competitions need a group to oversee the event and keep everyone in the competition honest. The White Team performs the role of adjudicator, as well as records scores for the Blue Teams given by the Green Team and Red Team on usability and security, respectively. The White Team also reads the security reports and scores them for accuracy and countermeasures. The White Team leader is usually an upper level undergraduate student or a graduate student.

In summary, for the CDC the Blue Team built their network and defended it, but the Red Team was the group doing the attacking. Also, the requirements for the network was constantly changing based upon the Green Team anomalies.

C. ISEAGE as a Playground Environment

Although taking a one semester class that uses ISEAGE allows students some valuable experience to build and protect networks, the pitfall is that the course only runs one semester. Then the equipment is reset and the networks that the students build are put back to original clean state. As part of the course evaluations, we discovered that it would be useful to allow students access to a centralized virtual lab year round so students could practice skills in an ungraded and experimental environment. Therefore a centralized virtual lab called the playground was created which is available throughout the year for students to build and experiment with different operating systems and security measures.

In the case of the playground, there are no requirements made of the students wanting to work in it. They are not given any network specifications or required to complete any reports. They are given open access to perform inquiry-based learning in their own time and speed. The systems that are under test would be the systems that they build and there is no one attacking them, but they could complete their own penetration testing as part of the inquiry-based learning.

D. ISEAGE as a Testing Environment

ISEAGE has been used to test data loss prevention devices for a major networking trade magazine and new testing series of different products is scheduled. Generally, the projects are the testing of commercial-off-the-shelf (COTS) products in a controlled environment. As part of each testing process the methodology and the metrics have to be developed. Here the student work is in development of the test metrics, performance of the tests, and the evaluation and results documentation.

The first three examples listed above (A-C) engaged students with creating and implementing networks of their own design. In this case, the network that is being developed in the ISEAGE testbed is focused on data flows being pushed through or to external devices connected into the testbed. There is more standardization of the network configuration. The creativity and learning comes from the development of metrics and the evaluation of the test results.

E. ISEAGE as a Research Environment

The ISEAGE security testbed was designed to provide an environment to conduct state of the art research in computer security and security tool development. ISEAGE is currently being used in several projects related to the modeling of critical infrastructures. Two projects are discussed in this paper. First, the ISEAGE security testbed is being used to model the State of Iowa cyber infrastructure with the goal of being able to determine interdependencies between systems and any weakness in the system. Additionally, "what –if" scenarios are developed to help the state develop contingency plans in case of a cyber attack. Once deployed, the State of Iowa will not only be able to test the infrastructure, but will be able to use ISEAGE to provide training of the staff and to try out new protection systems in a controlled environment.

The second project using the ISEAGE testbed is focused on the development a meta framework that allows modeling of critical infrastructure and assets with physical data which can be used for training, preparedness, and real-time reaction. This unified model is the Critical Infrastructure Modeling and Response Environment (CIMoRE) [pronounced "see more"] which represents a new paradigm for disaster planning and response. CIMoRE accounts for all critical infrastructure components such as roads, bridges, rail systems, water treatment facilities, power grids and telephone systems, cyber networks, as well as their interdependencies, in its single, unified framework. Because it is built upon the ISEAGE testbed, CIMoRE provides for a varying level of complexity in the inclusion or exclusion of critical infrastructure components. CIMoRE gives emergency planners and disaster responders the opportunity to view the physical locations of the critical infrastructure components, assess their interconnectedness, identify their failing health state, determine and avoid congestion, visually play out mitigation options, document analysis decisions and record the recovery of the critical components.

IV. Conclusions and Future Work

The use of the ISEAGE security testbed has provided the environment so that students have five different types of opportunities for real world experience: support of formalized classroom work; cyber defense competitions for high school, community college and four year students; inquiry-based learning in a playground environment for high school, as well as college students; testing environment for network devices such as firewalls, data loss protection, intrusion detection; research environment for senior and graduate student work.

The extension of the ISEAGE security testbed from graduate level research into the mainstream of undergraduate and graduate education has proven to be an outstanding way for college students to solidify concepts and gain real world skills in information assurance and network security. Undergraduate and graduate experiences, both in the classroom and out of the classroom, have become an integral part of much larger ISEAGE research project. While originally developed as a testbed for security research, the extension of ISEAGE's reach into general IA student education has been valuable.

By using the ISEAGE testbed, we provide our cyber security students with multiple opportunities to create and evaluate throughout their academic career. In addition to providing more numerous opportunities to participate in higher order thinking skills, ISEAGE also provides a wider array of activities with which to engage.

The ISEAGE security testbed is a continual work-in-progress. Currently a lab extender is under development to extend the ISEAGE closed infrastructure across the actual Internet, by placing a lab extender in a remote location connected via the Internet to a lab extender connected to the ISEAGE. The extender will use compression and special protocols to increase the effective bandwidth between two extenders. The lab extender can be used to provide remote testing of infrastructure components. The lab extender will also be used to setup remote virtual Internets for collaboration on research projects with other universities, agencies or businesses.

The authors are in the process of releasing the ISEAGE security testbed to other academic institutions. At the time of writing, we have two institutions using ISEAGE in their classrooms. One community college is using ISEAGE for a CDC-type activity for their own students in a network security course. The other is a state university that will be using ISEAGE to teach two introductory networking classes. These introductory networking classes will be patterned after the course taught in MIS at ISU and described above. The authors plan to distribute to additional institutions that have asked for similar configurations over the next several months.

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Integrating Control Concepts in an Embedded Systems Design Course

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***Abstract*—This paper describes a project experience in a microprocessor interfacing course, where computer engineering (CE) and electrical engineering (EE) students were joined to develop a project designing and implementing a Digital Controller for a Three Degree of Freedom Helicopter (3DOFH). This is a highly non-linear problem brought in by the EE students from the Process Instrumentation and Control Laboratory (PICL). Besides serving as the course project for the students, the motivation for taking such a project was to create a base platform using embedded microprocessors where control students could acquire signal conditioning and embedded software design skills in a more realistic platform than that provided by virtual instrument environments. This paper describes the course setting, design approach, and experience gained by the students, establishing a collaboration modality that could be emulated to bring multidisciplinary projects into traditional courses.**

I. Introduction

In a typical embedded system design course, students are expected to successfully apply learned concepts through a design project. The Microprocessor Interfacing (MI) course at UPRM is a technical elective for Computer Engineering (CE) and Electrical Engineering (EE) majors with such characteristics. In this course, students learn how to solve engineering problems by designing, testing, and implementing embedded systems prototypes to meet the quality and requirements of a real life problem. A key aspect of projects is to induce students to interact with other disciplines outside the traditional scope of EE/CE courses while learning about interfacing and embedded systems design.

This paper describes the experience of joining, through a microprocessor interfacing project, students from electrical engineering (EE) specializing in control with peers in computer engineering (CE) specializing in software. In our program, these areas run in parallel, with control EE students rarely taking the interfacing course and virtually no CE students taking control courses. The problem they chose to solve as project consisted of designing and implementing a digital controller for a Three Degree of Freedom Helicopter (3DOFH). This is a highly non-linear problem assigned to EE control students in the Linear Systems Analysis course. In that course, students solve the problem mathematically and verify its characteristics via a virtual instrumentation environment. The motivation for taking such a project was to create a base platform using embedded microprocessors where control students could acquire signal conditioning and embedded hardware and software design skills in a more realistic platform than that provided by virtual instrument environments.

Several works in recent literature have reported diverse experiences with either educational objectives or aiming at resolving specific application problems dealing with control system models and their implementation on specific hardware controllers [1], [2], [3]. Although these and other similar articles provide insight into the design of control systems, none of them focuses on the interdisciplinary experience and cross learning achievable by joining educational and implementation objectives in a classroom experience.

The rest of this document describes the educational setting and course structure where this experience took place. Next we provide details into the design of both the embedded system hardware and software components and their integration. Moreover, we discuss the control system design process. The last sections summarize the most important project outcomes, analyzing the lessons learned in this experience by both, students and instructors.

II. Educational Setting

A. Program Structure

The Microprocessor Interfacing (MI) course is currently offered as a technical elective for both computer and electrical engineering majors. Both programs are five-year long with about 165 credit-hours each. Each program requires students taking at least eighteen credits-hours in technical electives. These elective courses define their emphasis areas.

In the computer engineering (CE) program the emphasis areas include hardware & embedded systems (HWES), digital signal processing (DSP), and software & computing (SWCS). In the electrical engineering program (EE) students choose their electives in one of five areas that include electronics, control, power systems, electromagnetics, or communications.

The MI course is a valid technical elective for both programs, but is mainly taken by CE majors who declare their emphasis area in HWES and EE majors concentrating in electronics. Some students from either program in areas other than HWES or electronics also take this course in preparation for their senior design experience course, particularly when they plan to develop projects that will use embedded systems techniques.

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Students enrolled in the MI course are either in their last sophomore term or in their first semester as seniors. The course has as prerequisites the first course in Microprocessors, which is a core in both programs. Students are also required to have completed a course in programming languages and in digital electronics. These requisites ensure that students taking MI have fundamental knowledge in programming in both assembly and high-level languages, microprocessor-based systems, and understand the electronic structure of digital gates and drivers.

The MI course is offered in both spring and fall terms, with an enrollment of 20 to 30 students per term, typically distributed as 75% to 80% CE students and the rest are EEs.

B. Course Structure

The interfacing course has as an objective making students proficient in specifying, designing, and prototyping microprocessor-based embedded system. To achieve this objective, the course takes students through a tri-folded approach that combines classroom lectures, structured laboratory exercises, and a semester-long project.

1) Classroom Activities: As part of the classroom activities, students learn the fundamentals of how to develop microprocessor-based embedded applications. Discussed subjects include the architecture of embedded systems, design constraints, embedded systems life-cycle, interfacing and configuration of embedded peripherals, signal styles in traditional and serial buses, hardware prototyping techniques, embedded software design techniques, and concepts of real-time systems.

2) Laboratory Activities: In the laboratory, students work in teams of two or three members on a set of six pre-defined exercises. These exercises are completed before they delve into implementing hardware for their projects in synchronization with the subjects discussed in the classroom. The objective of these laboratories is for students to become familiar with the specific microprocessor they will use for their projects. The laboratory topics include the usage of processor's specific hardware and software development tools, using laboratory instrumentation, and exercises using embedded support peripherals that include general-purpose I/Os, interrupts, timers, low-power modes, serial interfaces, and data converters.

C. The Course Project

The project consists of a student proposed problem to be solved as an embedded system application. Students, working in teams of three or four members, submit a project proposal in the third week of classes. Proposals are structured following a set of guidelines published in the course web site. All problems proposed for the project must include four components in their solution, listed as follows:

a. **Microprocessor-based** meaning the solution must use a microprocessor performing non-trivial tasks.
b. **Communication** implying the system ability to communicate with another system.
c. **User Interface** allowing humans to somehow interact with the designed system.
d. **Control scheme** each system must have some form of control scheme within the application context.

Proposals are evaluated by the instructor and returned to the student with comments aimed at making the project feasible to be completed within the semester. Thereafter, in four additional stages, students go through the process of progressively developing a solution by a) developing an architectural design and software macro-model, b) a circuit design and software plan, c) implementing a building-block-level prototype and firmware, and d) system integration and application software.

For the architectural design stage, students use the problem specifications described in their proposals to develop a block-level diagram of their solutions and describing their hardware and functional descriptions. In this stage students also decide the processor to be used for their project, based on the system requirements. At this point, the architectural description is partitioned among group member, allowing each student in the group to contribute in the hardware and software design components of the project.

The circuit design stage assigns specific hardware and/or components to the functional blocks forming the system architecture to produce a schematic diagram of the system. This stage incorporates electrical and timing calculations to assess the correctness of the hardware design. A software plan based on the functional description of the previous stage is also developed.

Using commercial off-the-shelf components and a development kit of the selected processor, students develop working prototypes of each functional block in their designs and their firmware and provide the instructor a demonstration of the level of progress achieved so far.

The last stage is devoted to system integration and software application integration. All functional component prototypes are integrated according to the architectural design earlier developed. The application software developed for the system is also installed. The functional prototype is transferred to a printed circuit board, packaged, and a working demonstration provided to the instructor.

D. Course Evaluation

The course evaluation reflects the organization of activities as students receive credit for exams related to classroom lectures, performed labs, and project related activities.

Students complete one mid-term and one final exam mostly covering the material discussed in the classroom. Both are written tests, designed to assess the individual student proficiency in concepts and design criteria.

For the laboratory work, each lab session includes two or three exercises in interfacing and programming related to the discussed subject and completed by the students over a period of a week.

Each project stage is documented in a progress report discussed with the instructor in a group fashion. Students also take an individual oral examination after completing their prototype. This evaluation assesses the individual level of proficiency achieved by each group member in terms of the completed project.

At the end of the semester, students prepare a comprehensive written report of their project, documenting all stages of their designs and their prototypes. They also offer an oral presentation in front of their classmates about their project. This presentation is open to the academic community as well, and includes a live demonstration of their working prototypes. Some teams have used their projects to enter and successfully compete in local and national design contests.

III. The 3DOFH System

The integrative experience reported in this paper is based on the work developed by a mixed group of EE and CE students who took the MI course and proposed as project designing and prototyping an embedded system for the digital control of a Three Degree of Freedom Helicopter (3DOFH). The 3DOFH is a highly non-linear mechanical system emulating a stationary helicopter with two vertical propellers capable of rotating the structure in three different axes providing elevation (ε), jaw travel (φ), and pitch (θ) (see Figure 1).

The mechanical assembly is composed of a leveled arm mounted on a rotating base. At one end of the leveled arm is the helicopter part containing the two DC motors and propellers. By individually controlling the amount of power being sent to the DC motors, the horizontal arm can rotate around its center axis. This action produces a pitch angle θ proportional to the thrust vector forces developed by the voltage applied to the motors.

Since the DC motors alone cannot produce sufficient thrust to elevate the level arm, a counter weight is located in the opposite side of the helicopter to help these forces in the elevation (ε). With the right amount of pitch (θ) in the helicopter part, the system is able to rotate in the base part producing a travel angle (φ). The system has an three optical encoders to measure each angle: elevation, pitch, and travel. The objective of this system is to maintain a desired position and respond to disturbances with a desired control characteristics.

The system operates by establishing a set-point ($\varepsilon, \varphi, \theta$) via either a keypad or joystick. Once the set-point is reached, it must be kept in that position by the digital controller even in the presence of external perturbations and the inherent system noise. Figure 1 shows a conceptual diagram of the 3DOFH system denoting the motors, encoders, relative element positions and the controller.

The 3DOFH problem is traditionally assigned to EE control students in the Process Instrumentation and Control Laboratory (PICL). Its purpose is to provide students with an experience in the usage of linear state-space control systems. A custom designed platform is provided in the PCIL that incorporates the motors and sensors as shown in Figure 1.

For their PCIL project, control students linearize the system and proceed to implement it via a data acquisition card interface connected to a personal computer running a MATLAB/Simulink program. This virtual instrument setup runs on an ideal software environment where real world

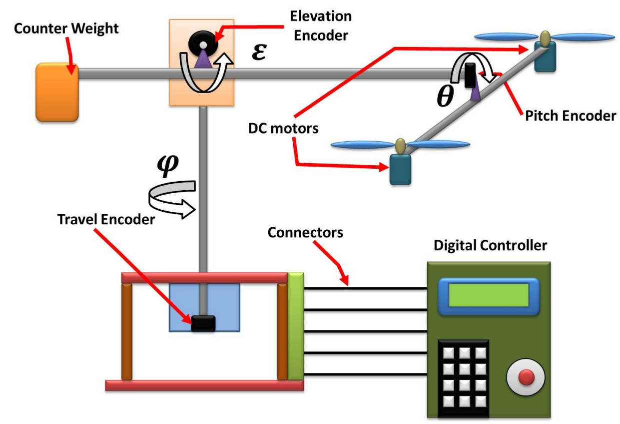

Fig. 1. Conceptual diagram for a 3DOFH system.

limitations and disturbances are not present. When using this approach, important details about sensors, motor interfaces, signal conditioning, and driver requirements are hidden from the students. This approach, although beneficial for novice control students, may limit the ability of advanced students to implement control system solutions in actual scenarios like those found in courses like the capstone design experience or in industry practice [4].

IV. The 3DOFH as an MI Project

The 3DOFH as an MI project represented an excellent scenario to bring out the hidden details in the implementation of a digital control system, while combining elements from electrical and computer engineering disciplines. With EE students bringing their background in control systems and CE students providing their expertise in digital hardware and software design for the same problem made for a convenient interdisciplinary experience.

To develop a successful solution, the students from both areas needed to work as team and acquire technical knowledge from each other's disciplines. The computer engineering students had to learn the basics of a closed-loop control systems, concepts of negative feedback, and compensator design. This basic understanding was necessary for the CE student to develop the appropriate embedded software to configure the microcontroller (MCU) peripherals.

The next sections describe the approach followed to implement the 3DOFH system as an embedded systems application. The description sheds light into how the concepts from both disciplines interbreed to produce a working solution to the problem.

A. Design Approach

The design of the digital controller for the 3DOFH project was partitioned into three main tasks. The first task was devoted to the hardware structure of the digital controller. As part of this task, a system block diagram was created, defining the controller architecture, a suitable processor selected, and the interfaces necessary for connecting the sensors and the MCU were designed. This stage also included the user interface hardware and the power supply system.

The second task consisted in the control system design. Here, the mathematical model of the system was obtained and the LQR compensator was designed. In the third task the embedded software was designed. Here, the algorithms for all MCU peripherals including timers, pulse-width modulation (PWM) modules, analog-to-digital converters (ADC), and quadrature encoder peripherals (QEP) were configured, and integrated with the Control Algorithm to yield a complete implementation. Below we provide additional details about each of these tasks.

B. Digital Controller

The digital controller module is the most important block of the system. It serves two fundamental purposes: first, it implements a control algorithm based on linear state-space design to reach and keep a given set-point. To this end the module incorporates signal conditioning circuitry, a dual motor driver, and a power supply subcircuit. The second controller function is to provide for a user interface that allows for configuring the controller parameters and directly interacting with the 3DOFH. The user interface integrates an LCD, a 4x3 keypad, and an analog, two-axis joystick. Figure 2 shows a block diagram illustrating the hardware components of the digital controller.

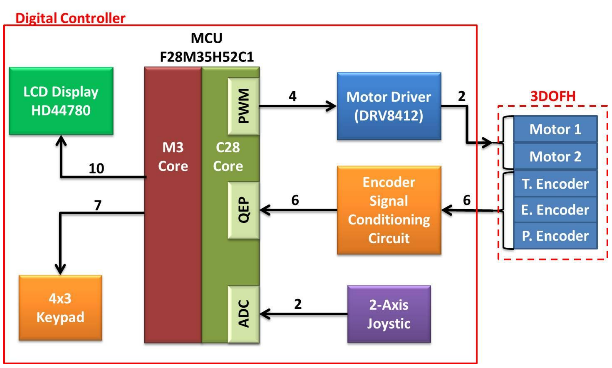

Fig. 2. Block diagram for the 3DOFH digital controller.

At the heart of the controller is Texas Instruments C2000 MCU. In particular, a Concerto F28M35H52C1 MCU was used [5]. The F28M35x Concerto MCU was a convenient selection as it provides a dual-core architecture incorporating an Arm Cortex M3 core operating as subsystem master, and a TMS320C28x core serving as subsystem control. The M3 core in the 3DOFH system was configured to partially control the user interface functions via the keypad and display modules.

The C28 core was devoted to all control functions, including monitoring the quadrature encoder peripheral (QEP) and managing the motor drivers through PWM signals. In addition, the C28 was in charge of sampling the analog signals from the joystick.

The motor driver on the right of the diagram (DRV8412) implements a dual H-Bridge driver to handle the two DC motors, receiving and amplifying the PWM signals sent from the MCU. The encoder-signal condition circuit (ESCC) attenuates the quadrature signals received from each of the encoders mounted in the axes of the 3DOFH assembly. The power circuit, not illustrated in the controller diagram, provides and distributes power to each of the components of the digital controller.

Communication between the M3 and C28 cores occurred through a dual-ported, shared memory block embedded in the C2000 chip.

The controller operation allows an user to either operate the system with a set default gains hardcoded in the controller's firmware or to specify via the user interface, a custom set of values defining a linear state-space design compensator.

C. Control System Design

The mathematical model of the three-degree of freedom helicopter (3DOFH) is based on the work by Ishitobi and Nishi [6]. The model is obtained from the sum of forces and momentums of the 3DOFH that results on a set of nonlinear state equations that describe the system behavior as shown below.

$$\ddot{\varepsilon} = \rho_1 \cos(\varepsilon) + \rho_2 \sin(\varepsilon) + \rho_4 (V_f + V_b)\cos(\theta) \quad (1)$$
$$\ddot{\theta} = \rho_5 \cos(\theta) + \rho_6 \sin(\theta) + \rho_8 (V_f - V_b) \quad (2)$$
$$\ddot{\varphi} = \rho_{10} (V_f + V_b)\sin(\theta) \quad (3)$$

This set of equations describes the system behavior in terms of angular positions (ε, θ, and φ) and the motor voltage inputs V_f and V_b. The terms "ρ_i" are parameters related to the mechanical properties of the system.

To design the controller, the system state equations were linearized to obtain a state-space representation of the form

$$\dot{\mathbf{x}}(t) = \mathbf{A}\mathbf{x}(t) + \mathbf{B}\mathbf{u}(t) \quad (4)$$
$$\mathbf{y}(t) = \mathbf{C}\mathbf{x}(t), \quad (5)$$

where $\mathbf{x}(t) = [x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8]^T$ is the state vector, $\dot{\mathbf{x}}(t)$ is the derivative of $\mathbf{x}(t)$, $\mathbf{u}(t) = [u_1, u_2]^T$ is the input vector, $\mathbf{y}(t) = [x_1, x_2, x_3]^T$ is the output vector, and **A**, **B** and **C** are constant matrices of appropriate dimensions. The 3DOFH state variables were assigned as follows:

TABLE I
STATE VARIABLE ASSIGNMENTS.

$x_1 = \varepsilon$	$x_4 = \dot{\varepsilon} = \dot{x}_1$	$x_7 = \int \varepsilon = \int x_1$
$x_2 = \theta$	$x_5 = \dot{\theta} = \dot{x}_2$	$x_8 = \int \varphi = \int x_2$
$x_3 = \varphi$	$x_6 = \dot{\varphi} = \dot{x}_3$	$u_1 = V_f$, $u_2 = V_b$

Notice that two additional state variables, x_7 and x_8, were added as the integrals of x_1 and x_3. This state augmentation was performed to eliminate the steady-state error in elevation and travel. The system was linearized by applying the

Jacobians to (1), (2), and (3). The resulting linear state-space constant matrices in the continuous-time domain were:

$$\mathbf{A} = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ \rho_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \rho_6 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{-\rho_{10}\rho_1}{\rho_4} & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\mathbf{B} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ \rho_4 & \rho_4 \\ \rho_8 & -\rho_8 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \quad \mathbf{C} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Matlab$^{(R)}$ was used to design the state-space feedback gains for the system. The linear state-space system was first discretized with a sampling period of T = 1ms. The feedback gains were designed using the Linear Quadratic Regulator (LQR). The LQR is an optimal control regulator that minimizes control effort and state-variable energy while resulting in a stable closed-loop system [7]. The performance index to be minimized was:

$$J = \int_0^{\inf} (x^T(t)Qx(t) + u^T(t)Ru(t))dt, \quad (6)$$

where Q is a positive semi-definite matrix and R is a positive definite matrix. These are weighting matrices for the state and input vectors respectively. During the design of the LQR, matrices Q and R were systematically modified to obtain the best step response from a simulation. These matrices were modified to shift the weights of the compensator to emphasize the control of specific state variables. The resulting controller was implemented in the form of a difference equation

$$\mathbf{u}(kT) = K[\mathbf{r}(kT) - \mathbf{x}(kT)] \quad (7)$$

In equation (7), $u(kT)$ is the input vector, K is the controller gain vector, $r(kT)$ is the system reference vector (joystick), and $x(kT)$ is the state-variable vector. Notice that (7) is written in the discrete-time domain with sampling period T. Figure 3 shows the control system block diagram. The 3DOFH is represented in a linear state-space format in the continuous-time domain. The outputs of the system are sampled by the QEP and discretized. Numerical differentiation was used to estimate the velocities and numerical integration is performed to obtain the state-variable integrals. These values are compared with the reference values sampled by the ADC and the error signal produced is fed to the controller gain matrix. The resulting input signals are used to adjust the duty cycle of the PWM peripheral to control the DC motors.

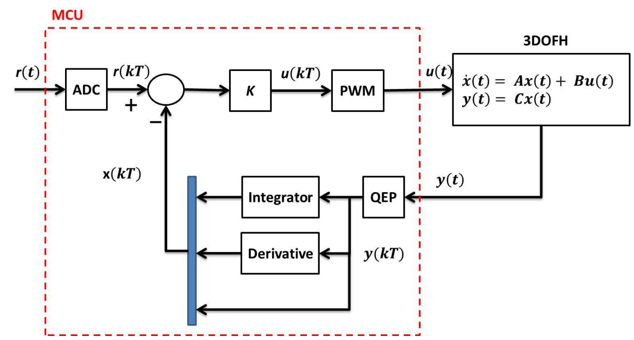

Fig. 3. Closed-loop linear state-space diagram.

D. Embedded Software Design

The embedded software was written in C-language using Texas Instruments' Code Composer Studio Integrated Development Environment (CCS-IDE). Although each MCU core can be individually programmed, the master M3 core needs to be programmed first to enable and make available the slave C28 core and its assigned peripherals.

Figure 4 shows a high-level flowchart of the system software organization. The system boots with the master M3 core, which in turn boots and initializes the slave C28 core. With both cores initialized all system peripherals required by the application can be configured. Next, the program, still running in the master core, waits for the user to select the controller configuration parameters. In the last stage, the control and user interface algorithms begin execution in their respective cores and remain running until the system is powered-off.

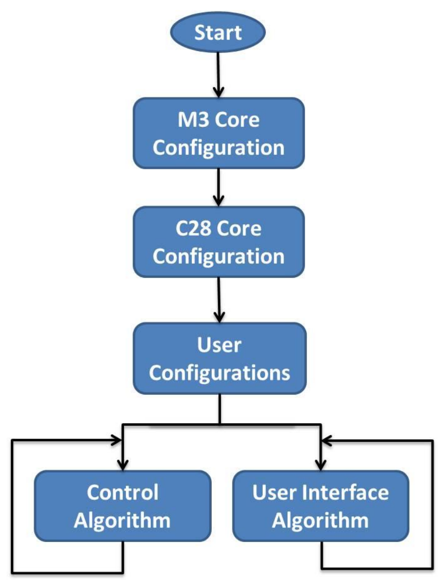

Fig. 4. Top-level flowchart of system software organization.

The M3 core plays its role as master by booting the slave C28 core and controlling the user interface.

The C28 slave core exerts control over the PWM channels, ADC, and QEP inputs, and running the control algorithms.

Two PWM channels were enabled, one per motor, each with its own 16-bit timer running at the C28 clock frequency. The average DC voltage applied to the motors was controlled by the duty cycle of their corresponding PWM outputs.

The optical encoder's outputs were managed through three on-chip quadrature encoder peripherals (QEPs). These allowed for updating the position counters without CPU intervention. The optical encoders in the 3DOFH have a resolution of 4096 counts per revolution. The QEP multiplies this value by four, resulting in a a total resolution of 16384 counts per revolution. The QEP counter was configured to initialize at 8,192, requiring the system to be pre-positioned in a balanced state at start to allow for initiating the control algorithm with a small, self correctable error.

The joystick, also managed via the C28 core, provides two analog outputs for jaw and elevation. These outputs are interpreted via the on-chip analog-to-digital converter only after a user, in the configuration process, enables the joystick to specify the system set point.

V. Project Outcomes

The students were successful in designing a controller, hardware, and software for a 3DOFH system and producing a working prototype of their design. The digital controller had all the features that were proposed for the system and its interfaces established the desired functionality. The user interface module effectively allowed for selecting between predefined or custom entered configurations and the joystick provided for smooth set-point selection establishing the pitch, jaw, and travel position of the system. While in operation, the user interface also provided real-time feedback of the 3DOFH angular position.

Stability was shown to be excellent for such a mechanical system, with a settling time less than 4s and less than 20% overshoot in response to a 90° step input in the travel angle. In lab performed tests the system was observed to reach steady-state in less than three seconds when strong disturbances were applied. The steady state error was also acceptable, about 0.09 radians as observed in the angular position feedback displayed on the LCD.

VI. Lessons Learned

Through the implementation of a three-degree of freedom helicopter project we were able to join computer and electrical engineering students from divergent areas in a cross-fertilizing classroom experience. EE students learned about software design, embedded systems and architectures, interfacing techniques, and multi-core systems. Computer engineering students in turn, learned about closed-loop system, digital control, linearization, system stability, and compensation.

They all were able to run a project from system conception through to prototype demonstration, passing through stages that included architectural design, circuit design, mathematical modeling, hardware/software integration, circuit and mechanical assembly, and technical documentation.

The experience provided a platform where control students could explore the details hidden in classical virtual instrument implementations. Computer engineering students developed a wider vision of the scope of applications that can be developed using their electronics and software background combined with knowledge from other fields.

From the instructors side, we interpret this experience as one paving the way to establish a set of experimental platforms to train control students on the details of implementing digital control systems using real life constraints. We expect to use this experience with computer engineering students to foster cross-disciplinary applications where embedded techniques provide solutions to complex, real-life problems.

VII. Conclusion

The outcomes from this experience showed us that it is possible to combine in a learning experience concepts and practice of traditional control system with those from an embedded system design course, enhancing the learning experiences of both EE and CE students. CE students learned how to implement digital closed-loop control systems on an embedded processor with a net learning gain beyond that obtained through the traditional open-loop systems they typically implement in their projects. For EE students, this experience allowed them to design and implement digital embedded controllers where real world limitations are present, delve into the software and hardware design strategies, signal conditioning, communication issues of an actual embedded implementation instead of the classical virtual instrument environment used in most control systems courses.

Acknowledgment

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Innovate Engineering Outreach: A Special Application of the Xbox 360 Kinect Sensor

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***Abstract*—In November of 2010, Microsoft released the Kinect sensor for the Xbox 360 video game console. This device—similar to a webcam—allows an individual to interact with an Xbox 360 or a computer in three-dimensional space using an infrared depth-finding camera and a standard RGB camera. As of January of 2012, over 24 million units have been sold. Using a combination of custom and open-source software, we were able to develop a means for students to visualize and interact with the data allowing us to introduce the concepts and skills used in the field of Electrical and Computer Engineering. The unique technological application, visual appeal of the output, and the widespread ubiquity of the device make this an ideal platform for raising interest in the field of Electrical and Computer Engineering among high school students.**

In order to understand the appeal of the Kinect, a working knowledge of the technical details of the device is useful. The novelty and appeal of the Kinect sensor lies in its infrared camera, which is comprised of two distinct devices. An infrared projector sends out a 640x480 grid of infrared beams, and an infrared detector is used to measure how long the reflection of each beam takes to return to the sensor. This data set is known as a "point cloud". This point cloud is a three-dimensional vector comprised of data points between 40 and 2000, which correspond to distance from the device of each beam. The data in this array can then be parsed to construct a 3d image. The Kinect's infrared camera operates at 30Hz, or 30 samples per second, so the device is able to deliver a frame rate that is sufficient to create the illusion of motion. This allows for the development of applications that give the user a sense of interacting in real time with the image on the screen. The unique visual appeal, novelty of interaction, and relatively easy-to-understand theory of operation make the Kinect an attractive platform for recruitment and outreach.

Using the Kinect, a recruiter is able to quickly and effectively demonstrate a range of concepts involving hardware, software, and the design process on a platform that students are familiar with and find appealing. In a short window of time they are able to show examples and explain the fundamental principles of the system while providing tangible, meaningful, and enjoyable interactivity with the device itself. This level of approachability and familiarity is rare among highly-technical fields, and provides an excellent catalyst to develop interest in Electrical and Computer Engineering education.

Keywords—Kinect; engineering; outreach; education; Processing; natural interaction; embedded systems; Xbox 360

I. Introduction

As referenced in a prior paper from our department [1], the University of Oklahoma's Electrical and Computer Engineering department (OU-ECE) suffered a sharp decline in undergraduate enrollment from 2004 to 2008, during which enrollment numbers dropped from 387 in 2004 to 246 in 2008. In order to rectify this, action was taken to form a student-driven recruiting effort that emphasized hands-on, demonstrative outreach communicated in a peer dynamic [2]. This recruiting and outreach program was immensely successful, as evidenced by the undergraduate enrollment rising to 399 students in 2012. During this time a number of unique innovations in OU-ECE outreach were produced. While many successful hands-on demonstrations were born out of this program, a key omission was identified in the explanation and demonstration of embedded real-time systems and their application. In order to rectify this, several demonstrations were developed around the Microsoft Xbox 360 Kinect sensor. This paper aims to provide an overview of the Kinect platform, discuss the technical details of the Kinect and our application, analyze the perceived benefits of our approach, discuss the results seen thus far, and introduce some possible ways to expand the platform to increase its effectiveness.

II. Device Overview

In November of 2010, Microsoft released the Kinect sensor for the Xbox 360 video game console [3]. This device—similar to a webcam—allows an individual to interact with an Xbox 360 or a computer in 3-dimensional space using an infrared depth-finding camera and a standard RGB camera.

This device has become immensely popular, and as of January of 2012, over 24 million units have been sold [4]. There are currently over 150 games available for the Xbox that utilize the Kinect sensor, and Microsoft is currently focusing on integrating it in to the Windows environment. While Microsoft has popularized the device, the actual technology was developed by an Israel-based company named PrimeSense. PrimeSense offers a range of 3d imaging solutions; all characterized by their system-on-a-chip (SoC) design and the open-source software solutions that accompany the device.

III. Hardware Overview

From the perspective of an end-user the Kinect is similar to a standard webcam, but the technology behind the device is distinct from other commercially available cameras. The device is, in fact, two distinct devices—an infrared camera and a standard RGB camera—that are processed into a single dataset by PrimeSense's SoC. The layout of the device is shown in Fig. 1.

The Kinect's 3-dimensional imaging is accomplished by the infrared camera, which itself is comprised of two distinct parts that are managed by the SoC. The Kinect contains an infrared projector that emits a 640x480 grid of infrared beams. This grid leaves the Kinect in a conical projection and is reflected off of the environment. The Kinect then uses an infrared detector to calculate the length of time it takes each beam to return to the device. The SoC then uses that measurement to extrapolate the distance from the device at each point, and returns a three-dimensional vector to the host machine that is comprised of data points between 40 and 2000. These data points correlate directly to the number of millimeters away the person or object is from the device. This concept is illustrated In Fig. 2. In addition to creating this vector, the SoC also collects and correlates data from the RGB camera, allowing the device to determine with reasonable accuracy what color is present at each point in the cloud.

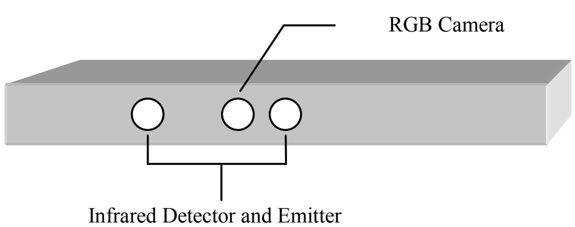

Figure 1 - Physical Layout of the Kinect

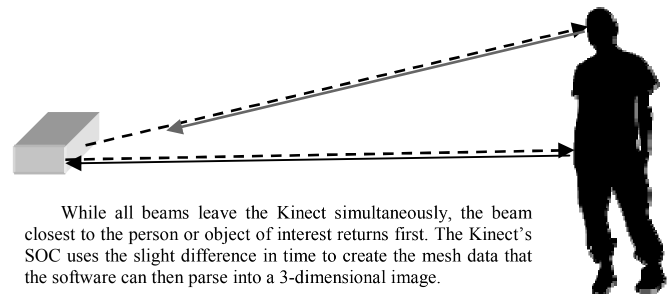

Figure 2 - Kinect Time Delay

Another key aspect of the Kinect's functionality is that it operates at 30 Hz, or 30 samples per second. This allows the device to deliver a frame rate that is sufficient to create the illusion of motion, and allows for the development of applications that give the user a sense of interacting in real time with the image on the screen.

While no single component of the Kinect is necessarily revolutionary, the combination of the components in to a complete system allows for an embedded system capable of real-time data acquisition, and enables powerful applications that are relatively simple to develop.

IV. Software Overview

By supplying the software to access the data from the Kinect in an open source fashion, PrimeSense has successfully fostered a large developer community around the Kinect. The PrimeSense Software Development Kit consists of two essential software solutions that facilitate development with the Kinect. The first is Open Natural Interaction (OpenNI), which provides an open-source API framework for development. Specifically, the OpenNI APIs allow access to voice command recognition, hand gestures, and body motion tracking [5]. The second software solution is Natural Interface Technology for End-User (NiTE). This software acts as a simple way to use the OpenNI framework with minimal CPU load [6]. NiTE provides the tools to quickly and easily turn the data from the Kinect device in to usable information about the depth, color, IR and audio data received from the hardware [6].

When choosing the development environment there were several key features that were important to us, both as developers and recruiters. In order for it to be an effective tool for distilling the core concepts, a simple interface and a robust development environment were vital. To this end, the demonstrations were developed in the open-source development environment "Processing" [7]. This environment vastly facilitates simple, rapid development, and contains many features that are a natural fit for the Kinect. By design, "Processing" is natively capable of generating robust, visually appealing displays using intuitive commands, and has a clean, simple user interface that lends itself to being incorporated in to the demonstrations. Another key component of our choice of development environment was the SimpleOpenNI wrapper for "Processing" that allows for even simpler access to the core features of OpenNI. An overview of the development hierarchy is provided in Figure 3.

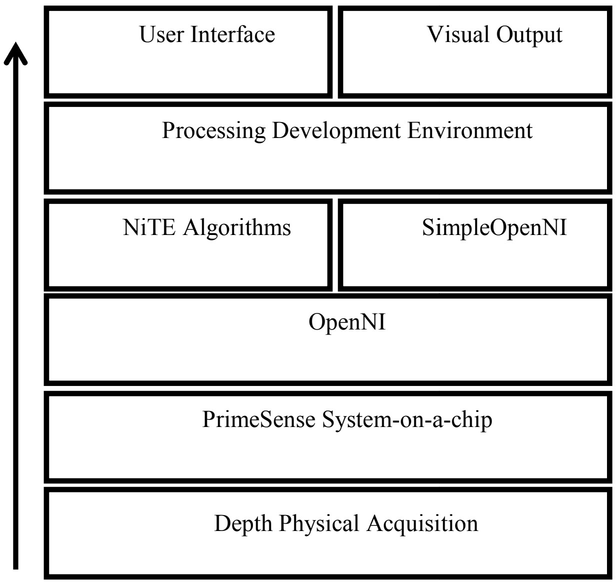

Figure 3-Software Hierarchy Overview

V. USE IN OUTREACH

Now that an understanding of the underpinnings of the Kinect hardware and software has been established, the device's application in our outreach efforts is discussed. We aim to accomplish this by providing an overview of the goals of this project, the product of our development, how it is employed in our outreach efforts, and what perceived benefits this project has yielded thus far.

In our experience, demonstrations that allow for some sort of physical interactivity serve as the best starting point for a discussion with prospective students. While demonstrations that embody this concept are abundant for many fields, embedded systems and sensing demonstrations have either been too complicated, for the length of time and level of understanding, or too simplistic to fully illustrate the importance of this field of study. With these goals in mind, we set out to develop a series of applications and demonstrations that use the Kinect to illustrate some of the fundamental concepts of ECE, and the result was a collection of engaging, interactive demonstrations that illustrate a wide range of topics.

To begin, we use a series of physics demonstrations developed by Amnon Owed [8] that involve the students being able to interact with geometric shapes that fall from the top of the screen. The Kinect is capable of detecting the user, outlining them, and then using that outline to allow them to manipulate the shapes on the screen using their movements. Using edge detection, the software is able to provide the user with the ability to hold their arms out and gather the shapes, sweep the shapes away from them, throw the shapes around, and otherwise use their physical presence to manipulate the virtual environment. Fig. 4 features a screen shot of this demonstration.

Figure 4 - Physics with the Kinect

Another powerful use of the Kinect is employing it as a controller for other software. To demonstrate this, we developed an application that allows the user to control Ableton Live, a music creation and synthesis application. Using the Kinect and the midi protocol, the "Processing" application is able to send commands to Ableton Live that allow the user to select different virtual instruments, control the volume, pitch, and various sound effects using their physical movements. This is accomplished by using skeletal detection to outline the user, and then assigning values to the relative positions of their limbs. This translates to the user being able to move their right hand towards or away from the Kinect to control the intensity of the note and up or down to control the pitch, while using their left hand to control the intensity of the reverberation or distortion present in the signal. A screen shot of the skeletal data that this application uses is shown in Fig. 5.

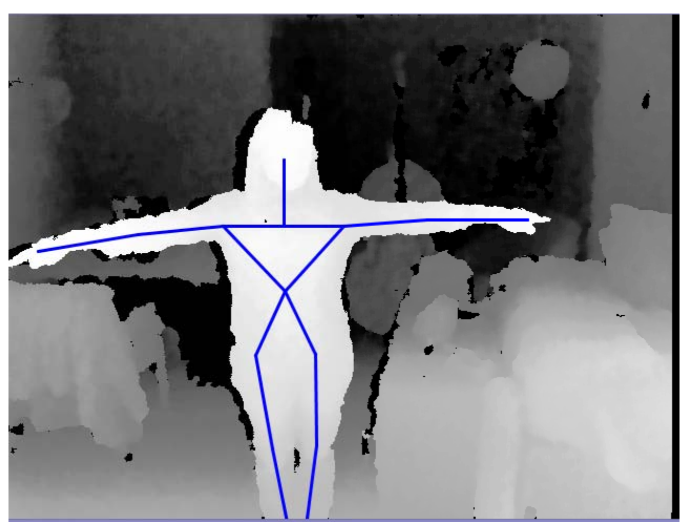

Figure 5 – Skeletal data from the Kinect

Both of these applications provide the prospective students with a novel and unique interaction, and often lead to a discussion of how these demonstrations are accomplished. Typically the student is interested predominately in either the hardware and signal chain necessary to implement the demonstration or the software employed to accomplish the interactivity, and both demonstrations lend themselves to a discussion on either topic.

When the student is predominately interested in the hardware, a quick synopsis of how the Kinect device functions is easily delivered by explaining the infrared camera as a mesh of individual data points. Using "Processing" we are able to show a view of the raw data and a simplistic rendering of a three dimensional image that allows the students to visualize the infrared mesh that the Kinect generates. This demonstration in itself is typically impressive, and often the students are surprised at the amount of information the Kinect is able to deliver. An example of the Kinects ability to render three dimensional images is shown in the screenshot in Fig. 6. The camera is sitting in front of the user, but the software is able to render the image from above.

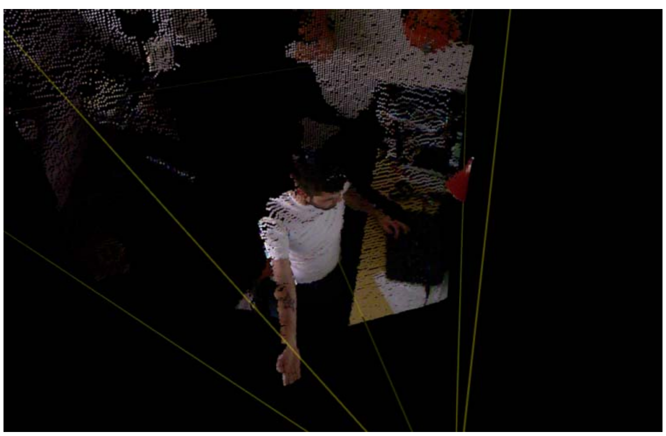

Figure 6 - Kinect data view

During the past year, we have used these demonstrations at a variety of recruiting events, both on and off of our campus and with various age levels. At a variety of traditional-format events where our recruiters are given a table and students are free to choose whom to talk to, the demonstrations were effective at catching the interest of prospective students. These demonstrations were employed at several recruiting events targeting high school students interested in attending OU, and were very well received. Through our conversations and interactions with students, we have come to believe that much of this success is owed to the familiarity of the device. As previously noted, there are over 24 million Kinect sensors in the homes of consumers. This is a device that these students associate with having fun and playing video games, and often this connection is enough to help convey the impact that electrical and computer engineers have on a wide range of activities in their daily lives.

Additionally, the Kinect demonstrations provide the opportunity to interact with students that are interested in video games that would traditionally only view Computer Science as a viable major. The associations that the Kinect brings often allow us a chance to speak with these students about the hardware and lower-level software that goes in to game development, and potentially convince them that ECE could be a better fit for them. While there are a variety of interesting demonstrations that we employ in our outreach, the Kinect creates a unique starting point for conversations with high school students about the degree and scope of ECE and helps attract students that would traditionally be interested in other areas of study.

The Kinect has proven to be an effective tool for outreach as a booth demonstration, but another important aspect of our work with the Kinect has been outreach targeted specifically to high school groups that are interested in the STEM fields. In the past year, we have used the Kinect demonstrations with various school groups, including a high school mathematics club, a high school robotics club, a high school physics club, and a pre-engineering club. When presenting to the mathematics club, we were able to relate the Kinect demonstrations to the mathematical algorithms that the Kinect uses to determine the depth of an object, the trigonometry it uses to align the color data with the point cloud, and various other applications of mathematics in technology. With the robotics club we shifted our focus towards machine vision, object detection, and the creation of responsive programming. With the physics club we focused on creating computer models and simulations, and using those simulations to predict and observe how the physical world would behave under a specific set of conditions. With each subject, the Kinect has served as a powerful tool for linking a prospective student's current interests with a related application in technology and engineering.

Using the demonstrations outlined above to broach the topic of studying ECE has proven to be effective. As we used these demonstrations over the past year, the response has been immensely positive due to the diverse applications of the Kinect, the novelty of being able to render objects in three dimensions, and the prospective student's familiarity with the device. While no specific, quantitative data has been collected for analysis at this point, our organization intends to develop the methodology measure the impact of this device and will begin collecting data in the coming months. Using the Kinect has allowed our recruiting team to reach a wider audience of students than other demonstrations and recruiting methods allowed.

VI. Future Development

Moving forward, there are several key features that we would like to implement in to our Kinect demonstrations. To heighten the effect of the demonstrations and to increase the appeal for students interested in physics, we would like to add the ability to adjust simulation settings in real time. This would give the user the ability to select the effect of various conditions such as gravity or the mass of an object. Another possible direction that we are exploring is using the LabVIEW development environment to create functional blocks that the students could use to write their own programs within a relatively short amount of time. Using this, a recruiter could allow the student to not only experience the demonstration, but actively engage in its creation. The LabVIEW development environment also lends itself to the creation of interfaces like the ones previously described that would be used to control simulation variables. Given these advantages, the possibility of simultaneous development could be beneficial.

We would also like to work on developing the Kinect in to a series of robotics demonstrations where the actions of the user would influence the behavior of a physical object. For example, the user's skeletal data could be used to determine the position of a servo motor, remote commands could be given through motion, or a robotic arm could be programmed to wave back when a user waves. The possibilities for effective, simple demonstrations are numerous, and we look forward to developing an increasing number of applications as our outreach efforts continue to grow.

VII. Conclusion

While OU-ECE's recruiting and outreach program has seen great success over the last five years, the Kinect has enabled our recruitment team to reach a greater number of students interested in a wide array of disciplines. Using a device which most students are familiar with and have had a positive association with has allowed us to introduce the fundamentals of embedded systems to a new generation of prospective students and enabled meaningful conversation pertaining to the importance of the fields of ECE. The student excitement generated by this device at recruiting events has surpassed all other demonstrations OU-ECE has deployed in the past and it has always been the most engaging demonstration of any event it has been shown. We believe others will find the Kinect an extremely useful tool for ECE outreach.

Acknowledgment

As noted, many of these demonstrations were either the direct product or derivative of other members of the open source community. To that end, we wish to thank the independent developer Amnon Owed whose work was used in our physics demonstrations, Professor Max Rheiner of the Interactive Design program at Zurich University of the Arts whom contributed countless examples that aided in our development, Professor Peter Froslie of the School of Art and Art History at the University of Oklahoma for his assistance with "Processing" and communication over the midi protocol, and independent developer Jordan Kuehn who assisted with various technical challenges as they arose. All of these people were an invaluable resource, occasionally without their knowledge or against their will.

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A Novel Approach to Teaching Amplitude and Phase Distortion Concepts Using Time Domain Methods

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***Abstract*— We present an alternative method to teach amplitude and phase distortion concepts using time domain methods. Typically, these concepts are taught using relatively expensive network analyzers. Here we show how a transcendental waveform, generated using relatively inexpensive waveform generators, and observed using standard lab oscilloscopes, can be used to illustrate amplitude and phase distortion, enabling the student to better understand systems whose magnitude responses are not flat, or whose phase responses may not be linear. Our methods allow students the opportunity to gain more insight into the characteristics of high fidelity (audio) systems.**

***Keywords*—distortion, frequency response, fidelity**

I. Introduction

The fundamental Fourier concepts of magnitude and phase response of a linear time-invariant system are taught in varying depths in most Electrical Engineering programs. However we find that students may not fully understand the concepts of magnitude and phase *distortion*. Here we present how experimental methods of time domain analysis using transcendental waveforms can be used to illustrate amplitude and phase distortion, as well as characterize the fidelity of an amplifier. The methods presented are intuitive, and allow the quantification of amplitude and phase distortion, with or without the use of a relatively expensive network analyzer. Most importantly, the methods inherently reinforce the requirements for a distortionless system, that is flat magnitude and linear phase responses.

One conventional way to measure amplitude and phase distortion of an amplifier is to use a sweep generator, or a periodic chirp signal and a network analyzer. If one measures a flat magnitude and linear phase responses from the amplifier, one can declare the amplifier is distortionless. Unfortunately, this does require the use of a network analyzer, which may or may not be available in an undergraduate laboratory. While this method is efficient, it may actually cause students to miss out on important time-domain observations.

Most undergraduate laboratories have generators capable of generating waveforms that are rich in harmonics, as well as two channel oscilloscopes, where comparisons can be made between input and output signals. For example, if one drives an audio amplifier with a square wave and observes both the input and output signals on an oscilloscope, one can tell a lot about the amplifier.* If the output and input only differ by a gain constant and perhaps a time shift, one can say that the amplifier does not suffer from amplitude or phase distortion. Conversely, if the output appears as a single sinusoidal wave, then the amplifier exhibits a great deal of amplitude distortion since it is acting as a filter. Thus by using wide-band periodic waveforms, one can determine the bandwidth of an amplifier, and reinforce student learning of Fourier series concepts from the time domain perspective. As a final example, consider a wide-band amplifier with large dynamic range and minimal amplitude distortion, implemented using negative feedback. One might expect that when driven by a square wave, the output waveform would also be square (except for scaling and delay). Instead because of phase distortion, the oscilloscope might display something very different from a square wave. Phase distortion in an otherwise high fidelity amplifier will cause the input harmonically related components to be delayed by different amounts, so the output will not match the input.

We find that the time domain techniques presented help students better appreciate the abstract concept of magnitude and especially phase distortion, help reinforce fundamental Fourier concepts, and can be accomplished without the added expense of network analyzers.

The following is a brief survey of how systems can be characterized with respect to distortion. Most of these are from the audio engineering literature with the focus on *measuring distortion and not necessarily in explaining signal processing concepts*. Griffiths [1] and Kuhn [2] describe the widely used method of square wave testing to measure amplitude distortion. They and most others who use this method do not deal with phase distortion, probably because the human ear does not readily pick up phase distortion. However, Lipschitz et al. [3] describes experiments on how the ear can perceive the effects of phase distortion. Cabot [4], [5] presents an excellent comprehensive treatment that describes the various types of distortion, and how these can be measured using single tone inputs and Fourier analysis. Blaess [6] and French

* With many amplifiers, it is easy overdrive the amplifier and cause it to output a square wave. Therefore, it is mandatory that the amplifier is operated in its linear range.

[7] use pulses and Fourier analysis to measure system distortion.

In this paper we first will re-state the definitions associated with distortionless systems, present a brief example of phase distortion and then present some simulations to illustrate what amplitude and phase distortions look like.

II. Distortionless Systems

A distortionless system is where the output signal has the same "shape" as the input except that the output is a scaled and delayed version of the input. More precisely, a system is *distortionless* if $y(t) = Kx(t - t_d)$ with $x(t)$ and $y(t)$ the input and output, respectively, and K and t_d are constants. Thus the system function is

$$H(j\omega) = Ke^{-j\omega t_d} \quad (1)$$

where $|H(j\omega)| = K$ and $\angle H(j\omega) = -\omega t_d$

There are many types of distortion, but we will only consider amplitude and phase distortion.

Amplitude distortion is when the K term is not constant or is not "flat" over all input frequencies. One example is a low pass filter.

Phase or *delay distortion* occurs when $\angle H(j\omega)$ is nonlinear with frequency. This often occurs in feedback systems.

Unlike amplitude distortion, phase distortion is not easily observed and does not have the same degree of coverage in beginning signals and systems courses. Therefore, we present a brief example of a system with and without phase distortion.

Consider a system with flat frequency response and linear phase with an input of

$$x(t) = 10\cos\frac{\pi}{2}(t-2) + 2\cos\frac{\pi}{6}(t-2) \quad (2)$$

and $H(j\omega) = 5e^{-j3\omega}$.

It can be shown that the output response is,

$$y(t) = 50\cos\frac{\pi}{2}(t-5) + 10\cos\frac{\pi}{6}(t-5) \quad (3)$$

We observe the response meets the non-distortion criteria as defined above.

We now consider the same input to a system with constant amplitude, but nonlinear phase with

$$H(j\omega) = 5e^{-j\omega^2} \Rightarrow 5\angle -\omega^2 .$$

It can be shown that the output response is,

$$y(t) = 50\cos\frac{\pi}{2}(t-3.57) + 10\cos\frac{\pi}{6}(t-2.52) \quad (4)$$

While there is no amplitude distortion, the uneven relative time delays indicate the system has phase distortion.

Finally, in systems without phase distortion, if the input is symmetrical, then the output would also be symmetrical.

III. Simulations

To illustrate the effects of amplitude and phase distoration, we simulate systems that contain both distoration types, apply a square wave rich in harmonics and observe the responses. Figure 1 shows the output from a system that has moderate amplitude distortion and linear phase. Figure 2 is the output from a system with very little amplitude distortion and linear phase. In comparing Figures 1 and 2, we observe the effects of ampltude distortion. The output from the system with moderate ampltude distorton deviates greatly from a square wave as noted by the high degree of low frequency ripple in the output, whereas the output from the system with little amplitude distoration is a relatively close fascimile of the original square wave input. The observed ripple frequency is approximately that of the highest harmonic in the system's passband. We also observe that the time domain signal, with added ideal delay, could become an even function of time. This symmetry typically imples that the system in question has a reasonably linear phase characteristic.

Figure 3 simulates a system with the same degree of bandlimiting as the one in Figure 2, except it has moderate degree of nonlinear phase, hence phase distortion is present at the output. Note the output contains the same harmonic components as the system of Figure 2, but the phase distortion has caused the positive and negative amplitudes to develop a nonzero slope. This is due to the uneveness of the output times for each of the frequency components. This is further shown in Figure 4 which simulates a system with a much higher degree of phase nonlinearity than that of the system of Figure 3. Figure 4 shows that one of the higher order harmonics is disproportionally delayed, confirming the point made in Eq. (3). Certainly, other types of nonlinear phases can be simulated, but the main point is that systems with nonlinear phase distort the output in a different way than systems with amplitude distortion. Specifically, we note that no amount of ideal delay can produce an even function for the signals in Figures 3 and 4. Such asymmetry typically implies that the system in question has some type of nonlinear phase characteristic.

Note at first observation of Figures 3 and 4, one might draw the conclusion that the signal doesn't have nonlinear phase, but exhibits the classic "overshoot" problem. At closer examination, the spike in amplitude *occurs before the input changes* whereas overshoot occurs due to the system's response to a change in its input.

IV. Conclusions

We have developed a method to test a system for amplitude and phase distortion using a square wave input. The simulations indicate that this method is a viable alternative to the standard, but relatively expensive method of using a sweep generator with a network analyzer. Furthermore, in this technique, Fourier series concepts are reinforced.

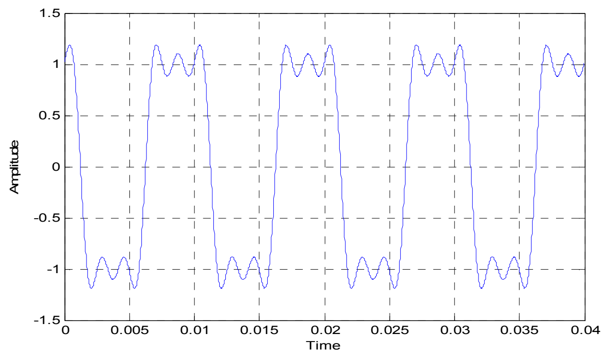

Figure 1. Waveform from system with large degree of amplitude distortion and linear phase. Ouptut only contains the the 1st, 3rd and 5th harmonics. Although there is distortion, we note that with proper delay, the output could become an even function of time. This implies no phase distortion is present.

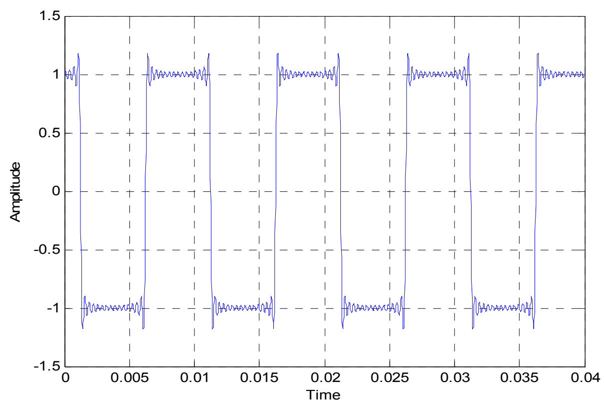

Figure 2. Waveform from system with negligible amplitude distortion and linear phase. Output contains 29 harmonics. Observe the time domain symmetry, such that an added delay could produce an even function of time. This implies the system must have exhibited linear phase.

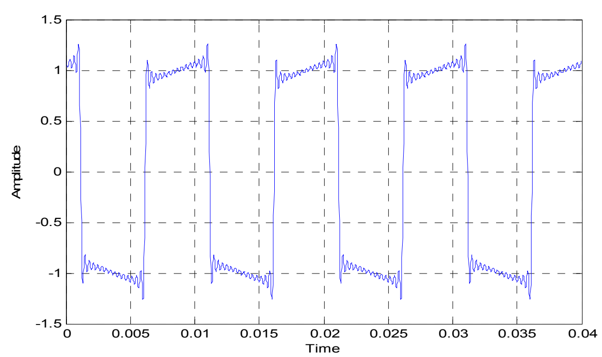

Figure 3. Waveform from system with negligible amplitude distortion and nonlinear phase. Output contains 29 harmonics. Unlike Figure 2, there is no ideal delay that could produce an even function, thus phase distortion must be present.

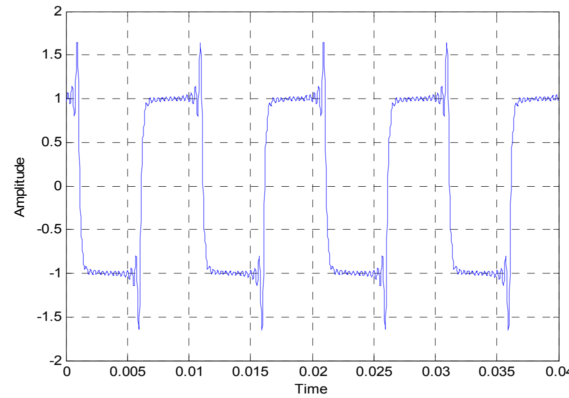

Figure 4. Waveform from system with negligible amplitude distortion and nonlinear phase. Output contains 29 harmonics. Again, there is no ideal delay that could produce an even function, so we know that phase distortion must be present.

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Just Because We Teach It Does Not Mean They Use It: Case of Programming Skills

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Abstract—**We are assessing the effect of our new freshman electrical engineering course sequence on follow-on courses. One of our assessments is a survey distributed to sophomores in electrical circuits and juniors in microelectronics courses. Roughly one half of freshman year is spent on programming in MATLAB and C, and problem solving using these programming tools. Our observation is that students consider programming important and have reasonably good confidence (self-efficacy) that they can solve problems using MATLAB and C. However, when asked about frequency of use for these tools students report using them somewhere between once a week and once a month. There is a significant number of students who report almost no usage at all. Results are consistent across sophomore and junior years with a slight up-tick in frequency of use for juniors. We are hypothesizing that students do not view MATLAB and C as tools for problem solving but as yet another item to acquire in their studies. Our plan is to change instruction in sophomore courses so that more problem-solving which requires programming will be introduced. The existing survey will be used to measure future improvement.**

Keywords—assessment; freshman engineering; programming.

I. Introduction and Motivation

The student experience during the freshman year has been recognized as one of the keys to attracting more students into engineering and improving retention [1]. In the ECE department at PSU we have recently designed and implemented a set of three freshman courses that include many of the best-practices approaches [2-4]. The first freshman course (ECE 101) is meant to be more inviting and encouraging to students. Instead of trying to filter them out of the program, we present them with a spectrum of engineering challenges that are fun to work on. The following two courses (ECE 102 and 103) concentrate on problem solving primarily using MATLAB [5] and on C-language programming and were meant to improve our students' programming and problem-solving skills.

In Fall 2011 the first cohort of students following the new curriculum reached junior year. Many of our students transfer from local community colleges which do not follow the same curriculum, making analysis of effects of changes in our curriculum more challenging. Our initial goals, and our research questions, were to determine if there is any positive impact of our new freshman curriculum on a) student preparedness and b) student success in the program. For the former we developed a brief self-efficacy survey. For the latter we will be analyzing student transcripts at the point of graduation. Our first cohort will be graduating this spring. It is hoped that this will provide evidence that our changes are effective as well as point out what parts of our freshman program may need improvement.

II. Assessment

Individual courses have their own assessment of course outcomes but this does not enable a longitudinal look at what students do with the knowledge and skills they develop during the freshman year. To answer that question we developed a survey that asks students about the importance of what they learned and how confident they are in their skills. We also ask them to estimate how often they use programming tools, namely MATLAB and C. Survey details are given below.

A. Survey

The survey was administered in two courses: a) first sophomore circuits class (ECE 221), and b) first junior microelectronics class (ECE 321) as detailed in Table 1.

Table 1 Number of respondents per course and term

	Fall 2011	Fall 2012	Winter 2013
ECE 221	21	26	10
ECE 321	16	5	14

For this report the most relevant questions are:

Q4. My knowledge of MATLAB is very useful in my engineering studies
Q5. I am confident that I can use MATLAB to solve problems in ECE 221/2/3 and other courses
Q6. My knowledge of programming is very useful in my engineering studies
Q7. I am confident that I can use my programming skills to solve problems in ECE 221/2/3 and other courses
Q8. Material and techniques I learned in ECE 101+102+103 or ECE 102+103 have been useful in the follow-on courses
Q9. I use MATLAB or programming language(s)

Questions 4 to 8 use a five-point, Likert-type scale: strongly agree (1), agree (2), neutral (3), disagree (4), and strongly disagree (5). The last question is on frequency of use and has a scale: Very frequently (daily) (1), Frequently (2-3 times a week) (2), Seldom (once a week) (3), Very infrequently (once a month) (4), Almost never (5).

As a first step in our analysis we examined the data in the aggregate but separated by course. Our expectation was that we would observe some improvement in self-efficacy in the junior year. Aggregation is further justified by lack of any large differences in histograms of answers to various questions among different years. We will look at averages and histograms (distributions): averages may uncover some larger shifts or trends, while histograms give a more detailed look at individual questions. Since our data is very new we did not have time to separate out the native vs. transfer populations – this is the next step in our analysis.

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III. SURVEY RESULTS

Figure 1 presents averaged survey data for questions 4 to 9. Data is aggregated across years and standard deviation is shown. Note that lower number means higher agreement with the question. Numbers 221 and 321 indicate the sophomore and junior courses, respectively. Students' perception of importance or usefulness of MATLAB (Q4) and programming (Q6) is fairly high. However, their self efficacy, i.e. confidence in their skills in MATLAB (Q5) and programming (Q7) is somewhat lower. Remarkably, there is hardly any difference between juniors and sophomores and, if anything, juniors have somewhat lower confidence, as judged by the distribution shown in Figure 2 for Q7. This is similar to the observation reported in [6] that "data comparisons between the freshman and the sophomore courses at MSU indicate a loss of confidence in the use of some skills from the time students take the freshman course to the time they enter their sophomore year."

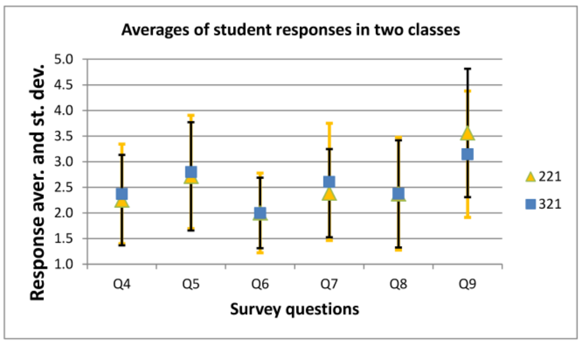

Figure 1. Average scores for questions Q4 to Q9.

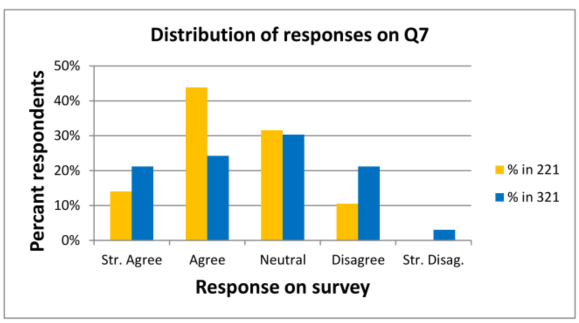

Figure 2. Self-efficacy for MATLAB skills.

Figure 3 shows the response to Q8, referring to the general preparation provided by the freshman sequence. Based on Figures 1 and 3, we observe that students find our freshman courses useful, but that there is room for improvement. Juniors also seem to be slightly more positive about their experience than sophomores. Figure 4 shows the response to Q9, referring to the frequency of use of programming tools, both MATLAB and C. Recall that "1" is the most frequent use and "5" the least. From Figure 4 we wanted to find some support for student estimate of self-efficacy, but we were not expecting to find that half of our students report using programming or computational tools once a month or almost never!

The situation improves somewhat for juniors vs. sophomores, but the frequency of use seems too low for both. Our working hypothesis is that this is due to lack of requirements in follow-on classes. Students forget the tools, or do not use them frequently enough that they become indispensable (the way, for example, a calculator is). If so, then we will have to introduce some changes in our curriculum. Our results indicate that it is not sufficient to look at self-efficacy alone, but we also need to verify that students use their skills frequently enough to maintain the initial proficiency.

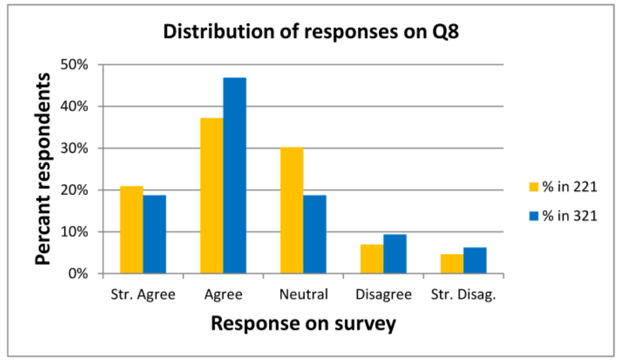

Figure 3. Students' estimate of usefulness of their freshman preparation.

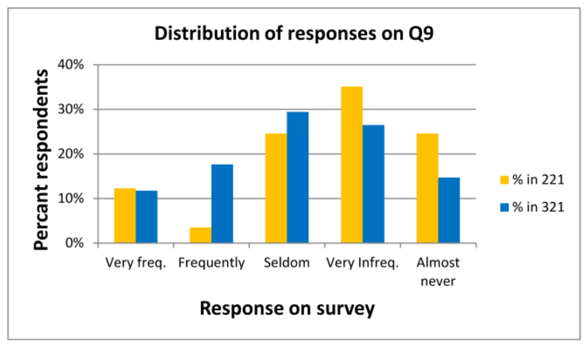

Figure 4. Frequency of use of programming tools.

In response to the first year's survey, we are including more MATLAB programming in ECE 222 and 223. In 222 a lab was introduced on symbolic MATLAB, system representations and SIMULINK. In 223, emphasis is put on using MATLAB in a filter design project. In ECE 321 we plan to use MATLAB for analyzing circuit performance under parameter variation and for projects. The survey planned for the end of the year will help us assess whether these changes improve the situation.

IV. CONCLUSIONS

Overall, our initial data and analysis show good levels of student satisfaction with their preparation in freshman year and reasonable levels of self-efficacy in the use of MATLAB and C programming. There is room for improvement, especially since self-reported frequency of use is lower than our expectations. This points to the conclusion that these tools must become an integral part of the entire curriculum if they are to become really useful to – and be used by – our students. In other words, we have to provide better scaffolding and repeated exposure to authentic computational problems across years [6,7]. These results also lead us to believe that it is critical to ask not only about student self-efficacy but also about frequency of use. Students may be confident but never use the tools, and that bodes ill for their actual proficiency.

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Developing The Cellbot Learning Framework (CLF) -

An Interdisciplinary Model For Integrating Mobile Computing With Robotics To Innovate STEM Education and Outreach

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Abstract - **Mobile computing and robotics have been used as two separate approaches to engage university and pre-university students in STEM education. We are in the process of developing an innovative learning model that combines these two approaches into an integrated framework, where students would learn to make robots and control them via Android applications. By creating these cellbots, students will learn Android app programming and robot building together. Through CLF, we strive to engage both university and pre-university students in a creative environment that enables joint learning of programming logic and engineering concepts. CLF will also serve as an interdisciplinary tool to interface science with engineering. It will further pave the way for building diverse student communities by bonding different learners. The overall goal is to enhance STEM curriculum and outreach activities for recruiting more STEM majors. As part of implementing CLF, we are developing a STEM workshop for high school students, which will consist of hands-on activities on working with BERO (Be The Robot) and designing cellbots. Our future plans comprise of deploying CLF in introductory STEM courses to promote the diverse and interdisciplinary nature of STEM disciplines.**

I. INTRODUCTION AND BACKGROUND

The global technological advances of the last decade have made a major impact on STEM curricula. On one hand, new courses, based on mobile computing, have expanded STEM disciplines and on the other hand, interdisciplinary courses, based on robotics, have enhanced STEM topics.

A. *Significance of Mobile Computing*

Given the increasing demand and accessibility of Android apps, skills at developing these apps are required of present STEM majors, who need to adapt to the ever changing STEM disciplines. This has led to the advent of new STEM courses based on Android programming, an emerging topic [1]-[3].

B. *Significance of Robotics*

Robotics has been around in STEM education as a classic, multidisciplinary engineering topic [4]-[13]. Teaching programming logic and automation via robot simulators and demonstrating AI topics through robot prototypes are practices that have been successful in reinforcing STEM learning [6]-[13]. The subject of robotics has its own charm and has always drawn in students as STEM majors.

II. PURPOSE AND MOTIVATION

Even though a lot of research and innovative practice has gone into the above two STEM fields separately, not much interdisciplinary work has been done to combine the above two topics into one for the benefit of early STEM education and outreach. [14]-[15] mention the idea and purpose of combining mobile computing and robotics into one course, but the resulting learning environment is clearly intended towards upper level STEM classes, the audience being STEM juniors and seniors. What our CLF brings forth is basically a novel learner platform of mobile computing and robotics put together into an integrated model for introductory STEM education and STEM outreach. The unique purpose of CLF is innovation of STEM education and outreach for bringing together STEM students from different interest areas. CLF is a way for students to learn Android app programming while making robots. The use of Android apps to maneuver robots is intended towards stimulating the young minds and motivating them to take up STEM majors. One of the major challenges of STEM education is to teach freshmen the art of programming. CLF aims at making this job easier by demonstrating programming logic and its outcomes through robot actions via an Android app. It is meant to excite students and engage them in both Android app programming and robotics by connecting the two distinct fields meaningfully. It is also intended for attracting students to STEM majors by early hands-on introduction to advanced topics like wireless communication, HCI (human-computer interaction), AI (artificial intelligence), ML (machine learning), object detection.

III. CLF DESCRIPTION

CLF currently contains two learning components - Cellbot Building Module (CBM) and BERO Based Module (BBM). CBM involves cellbot building from scratch using robot platforms like Arduino microcontrollers [16] and pairing them with Android smartphones. BBM encourages exploring and programming BERO, which is a pre-built robot controlled wirelessly by a bluetooth-enabled Android device [17].

A. *CBM Description*

CBM comprises of building a prototype cellbot through a combination of engineering and programming techniques using hardware elements (like Arduino boards) and opensource software components [18]. The electronic Arduino board is chosen because of its ready availability, cheap price and user-friendliness. CBM is inspired by Google's cellbot project [18] with the objective of driving a robot using an Android smartphone as a remote control. The opensource cellbot app [18], as displayed in Fig. 1, is a handy Android API (application program interface) as it is compatible with several robotic platforms and operates a robot remotely from a

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mobile device, desktop or a web browser. Once connected to a robot, this app acts as a remote control in its brain mode, rendering it easy to navigate the robot and chat with it remotely using text messages through Google Talk. Using CBM, students will get exposure to Android app programming, UI (user interfaces), robotic platforms and smartphone capabilities. The CBM hands-on activity serves as an educational tool since it teaches both programming and engineering skills over a single platform. The communication with a robot through an Android smartphone also introduces fundamental STEM technologies and HCI concepts such as voice recognition, text-to-speech conversion and basic client-server communication using chat.

B. BBM Description

BBM consists of working with the pre-engineered, affordable BERO [17], which is driven by an Android device (such as a smart phone or a tablet) via bluetooth. There are several benefits of selecting BERO for this learning module. Its major advantages lie in the following attributes:-

- Small, compact size and relatively less cost
- Opensource app and opensource code (free download)
- Full set of functionalities with advanced in-built features
- Different user modes/options (user-friendliness)
- Exhibition of simple event-driven programming logic, including events, macros, functions, data types, etc.

Fig. 1. Cellbot Android app and prototype: CBM (CLF).

IV. IMPLEMENTATION DETAILS

The CLF implementation process consists of two parts - STEM outreach and STEM education. The first part focuses on the use of CLF for reaching out to pre-university learners (prospective STEM majors), while the second part concentrates on the use of CLF for university students. We utilize BERO in its basic play mode (non-developer) for CLF STEM outreach activities, while we use BERO in its developer mode (with Android SDK and Java) for CLF STEM education sessions. By using BERO for CLF, we provide learners the advantage of early hands-on experience with many significant interdisciplinary concepts and STEM technologies, including basic programming elements, program control logic and engineering techniques.

A. STEM Outreach

As part of the CLF STEM outreach work, we will be incorporating BBM into our upcoming STEM outreach sessions. These outreach activities will be targeted towards recruiting pre-university students for STEM majors. The workshops will focus on using BERO for hands-on experience in the play mode with motion, light and sound control. The advantage of employing BERO as an outreach tool is that it is a pre-built cellbot that can be introduced as an animated, mobile, robotic toy platform for playing with. Learners do not require any prior programming background to get started in this mode. In fact, our hands-on activities for pre-university students involve only visual programming and not writing actual code. These beginner's exercises will teach them how to control BERO with its open-source Android app (as shown in Fig. 2) and how to make the robot walk, dance, play music and do other exciting stuff. The introductory BERO exercises enable easy robot manipulation through an Android device.

The hands-on topics provide many learning opportunities, as listed in Fig. 3. Witnessing the variety of different hands-on experiments with BERO leads to early understanding and appreciation of STEM subjects, thereby creating an impression and engaging young minds at a nascent stage.

Fig. 2. BERO Android app: BBM (CLF).

B. STEM Education

As part of the CLF STEM education component, we adopt both CBM and BBM. We use BERO in both of its modes - developer mode as well as play mode. Usage of both modes enhances the overall learning at the university level by revealing the full range of BERO capabilities and features. BERO programming in dual mode demonstrates more programming concepts and offers more learning opportunities. We plan to deploy CBM in the outreach activities of the ASU Robot Society [19]. We also intend to include the CLF STEM education component in our introductory CS (computer science) programming courses at the CS0 and CS1 levels. CLF STEM education for university students will include hands-on BERO programming exercises (using the developer mode) in addition to the beginner's exercises (using the play mode). BERO in its developer mode serves as a good educational tool for STEM majors as it provides a multitude of opportunities for them to study and learn different aspects of programming. The opensource BERO application code base comprises of an Android app and BERO firmware (system routines). The app communicates with the advanced BERO internal operating system via bluetooth. The bluetooth communication routines (code) are stored on the Android device. The BERO programming exercises of CLF STEM education are based on the opensource BERO app code. Some of our sample BERO developer programming exercises for CLF STEM education are cited in Fig. 4.

Topic #	*Topic Name*	*Expected Outcomes*
I	BERO Android app, GUI (graphical user interface), macro editor	See and use function control buttons, macro control buttons, BERO commands, macro data, events; learn about bluetooth (HCI, communication technology)
II	Built-in features: robot arm motion, sound playback, drive train, IR (infra-red) obstacle avoidance	Experience and learn about HCI, AI, ML, data coding/compression, object detection/tracking, IR sensor

Fig. 3. Example hands-on topics: CLF STEM outreach.

V. PROJECT STATUS AND EVALUATION PLAN

The CLF implementation process is currently in its early stages and we will be starting the pilot deployment phase in summer 2013. We have developed BBM and are in the process of developing CBM. We plan to conduct a summer STEM workshop for local high school kids and intend to deploy the CLF STEM outreach component in the workshop sessions. This workshop is through our partnership and collaboration with the local K-12 education systems (12 high schools). We also plan to incorporate BBM into one or more of our CS0 and CS1 programming classes in fall 2013. The CLF hands-on lessons of the upcoming summer workshop and the fall programming course(s) will contain programming exercises for making BERO respond and react to simple message commands/instructions through a given Android device. Additional hands-on activities will include setting up BERO's multi-motors and IR sensors to produce navigation through obstacles, dancing moves, etc. Thus, by the actual IEEE FIE 2013 conference date, we should have preliminary evaluation data for the CLF performance, including student feedbacks/survey results from the CLF STEM outreach sessions as well as the CLF STEM education activities.

VI. CONCLUSION AND FUTURE WORK

Given that Android apps and robotics are generally considered as two separate STEM areas and are treated independent of each other, CLF integrates these two different subject matters into one innovative model for enhancing STEM education and outreach. CLF looks to build a creative, fun-filled environment, which would pave the way for learning of application programming along with meaningful engineering. CLF is also meant for building diverse learner communities across STEM disciplines by bringing together students of different backgrounds and varied interests. It acts as an innovative hands-on learning tool for understanding programming strategies and STEM fundamentals while experiencing an exciting integrated application of mobile technology and robotics. Using CLF, we intend to encourage more student participation in STEM by engaging learners in creative work and making them realize the broad range and diversity of STEM applications. Possible scope of future work lies in implementing a CLF that is iOS compatible, works with iPhones and is capable of being controlled via Wi-Fi.

Exercise #	*Exercise Name*	*Expected Outcomes*
I	Change commands to BERO using control message strings	Learn about command set up using data strings, functions, parameters and parameter passing; understand string variables and learn to use them through BERO commands
II	Schedule the signal sent to BERO with a given sending rate	Learn about timing configuration; understand data types: integers, floats, assignment operators and operations; learn to use them through scheduling program
III	Decide BERO action based on obstacle detection via IR radar	Understand IF conditional statement for decision making logic and learn to use it via IR sensor input

Fig. 4. Sample programming exercises: CLF STEM education.

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Engineering the Human Heart in the Sixth Grade Classroom

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***Abstract*— A Framework for K-12 Science Education has been released that provides further support of K-12 engineering education by framing requirements for K-12 engineering standards for the science classroom. This study uses the engineering themes from the framework to evaluate how an engineering learning experience affects student achievement in science and engineering in the context of a science classroom. An engineering design challenge, Engineering an Artificial Heart, was developed for a pre-existing science instructional lesson, the human heart, for its use in a 6th grade science classroom with 32 students. Students' achievement of learning objectives for science and engineering concepts were measured using content assessments, student artifacts, and semi-structured interviews. Preliminary analysis shows positive learning gains for science learning objectives and evidence of performance for the engineering learning objectives.**

***Index Terms*—K-12 engineering, learning through design**

I. INTRODUCTION

The National Research Council has released the Framework for K-12 Science Education, which is serving as a guide for the Next Generation Science Standards (NGSS) and informing state-level decisions for K-12 science education [1]. Engineering has a significant role in the framework and will require the engineering education and teaching communities to develop strategies for building the upcoming engineering standards into the science classroom.

A. Engineering in K-12 Education

To date, engineering education for K-12 has been successful in building momentum. With several dozen engineering education programs and curricula in school districts around the U.S. and growing, engineering education is reaching students around the nation [2]. The implications of engineering in K-12 are being documented by several research initiatives; some of the positive outcomes include boosting learning and achievement in math and science, increasing interest in engineering as a career, and improving the technical literacy of students [2]. Despite the benefits that students have received from engineering education, these programs and curricula have come from multiple perspectives of what engineering should look like in K-12 and have varying learning objectives that are designed to meet the program's needs.

Other school subjects, on the other hand, have a long-standing history in the classroom and are supported through established learning standards. When the landmark report *Engineering in K-12 Education: Understanding the Status and Improving the Prospects* was published, engineering did not have formal learning standards and therefore engineering education did not have a consistent presence across schools and states. The NGSS offers a foundation for K-12 engineering education to build upon by providing guidelines to inform the development of engineering standards and learning progressions. This provides opportunity to address unanswered questions for K-12 engineering education that have potential to impact the pedagogy for engineering, such as how does engineering provide a context for exploring science concepts in the science classroom.

B. Engineering in NGSS

The NGSS framework is organized with three dimensions: science and engineering practices, crosscutting concepts to unify science and engineering, and disciplinary core ideas. Engineering themes are present in each of the three dimensions. Throughout the framework, engineering is represented by the systematic, iterative practice of design. Learning engineering by design is supported in the literature as useful for K-12 students and is the focus of the majority of K-12 engineering education curricula [2]. Table 1 displays the extracted engineering themes from the framework.

TABLE 1. ENGINEERING THEMES IN THE NGSS FRAMEWORK

Dimension 1: Engineering Practices	Dimension 2: Crosscutting Concepts	Dimension 3: Disciplinary Core Ideas
1. Defining problems 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Designing solutions 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information	1. Patterns 2. Mechanism and prediction 3. Scale, proportion, and quantity 4. Systems and system models 5. Energy and matter 6. Structure and function 7. Stability and change	1. Engineering design 2. Links among engineering, technology, science, and society

II. IMPETUS FOR THE STUDY

The impetus of this work is to address how an engineering learning experience, built from the engineering objectives outlined in the NGSS framework, affects student achievement in science and engineering in the context of a science classroom. As a first step towards this research goal, an engineering design challenge, Engineering an Artificial Heart, was developed for a pre-existing science instructional lesson, the human heart, for its use in a 6th grade science classroom. The engineering design challenge was embedded with core features from each of the three dimensions of the framework. It is hypothesized that the engineering learning experience, using the core features of the NGSS framework, will be effective in the science classroom. Learning through engineering design provides students with opportunities to make deep connections to the material. For instance, modeling in engineering design provides an opportunity to explore the functional parts of a system, the ways in which the roles of the parts are performed, how the functions of the parts interact with each other, and what the parts of the model represent [3].

III. METHODS

For two weeks, 32 6th grade students engaged in the bioengineering design challenge, Engineering an Artificial Heart. A researcher from the university taught the learning experience alongside the 6th grade classroom teacher. Students worked in groups of four, making eight groups.

The science learning objectives were taken from the classroom teacher's pre-existing science lesson on the human heart and were:

- Students will demonstrate knowledge of the major structures of the heart and their functions. (S1)
- Students will be able to explain why the heart is a double pump. (S2)
- Students will be able to explain that blood has a direction of flow through the heart. (S3)
- Students will be able to explain that the function of heart valves is to prevent backward flow of blood. (S4)

The engineering learning objectives were developed using language from the NGSS framework. The objectives for Dimension 1 emphasized that students should be able to demonstrate their ability to engage in the engineering practices. Specifically, this included the following.

- Students will be able to define the engineering design problem that can be addressed through the development of an artificial heart model and includes multiple criteria and constraints, including scientific knowledge about the heart that may limit possible solutions. (D1-1)
- Students will be able to develop an artificial heart model to generate data to test ideas about the designed system – the artificial heart - including inputs and outputs. (D1-2)
- Students will be able to engage in argumentation from evidence to provide reasoning for the strengths and limitations of their artificial heart models. (D1-3)

For Dimension 2, crosscutting concepts, two concepts were selected for their applicability to this lesson: (1) systems and system models and (2) structure and function. The systems and system models concept required that students be able to define the system under study and its interconnecting parts (i.e. the human heart and its atria and ventricles) and make explicit a model of that system (in this case, through engineering design). The structure and function concept required that students explore the way in which an object (i.e. the human heart) is structured and determine its properties and functions. The appropriate learning progressions in the framework were used to develop the learning objectives for these concepts.

- Systems and system models: Students will be able to move beyond simple drawings of the system under study and make explicit the interactions that are invisible to the eye (e.g. movement of blood from one heart chamber to the next). Students will be able to use artificial heart models to interpret and explain a natural system, the human heart. (D2-1)
- Structure and function: Students will be able to analyze a complex structure, the human heart, and be able to communicate how shapes of the structure and substructures are related to the function. (D2-2)

For Dimension three, disciplinary knowledge, both strands were included in the learning objectives: engineering design and the link to technology and science.

- Students will be able to demonstrate their ability to engage in the process of engineering design, including problem definition, gathering information, developing possible solutions, evaluating the solutions, building, testing the solutions and identifying the characteristics of the design that performed the best, and revising the design to optimize the solution. (D3-1)
- Students will be able to gather information on artificial hearts and participate in discussions about engineering advances for artificial heart. (D3-2)

These learning objectives were then used to develop the learning activities for the engineering learning experience. These are listed in Table 2.

TABLE 2. LEARNING ACTIVITIES FOR ENGINEERING AN ARTIFICAL HEART

Day	Learning Activities
1-2	Students were introduced to the bioengineering design challenge, including criteria and constraints. Students were asked to explore what is engineering through hands-on activities. Students began to gather information on the human heart from in-class materials (e.g. models, library books, animations, etc.)
3	Students worked together to assemble their knowledge of the human heart as a system into a structure-function chart using their whiteboards and group discussions.
4-5	Students explored the double-pump action of the heart using double siphon pumps. Students explored other types of pumps and built centrifugal pumps from pens and ball bearings. Students began to develop possible solutions for their artificial heart models.
6-7	Students evaluated their solutions and built the most feasible artificial heart model from recyclable materials.
8-9	Student groups presented and compared their models. Students tested their models, collected data, and revised their models. The presentations included the strengths and limitations of the models.
10	Student groups completed the revisions of their artificial heart models and presented them to the class. Students' presentations focused on the parts (structures) of their models and the purpose of the parts (functions) and how this helps explain the human heart system.

IV. DATA COLLECTION AND PRELIMINARY ANALYSIS

Using a mixed-methods approach, qualitative and quantitative data were collected from the students. Quantitative data were collected from two science content assessments, Draw the Human Heart, an assessment that asked students to draw the structures of the human heart, label their functions, and draw arrows marking the direction of flow of blood, and The Heart as a Pump, an assessment that asked students to explain why and how the heart acts as a pump. As a preliminary analysis, these assessments were evaluated and dichotomously scored for their correct and incorrect science conceptions about the heart outlined by the science learning objectives. A paired samples t-test was performed. Table 3 presents these results. Students' performance for the science learning objectives resulted in statistically significant differences; these differences are considered meaningful due to the large effect sizes, particularly S1, S3, and S4. Figure 1 presents an example post test. A typical pre test was one where the student drew a heart shape in the middle of the body.

Qualitatively, semi-structured interviews were conducted with student groups prior to the engineering learning experience, at a mid-point, and after the conclusion of the engineering learning experience. The science and engineering learning objectives were used to probe students for their understanding of science and engineering concepts. Artifacts from the student groups were also collected, including the artificial heart model and design notebook. As a preliminary analysis, the student artifacts and interviews were examined for their satisfaction of meeting the engineering learning objectives. Table 4 is a chart of these results with the last row representing the percentage of the class meeting the particular objective. A more in-depth analysis is currently taking place.

The purpose of this work was to show how engineering design affects student achievement in science and engineering in the context of a science classroom. These results provide preliminary support that engineering design contributes to science and engineering achievement in the science classroom.

TABLE 3. STUDENTS' LEARNING GAINS FOR THE SCIENCE CONCEPTS

	Paired Samples Statistics				
	N	SD	t	p	Effect Size
Knowledge of major structures and functions of the heart (S1)	32	0.492	4.313	<0.001	0.594
Explanation of how the heart is a double pump (S2)	32	0.336	2.104	0.022	0.223
Blood flow is directional (S3)	32	0.499	4.605	<0.001	0.594
Function of the heart's valves (S4)	32	0.507	5.230	<0.001	0.725

TABLE 4. EVALUATION OF ENGINEERING LEARNING OBJECTIVES

Student Group	D1-1	D1-2	D1-3	D2-1	D2-2	D3-1	D3-2
1	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X
4		X					X
5		X					
6	X	X	X	X	X	X	X
7	X	X					X
8	X	X	X	X	X	X	X
Total	75%	100%	62.5%	62.5%	62.5%	62.5%	87.5%

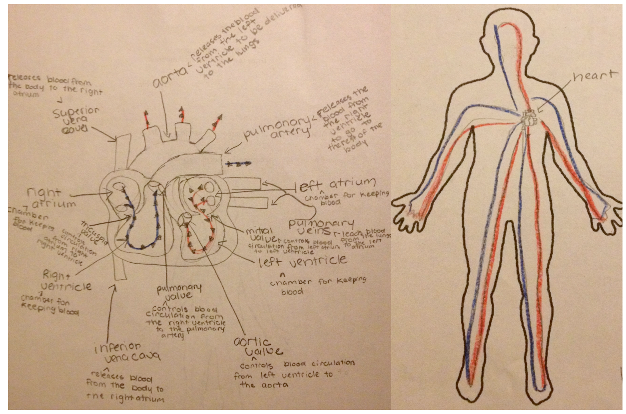

Fig. 1. Example of a student's post-assessment for Draw the Human Heart

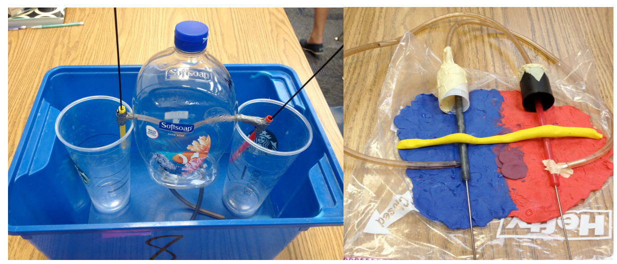

Fig. 2. Examples of two artificial heart models

V. FUTURE STEPS

Further analysis is underway, including (1) evaluating the curricula with the middle school performance standards, developed from the NGSS and released April 10, 2013, (2) comparing student science achievement to the engineering achievement across each student, and (3) coding the interviews for emergent themes. The results of this study will be used to revise and extend the learning experience for the next implementation. For the next implementation, it will be critical to collect data from a control group that does not partake in this engineering design learning experience to have a clearer picture of how engineering design affects student achievement in the science classroom. During this implementation, classroom time was a limiting factor. By including engineering design, the class time doubled. These practical issues will have to be addressed as the engineering standards are added into the classroom. The authors hypothesize that the hands-on exploration of the heart as a double pump through engineering design could aid in students' understanding of other related science content (e.g. the lungs as a pump, a typical lesson that follows the heart). It would be fruitful to measure students' understanding of the related content to evaluate the effectiveness of engineering design.

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Mastery Goal Structures for a Fourth Grade Science Classroom

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***Abstract*— This study investigates the influence of modeling instruction for a solar engineering design challenge on students' achievement goal orientations. Two classrooms received five weeks of modeling instruction using whiteboarding strategies. Students' goal orientations were measured before and after the learning experience using the goal orientation sub scale of the self-report questionnaire, *Patterns of Adaptive Learning (PALS)*. Preliminary analysis revealed that students' performance approach and avoid goals increased, but saw no improvement in the students' mastery goals. This study provided insight to the possible ways in which modeling instruction may be enhancing negative performance goals within the context of a high-stakes environment. Discussion highlights the importance of motivational supports for creating a classroom environment that supports mastery learning.**

***Index Terms*—K-12 engineering, modeling, achievement goals**

I. Introduction

The National Academy of Engineering has called for the integration of engineering into the science classrooms due to its potential to increase STEM literacy as well as increase awareness and interest in engineering careers [1]. Much of the effort has focused on the development of engineering education curricula and instructional strategies for delivering the content. Equally as important is understanding how to support student motivation in the classroom because of its key role in cognition and learning.

A. Achievement Goal Theory

Achievement goal theory is one aspect of the motivation continuum and explains how students' mastery and performance goals affect their achievement, persistence, and interest in the topic [2]. In this framework, different types of achievement goals are distinguished: performance-approach, performance-avoidance, and mastery [3]. Each of these goals represents a different relationship between an individual's valence and definition of competence [4]. With a performance-approach goal, a student focuses on demonstrating superiority and competence and attempts to outperform peers. Conversely, with a performance-avoidance goal, a student focuses on avoiding failure and appearing as incompetent. A student with a mastery goal orientation focuses on mastering tasks and learning. Each of the goal orientations has shown to have different consequences for learning, but mastery goals are considered to be the most favorable due to their ability to generate and maintain long-term interest and well being. Mastery goals also lead to improved self-regulated learning which helps students set better learning goals, monitor and assess their goal progress better, implement more effective learning strategies, seek assistance, persist better, adjust strategies better, and set more effective new goals [5].

Environments impact students' goals, and classrooms can be structured in ways that support or deter students in setting adaptive goals [6]. These support structures include providing students with opportunities to set individual goals, remain focused on the task, and de-emphasize performance based on social comparison. However, these support structures are often neglected in the classroom due to high-stakes testing, pressures for performance, and structural changes in U.S. classrooms including curriculum changes [5]. Instead, U.S. classrooms favor a more direct, authoritarian approach and are increasingly performance-oriented. The effects of this classroom climate can be damaging because it encourages performance-oriented goals. There is evidence that performance-avoid goals offer few benefits; and performance-approach goals, although may lead to improved achievement, may decrease interest [2]. To support students in developing interest in engineering, it is beneficial for the educational setting to be structured in a way that allows students to develop mastery goals. This study seeks to explore whether adaptive orientations through mastery goals can be encouraged through engineering design challenges, taught using modeling instruction.

B. Modeling Instruction

The foundation of modeling instruction is that the making of conceptual and physical models enables students to learn and do engineering [7]. Modeling is specifically useful in engineering education because it provides a method for teaching engineering design and provides opportunities for students to make connections to the scientific concepts that drive the behaviors of their models. Whiteboarding is a specific aspect of modeling instruction that supports students in reflecting upon their engineering work, developing explanations for their engineering decisions, and engaging in critique and evaluation of their own and other students' work. Because whiteboards are generally large and erasable, they allow for sharing, negotiation, and open discourse of conceptualization, modeling, and problem solving, which greatly enhances and enables modeling instruction in a classroom. Modeling instruction, and specifically whiteboarding, has many attributes that are seemingly linked to the underpinnings of mastery goals. This study explores the relations between this instructional model for engineering design challenges and students' goal orientations and interest

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in engineering. This paper seeks to add to a larger conversation about the development of appropriate engineering education instructional strategies that will aid in a mastery emphasis within the classroom and enhance positive socio-emotional outcomes and academic achievement.

II. Research questions

(1) Do 4th grade students' achievement goals change after modeling instruction?

(2) Do 4th grade students' interest in engineering careers change after modeling instruction?

III. Methods

To determine the impact of modeling instruction on adaptive goal orientations among 4th grade students, two engineering design challenges were implemented in two 4th grade science classrooms within the same school district. The selection of classrooms stemmed from a university partnership with the school district. Instruction took place for five weeks in both classrooms with 60 minutes per class session. The first classroom had 24 students and the second classroom had 30 students. Classroom one and two are in the same school district, but serve different populations of students. Classroom one is from a Title I school with 57% students on free or reduced lunch; whereas, classroom two is an honors class and from a school that has 19% of students on free or reduced lunch. Before instruction began and after instruction concluded, students were asked to complete the goal orientation sub scale of the self-report questionnaire, *Patterns of Adaptive Learning (PALS)*. Using a five-point, Likert-style response, this scale asked students to respond to their perceptions of goal structures in the classroom and their personal achievement goal orientations. In addition, students were asked to respond to questions about their interest in engineering careers.

A researcher from Arizona State University's Quantum Energy and Sustainable Solar Technologies (QESST) - who has 13 years of science teaching experience at the school district under study and specialization in modeling instruction - worked alongside the fourth grade educator to deliver modeling instruction for two engineering design challenges on solar energy topics. The researcher and the classroom educator documented daily reflections on their perceptions of challenges with implementing modeling instruction and on the classroom climate. During the 25 class sessions, students were led through the phases of the engineering design process (identify the problem, gather information, imagine solutions, evaluate, plan, build, and revise) to design and build a solar oven and electrical circuits - series and parallel - that powered small objects (e.g. light bulb or small motor). In addition to experiencing the systematic and iterative nature of engineering design, some of the science content learning objectives included: energy can take many forms, one of which is heat and another is electrical energy; energy can be transferred between objects or systems; certain materials are better conductors of heat; electrical circuits transfer electrical energy; electricity can flow through a circuit if there is a power source and the circuit is closed; and many scientific principles of energy can be used to inform decisions about engineering design.

At the end of each class session, students were brought together in a circle with their whiteboards to discuss their daily objectives and outcomes and to engage in scientific argumentation over their thought processes. Students were asked to demonstrate their engineering and scientific understanding and were actively provided with feedback from the educator, researchers, and peers. Students were also encouraged to actively revise their engineering design ideas and were guided through revising any scientific and engineering misconceptions. The whiteboarding sessions allowed the QESST researcher and the educator to personalize learning objectives for each team and to respond to the unique design problems that each team was having.

IV. Results

This study represents a work-in-progress. The results presented here are preliminary. Despite low sample sizes, the results are being used to provide insight to the solar engineering learning experience and will inform revisions made to the experience for the upcoming school year.

A paired samples t-test was performed for classrooms one and two. The pre and post composite scores were compared for each category (e.g. type of goal orientation and interest in engineering careers) to determine the change in achievement goals and interest in engineering careers after modeling instruction had taken place. The tables below present these results. The significant findings are bolded.

TABLE 1. RESULTS FROM STUDENTS' RESPONSES IN CLASSROOM ONE

	Paired Samples Statistics			
	N	t	Std. Deviation	Sig.
Mastery Goals	18	-0.372	0.422	.357
Performance Avoid Goals	**18**	**2.297**	**0.903**	**0.017**
Performance Approach Goals	**18**	**2.803**	**0.645**	**0.006**
Interest in Engineering Careers	17	0.838	0.724	0.419
Awareness of Engineering	17	-1.322	0.734	0.103

TABLE 2. RESULTS FROM STUDENTS' RESPONSES IN CLASSROOM TWO

	Paired Samples Statistics			
	N	t	Std. Deviation	Sig.
Mastery Goals	14	-0.603	0.295	0.278
Performance Avoid Goals	**14**	**4.059**	**0.795**	**0.001**
Performance Approach Goals	**14**	**2.735**	**0.977**	**0.008**
Interest in Engineering Careers	**14**	**3.097**	**0.992**	**0.004**
Awareness of Engineering	14	-0.325	1.097	0.375

V. Discussion

A. Research Question 1

The 4th grade students reported that their mastery goals had little change over the five-week learning experience, but that their performance-approach and performance-avoid goals increased significantly. These results indicate an orientation towards demonstrating competence as well as avoiding failure and appearing as incompetent in front of peers. Evidence from previous studies have shown that performance-approach and avoid goals can increase when students are in a situation when social comparison is emphasized [5]. This evidence is useful in understanding how modeling instruction for this solar engineering design challenge affected students. Despite no change in mastery orientations, performance-approach goals did improve. This is important to note because performance-approach goals have been argued to contribute to adaptive outcomes (e.g. persistence and longer engagement with the materials). When combined with mastery goals, these goals have been shown to have positive effect on students' approaches to learning [8]. However, performance-avoid goals are not favorable due to their negative effects on learning. There is evidence that performance-avoid goals lead to poorer academic performance and lower levels of engagement with the material [8]. Efforts should be made to reduce these avoidance orientations by revising the structure of the classroom and delivery of instruction.

A critical analysis needs to be taken with modeling instruction to identify the aspects of instruction that are emphasizing the negative and positive aspects of performance. In addition, a comparison group is needed to further understand the effects of modeling instruction on achievement goal orientations. These changes will be made for the next implementation of modeling instruction for the solar engineering design challenge, but a preliminary discussion of modeling instruction for engineering design follows.

Modeling instruction and whiteboarding rely upon showing your work to peers, constructing explanations for your work, and receiving feedback from peers in order to inform the revision process for the engineering solution. Collaboration and communication are also a core part of the practices of engineers. However, when modeling instruction and whiteboarding are situated in a school context that emphasizes high-stakes performance and provides little time for explanation and revision due to limited science class time, then engineering design through modeling can begin to emphasize negative performance features rather than supporting mastery learning. This can be improved by identifying appropriate rewards for students, such as recognizing the students' progress and accomplishments during the public whiteboarding sessions; providing multiple opportunities for students to present and revise their understanding of engineering topics; providing students with structured autonomy (e.g. students are given some choice about how they will monitor their performance); and emphasizing that evaluation is self-referenced, meaning that it based on personal improvement and their mastery of engineering learning objectives.

B. Research Question 2

The 4th grade students in classroom two reported greater interest in engineering careers, but no change was calculated for classroom one. Classrooms one and two consist of different demographics, and the additional at-home support structures may be an influencing factor. More information is needed to explore this relation. Informing students of opportunities for engineering careers is an important aspect of engineering education because it can serve as an extrinsic motivator and increase interest in engineering. Classrooms can impact interest by creating the appropriate support structures and opportunities for learning.

VI. Future Steps

K-12 engineering education is at a critical time where K-12 engineering standards are being developed for the science classroom through the Next Generation Science Standards. As instructional strategies for engineering are determined, their impact on classroom goal structures will be of great importance due to the impact of mastery and performance goals on educational outcomes. QESST will continue its partnership with the classrooms from this study and extend the study to include additional 4th and 5th grade classrooms within the school district. The aim is to contribute evidence for best practices of modeling instruction that support achievemenet goal orientations.

Acknowledgment

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Exposure Matters: Understanding the Experiences of Rural Cultures

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Abstract— **Engineering has been shown to be an important field of study and practice for economic and technological development, as well as an opportunity for students to improve their standard of living and their communities. Engineering also has the potential to provide a powerful career path in places that suffer disproportionate economic losses from shifts in the global economy, particularly as the growth of mobile communication technologies enable virtual work and local business development in areas formerly considered "remote" or "inaccessible." Despite these opportunities, little investigative work to date has been done on recruitment of engineering students from rural cultures that are typically underrepresented in the field. To address this gap, this paper explores two such cultures: the Central Appalachians in the United States of America and the Maori in New Zealand. We present a review of the current situation in each region, along with preliminary findings from a study of Appalachian students, to identify both similarities and differences between the two peoples that can be used to enhance recruitment efforts and provide a global context for understanding the experiences of rural cultures.**

Keywords—Maori; Appalachia; Engineering; Career Choice

I. INTRODUCTION

Engineering has been shown to be an important field of study and practice for economic and technological development; pursuing engineering degrees and careers provides a potential opportunity for students from marginalized, rural and/or socio-economically disadvantaged communities to improve their standard of living and that of their community. However, geographic and cultural circumstances can limit these students' knowledge and understanding of engineering as a possible career choice. For example, previous work shows that individuals from rural cultures often lack exposure to professionals which limits their knowledge and understanding of such professional career fields [1-3]. As a result of a lack of exposure to and awareness of fields such as engineering, students may be less likely to pursue such fields.

Little research exists on the methods and impact of recruitment, specific to engineering, situated in rural geographical contexts. This work in progress explores two such cultures: the Appalachians in the United States of America and the Maori in New Zealand. We present a brief review of the current situation in each region, along with preliminary findings from a study of Central Appalachian students, to identify both similarities and differences between the two peoples that can be used to enhance recruitment efforts and provide a global context for understanding the experiences of rural cultures.

Information and data for the Central Appalachian region of the U.S. is drawn from publically accessible archives and from an NSF-funded research project aimed at identifying barriers to engineering as a career choice. Overall, the NSF funded project is a three-phase, sequential mixed method study of factors influencing engineering career choice in the Appalachian region. This paper draws on data from the first, qualitative, phase. Development of the interview protocol has been previously described [4]. Due to space limitations and our choice to highlight the research context, the data analysis is not described in detail but it followed methods prescribed by Miles and Huberman [5].

One framework being used to analyze the qualitative data is Future Possible Selves (FPS) [6]. This framework has been used to study populations of youth facing similar barriers, including barriers raised by cultural biases and socio-economic class [7-10]. FPS provides a useful lens to better understand how students view their future hoped for and feared self to allow us to see if, and where, engineering fits among the future possible selves of Appalachian high school students. Similarly, ideas from Multiple Selves theories allow us to understand how views of engineering selves might be consistent with or in conflict with other visions of the self that stem from rural marginalized identities [11].

Information about the Maori people of New Zealand is drawn from publically accessible New Zealand government archives and existing academic research to understand the culture. This information will be augmented via future field studies as the project unfolds. In this paper, we present information regarding the two cultures which can be used to 1) inform subsequent research studies regarding barriers unique to the Maori people of New Zealand and residents of Appalachia of the United States, and 2) develop interventions adaptable to rural cultures to reach potential engineering students in these underserved areas.

II. APPALACHIA AND APPALACHIAN YOUTH

Appalachia, as a region, extends from southern New York to Northern Mississippi in the United States of America. The regional definition is adopted from boundaries defined by the Appalachian Regional Commission (ARC). ARC was formed

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in 1965 to address the issues of poverty found in this region of the United States [12]. At inception of the ARC, one-third of the Appalachian population lived in poverty and the per capita income was 23 percent lower than the average for the United States, and unemployment was rife [13]. Almost fifty years later, little has changed in the economic conditions and the region still contains many rural and isolated areas despite national advances in transportation and communication infrastructure [13]. Today, the Appalachian region as a whole still lags behind national averages in education and economic levels with the rural and isolated regions displaying even lower levels than more populated regions [13, 14].

Compounding the issues of lagging economic and education levels is the migration of aspirational Appalachian's for education, many of whom do not return to the area. Historically pursuing an education has caused many individuals to migrate away from the Appalachian region. This migration pattern has created the perception that education strips individuals of their roots and heritage [15]. The Appalachians who do choose to remain in the region due to the close families and communities, report high satisfaction with life [16].

Appalachia as a whole is expansive. Therefore, to narrow the scope of our study we focus on the Central Region of Appalachia. This is an appropriate choice because Central Appalachia represents the geographic and cultural conditions typically associated with the Appalachian mountains [17]. Like Appalachia as a whole, Central Appalachia has historically been heavily influenced by poverty and continues to have high numbers of rural and low income counties [17]. In addition to poverty, this region has a low college completion rate and high instances of migration out of the region [17]. These conditions support the idea that students may lack exposure to a full range of career options making this region appropriate for the study.

III. Maori and Maori Youth

Aotearoa/New Zealand is an isolated collection of islands in the South Pacific, 1,500km east of Australia. Accordingly, it was one of the last lands to be settled by humans, with Maori arriving in canoes from the mythical tropical homeland of Hawaiki around the 1300s, and British-dominated colonization occurring in the 1800s.

The urbanization of tribal Maori began with their active participation in trade with the British around settlements, and grew with the income opportunities afforded to unskilled labor in a protected economy built of supplying captive markets through the 1950s to 1970s. Many Maori advocated assimilation into British New Zealand values and norms, and Maori were alienated from their tribal people and family as they moved to the cities to work. Indeed use of Maori language by Maori students in schools was a punishable offence. This urbanization brought with it the attendant problems which reinforced the stereotype Maori as under-motivated physical beasts not too far removed from the bush, and unsuited to urban civilized life.

In 2001, Maori youth made up 17 percent of the Maori, and is projected to increase to 26 percent by 2021. In New Zealand's compulsory child education system, Maori youth are proportionally represented in primary and secondary schooling, yet only 7 percent of the total number of all students enrolled in tertiary education [18]. Forty-five percent of Maori students left school without reaching the minimum school leavers qualification, NCEA level 1, in 2006 [19], compared with 74% of New Zealanders of European background and 87% of New Zealanders of Asian background.

IV. Findings from Central Appalachia

Several similarities exist in the Appalachian and Maori people in their homelands, such as being underrepresented in higher education and wages. Further, both Appalachian and Maori peoples are founded on strong community and family values, lack of role models with exposure to post-secondary careers, and previous work suggests some are reluctant to move away to study. These similarities suggest that stakeholders interested in enhancing participation in engineering could benefit from a deeper understanding of how students in these cultures perceive engineering as a career.

Preliminary evidence in Appalachian supports the claim that exposure to careers matters to students in these rural cultures. Evidence can be seen in the data from Alyssa. She discussed how exposure to engineering changed her career path. She describes her exposure by saying:

"*I took a class senior year, called Introduction to Engineering, Principles of Engineering, we just talked about the different, various types of engineering, and like, what they're composed of and what they study and I really became interested in Chemical Engineering because I like chemistry and math, and just any kind of science. And that just really sparked my interest to engineering"*

She went on to discuss how this exposure changed her decision from becoming a pharmacist to a chemical engineer.

"Okay, well I didn't know anything about engineering until that class. I never really considered it at all. I was interested in pharmacy, which, deals with chemistry a lot. And so I went into that class, we just talked about the different types and then when I learned of chemistry having an option in engineering, I was really interested. And then the biology helped even more, and it was really cool when we did experiments and just, it really showed how cool engineering could be."

Our data also reflect a desire to remain in the area. Based on the literature, we expected this to be the case and found that it was indeed true. For example, Alyssa hopes to use her bio-molecular concentration within Chemical Engineering to contribute to cancer research in the future. One fear Alyssa has with her future career choice is relocating to a different area. When asked about this she said:

"That's one thing I'm worried about. You hear a lot of people that talk about their co-ops 'Oh, it's in Texas', 'it's in another country', it's like, oh, I don't really, I'm not prepared for that yet."

When asked why this mattered to her she replied:

"Cause I just want to, I want to be close to my family and somewhere where I'm familiar, it would just be hard to go off by yourself, somewhere, that far."

Through exposure in high school Alyssa gained an understanding of engineering as a career choice and found that it aligned well with her interests. Prior to the exposure, Alyssa describes her minimal knowledge of the engineering field. Note that few rural high schools in the region offer engineering courses similar to Alyssa's.

V. Conclusions and Future Work

The use of a framework constructed on possible selves and the inherent attention on values and socio-cultural contexts, provides a potentially useful lens to better explain the reasons Appalachian and Maori students choose engineering related subjects either while still at secondary school, or upon entry to university. The similarities and differences in Appalachian and Maori people, and the contexts they live and make choices in, suggest that a fruitful pan-cultural study be performed among the Maori of New Zealand similar to the current study in Appalachia. Such a study may reveal insights into one being ported over to the other, as well as the identification of hitherto unknown characteristics and traits of either Appalachian or Maori which may allow a tailored and unique intervention.

As the results from Central Appalachia show, barriers do exist that limit entry into the engineering field and therefore further study of similarly marginalized groups is appropriate. The results show that although exposure is important, the barriers may not be that simple. Alyssa shows us that even with exposure to engineering which resulted in plans to pursue a career in engineering, she still worries that she will not be able to find a career in her field close to family. It is therefore proposed to commence a related and interdependent study of Maori New Zealanders to build a theory that explains engineering as a career choice among these peoples. Once the barriers which limit student's decision to choose an engineering related field are understood, school systems, universities, and other stakeholders can begin to use the knowledge in the design of intervention programs. This work could go a long way in helping to economically diversify two peoples from differing parts of the world who share similar values and problems, and who are typically underrepresented within the engineering field.

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Development of Interactive 3D Tangible Models as Teaching Aids to Improve Students' Spatial Ability in STEM Education

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Abstract— **Spatial abilities have been reported to be critical for success in Science, Technology, Engineering, and Mathematics (STEM) education. Research findings prove that spatial abilities can be improved significantly through training. This project develops 3D tangible models (TMs) and their corresponding computer graphics (CGs) as teaching aids to improve students' spatial abilities. The TMs and their CGs work together in a real- time, interactive manner. The TMs use a sensor board containing an attitude heading reference system to track and send their real-time 3D orientation on three axes to a computer. A program renders the 3D graphic models of these TMs on the computer screen and updates their 3D orientations. By manipulating the TMs and observing corresponding CGs on computer screens in real time, students will experience the displays of the same objects which undergo rotations in space from infinite viewing angles, resolving visual ambiguities. The system offers potential advantages over static pictures by explicitly rendering dynamic rotations of 3D figures over space, rather than requiring students to "mentally" figure out those rotations. The models in this development project will be used in an experiment to evaluate how they affect students' spatial abilities.**

Keywords — engineering education; spatial ability; STEM education; AHRS.

I. INTRODUCTION

Advances in science and engineering depend on a workforce that has solid education in Science, Technology, Engineering, and Mathematics (STEM). Research findings prove that spatial skills play a critical role in developing expertise in STEM education [1,2,3]. Spatial ability as a whole encompasses one's ability to generate, recall, and manipulate 3D objects within one's mind [3]. For engineering students, spatial ability is reported to have direct effects on academic success and retention in engineering programs [1, 2]. For high-school and pre-engineering students, spatial ability helps them understand and excel in geometry, basic chemistry, physics, and engineering graphics courses [3].

Not many people are born with high spatial ability. However, research findings prove that spatial ability can be improved significantly through training, particularly for poor spatial test performers [1,2,4]. Blasko & Holliday-Darr [2] reported longitudinal research on a spatial training program on 327 freshmen students at Penn State Erie and found that training is effective for improving spatial skills. Students who completed the training showed better spatial performance and increased grades and retention. Researchers at the University of California at Berkeley further confirmed that females improved more than males in spatial ability, and performed as well as their male peers after spatial strategy instruction [1]. Spatial abilities are not only trainable but also measurable. Spatial abilities are measured by a number of tests which include: (a) Mental rotation test (MRT) for spatial relation [4,5,6] and (b) Purdue Spatial Visualization Test - Visualization of Rotations (PSVT: R) [7].

II. THEORETICAL FRAMEWORK

Spatial abilities can be developed through a variety of activities, such as playing 3D computer games, learning geometric modeling in calculus, and sketching (by hand or computer) in engineering graphics courses [3]. For the purpose of spatial training, some studies have investigated different means of intervention to develop spatial ability within students with the aid of TMs such as construction toys, 3D blocks [8, 9], interactive computer graphics software such as augmented realities, virtual realities [10], or combination of these [11, 12].

The use of TMs in the development of spatial abilities seems to be employed by many K-12 educators. In a study investigating the effects of four types of spatial instruction on secondary students, Pillary [8] found that learning with physical models (Meccano construction sets) causes the least extraneous cognitive activities and makes available sufficient cognitive resources for learning spatial tasks. Casey et al. [9] found that the use of block-building intervention develops spatial reasoning skills in kindergartners on three measurements of spatial visualization, mental rotation, and block building. With the advances of computer technology, the approach of using interactive computer graphics software in spatial training is becoming more popular. As in [10], the interactive computer software is used along with 3D solid modeling and found to be effective in the development of spatial skills in undergraduate engineering. Sorby [11] used TMs (snap cubes) and interactive software in a study aiming to develop 3D spatial skills for K-12 students. She found that 3D shapes are highly rated as helpful training methods for modules dealing with isometric, orthographic drawings, and rotation of objects about a single axis. Reference [12] discuses the combined approach of using TMs and augmented reality (AR) models to investigate the relationship between 3D objects and their projections on engineering students in Engineering Graphics Course. This research's results indicate that the TMs and AR models significantly increased students' spatial abilities. Its finding also reveals that the use of TMs as supplementary teaching

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materials can raise students' levels of curiosity and intention to learn and allow them to touch, and actively participate with the models.

No work has been done that combines TMs and CGs software in a real time, interactive manner in STEM education. In this development project, students can manipulate the TMs and observe their corresponding 3D CGs on a computer screen in real time. They can experience the displays of the same objects which undergo rotations in space from infinite viewing angles, resolve visual ambiguities, and explore the relationships between 3D physical objects and their 2D images. The system can offer potential advantages over traditional training with static pictures by explicitly rendering dynamic rotations of 3D figures over space, rather than requiring students to rotate mentally those figures in their minds. Students can learn with the TMs and CGs separately in manual mode or let them work concurrently in synchronous mode.

III. Methodology

This first phase of a two-phase project develops TMs and their CGs of 3D objects similar to those usually seen in Shepard & Metzler's (1971) MRT and Guay's (1977) PSVT:R tests (Fig. 1 and 2). The TM is embedded with a sensor board containing an attitude heading reference system (AHRS) and a microcontroller. AHRS is a set of sensors (gyroscopes, accelerometers, magnetometers) that measured and reported an aircraft's velocity, orientation, and altitude in space in terms of roll, pitch, and yaw information. AHRSs are designed to replace traditional mechanical gyroscopic flight instruments. With the recent advances of micro-electromechanical systems (MEMS) and sensor technology, AHRSs are very compact and cheap and have a broad range of applications in daily life, from sensors for airbags to built-in car navigation or camera's stabilization systems [13]. In this project, the AHRS tracks TM's real-time 3D orientations on three axes while the microcontroller processes orientation data from AHRS and delivers them to a computer (via wired or wireless connection). Computer program renders the 3D graphic model of that TM on the computer screen and updates its 3D orientations in real time. Fig. 3 shows a TM in a modified PSVT: R test.

On the second phase of the project, the models developed in this first phase will be used in an experiment to evaluate how the models affect students' spatial abilities.

IV. Materials

A. Tangible Models(TMs)

TMs are hollow 3D objects which are made from plastic styrene sheets and sculptural epoxy. The hollow design and plastic material are used to guarantee that the objects are light in weight so that students can hold, tilt, rotate, and observe them from infinite viewing angles (Fig. 3 and 4). The hollow space inside the TMs is also used to conceal the sensor board and batteries.

AHRS sensor boards are supplied by various providers and pre-fabricated with built-in sensors and with/without microcontroller (ATmega328) (Fig. 5). Some modifications and customized assembly are needed to suite this project application.

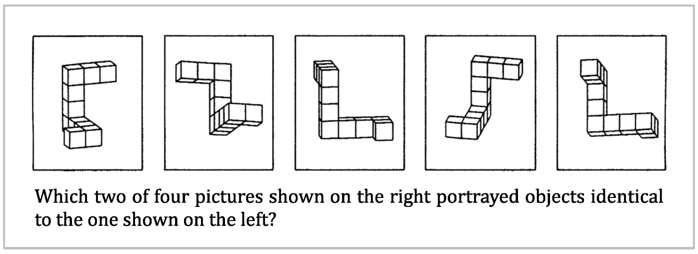

Fig.1 An item in MRT [4, 5, 6]

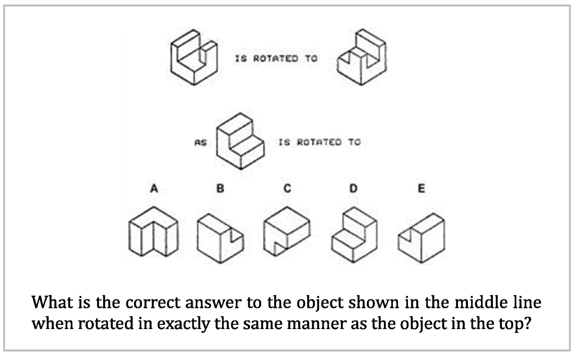

Fig. 2 - An item in Purdue Spatial Visualization – Rotation [7]

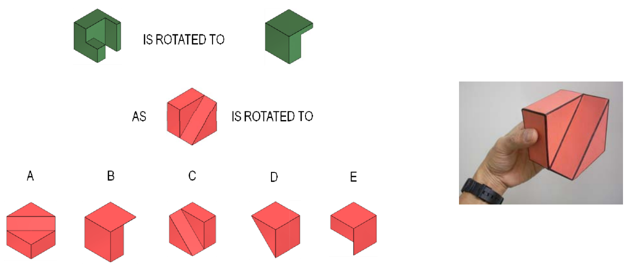

Fig. 3 - A modified Purdue Spatial Visualization – Rotation and its TM

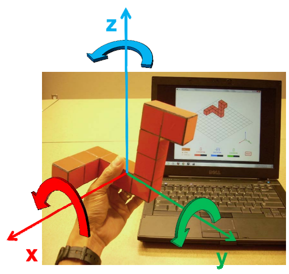

Fig. 4 - A tangible model for MRT

B. Computer Graphics(CGs)

Computer graphics models which correspond to the developed TMs are created and rendered by Processing. Processing is a open source programming language introduced by Casey Reas and Benjamin Fry from the Aesthetics and Computation Group at the MIT Media Lab in 2001 [14]. It was specifically designed to render real-time interactive 3D graphics. By making use of OpenGL, a cross-language, multi-platform application programming interface (API), Processing programs can take advantage of hardware acceleration from graphics processing units (GPUs) on graphics cards installed on most computers to render interactively 2D and 3D computer graphics. Programming codes written in the Processing language will process AHRS data generated from the sensor board inside the TMs and graphically represent rotations of CG models on a 3D plot (Fig. 6).

Fig. 5- An AHRS sensor board

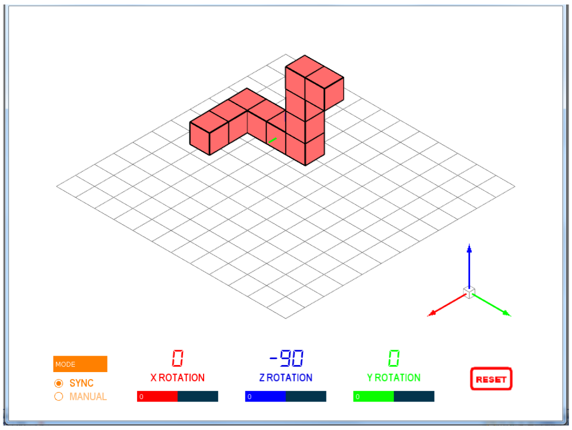

Fig. 6 - Computer graphic of a tangible model in Fig. 4

V. Preliminary Results & Future Work

A prototype of an interactive computer program in Processing, two TMs, and their 3D CGs have been created. The system works in the lab in both manual (CG rotations on three axes are controlled individually by three scrollbars) and synchronous modes (TMs and CGs rotate at the same time). TMs and CGs can be connected via wired or wireless network. More TMs and CGs that cover fundamental geometric features and engineering graphics are being added. The graphical user interface (GUI) of the interactive software is being improved to give users more control and options.

Upon completing the development phase, the system will be used in an experiment on high school and pre-engineering students in the next phase to evaluate how the models affect their spatial abilities.

Acknowledgment

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A Comparison of Single and Mixed Gender Engineering Enrichment Programs for Elementary Students

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Abstract*— The Center for Pre-College Programs at New Jersey Institute of Technology sponsors a series of summer enrichment programs designed to increase academically talented students' interest in the fields of science, technology, engineering and mathematics (STEM). Programs such as these can be instrumental in informing young students about careers in engineering and technology and helping ensure they receive the academic background required to prepare for these careers in college. One of the programs has been designed specifically for young girls in an effort to increase the number of women interested in engineering and other technological careers. Although there is much debate about the relative effectiveness of female-only programs, previous research comparing aspects of our female-only program to equivalent mixed-gender programs has shown that they can be particularly effective in reaching young girls, influencing their perceptions of engineers and attitudes toward engineering as a career. The addition of equivalent male-only programs has prompted additional research comparing changes in students' perceptions of engineers and attitudes toward engineering, as well as increases in learning and content knowledge. The three different gender grouped programs (female-only, male-only and mixed-gender) were identical in content. The single gender programs within the same grade were taught by the same teacher. Although the mixed gender programs were taught by a different teacher the curriculum was exactly the same. In addition to objective measures of effectiveness, teachers were interviewed to collect qualitative data about the climate in the classroom and students' interactions within the three different gender groupings. Results show differential effects among the programs, not only in terms of perceptions, attitudes and learning, but also in the classroom climate and students' interactions in the classroom.

Keywords*— *single gender education; engineering enrichment; female only; male only; STEM

I. INTRODUCTION

The increasing demand for more engineers in the United States workforce is expected to continue in to the next decade [1] but the number of students choosing to study engineering is not increasing at the same rate [2-3]. The chronic under representation of females in engineering is one of the major contributing factors [4-5] despite fact that gender discrimination in engineering wages has been almost eliminated, with women earning 97% of the wages earned by men [6]. To encourage more female students to pursue engineering studies, it is essential to eliminate misinformation and negative impressions about engineers and engineering [7-9]. Research on engineering recruitment indicates that many students, particularly young girls, do not know what engineering is and what engineers do, and their parents, teachers, and school counselors often do not know enough about engineering to help inform these students about careers in engineering [7,10-12]. Unlike many professions, engineers are rarely depicted in the media and outreach efforts often fail due to negative stereo-types. Therefore, not enough students explore the various fields of engineering when considering their college major and future career options and as a result do not prepare academically in middle and high school.

The Center for Pre-College Programs at New Jersey Institute of Technology sponsors a series of summer programs designed to increase academically talented students' interest in the fields of science, technology, engineering and mathematics (STEM) [12]. Programs like those offered by the Center for Pre-College Programs can be instrumental in informing young students about careers in STEM, particularly engineering, and help ensure they receive the academic preparation required to enter college programs in engineering or other highly technical fields [13-14]. One of the programs, Woman in Engineering and Technology, still called FEMME for the original name, Females in Engineering: Methods, Motivation and Encouragement, was designed specifically for young girls in an effort to increase the number of women interested in engineering and other technological careers [15-16].

The FEMME program spans grades four to eight, with each grade level focused on a different field of engineering. Middle school is not only an important time for students to begin thinking about future careers, but because boys and girls do not differ much in technical abilities until their high school years but rather in their attitudes toward technological careers like engineering [8, 17]. By the latter middle school years, girls start underestimating their own technical abilities and begin to place more importance on being popular rather than academic performance [18, 19]. During high school they enroll in fewer mathematics and science courses, and thus lack the background needed to enroll in college STEM programs [17]. Early intervention is needed to address this problem because once students, particularly females, reach college it is too late to prepare [8, 9, 20]. Although there is much debate about the effectiveness of single-gender education [21, 22], all female enrichment programs like FEMME can be particularly effective in reaching young girls, influencing their attitudes before they reach high school [23, 24].

II. Background

Initially single-gender education was for affluent students, mostly boys, but by the 1970's educators began exploring better educational options for girls in response to the emerging "Gender Gap" between the academic achievement of boys and girls [25]. Considerable research can be found describing the many benefits of single-gender education for girls, suggesting such things as girls' increased confidence, being more likely to ask questions, and maintaining behaviors that tend to disappear due to male dominance in the classroom [26]. Studies of classroom behavior in co-educational classrooms also document teachers' differential treatment of boys and girls, for example, being more tolerant of boys' disruptive behavior and encouraging boys to solve problems on their own while helping girls who experience trouble [22, 27-28], further suggesting the benefits of single gender education.

In contrast, more recent reviews of the literature summarizing the investigations of single-gender education caution that much of the research is not rigorous and scientifically based, including a focus on private and Catholic schools where subjects are basically self selected [25] and provide no strong conclusions supporting or dismissing the overall benefits [29]. Researchers have begun to recommend that there should be a clear rationale with specific goals for single-gender education [30-32]. Summer enrichment programs like FEMME, designed with the goal to increase the number of women interested in engineering and other technological careers in an atmosphere free from male dominance are consistent with this recommendation and prior evaluations of the FEMME program have been positive [16].

A. Success of the FEMME Program

Although the initial evaluations of the FEMME program were primarily formative in nature [33] results were positive. Follow-up studies of program participants who had completed high school found that almost 70% reported they were either currently enrolled in a technology based degree program or had chosen a career path in STEM [32].

More rigorous evaluations of the FEMME program [34-36] used the Middle School Attitude toward STEM survey [12]. The MASTEM has been revised to have six subscales; Interest in engineering: stereotypic aspects (Stereotypic), Interest in engineering: non-stereotypic aspects (Nonstereotypic), Negative opinions about STEM (Negative), Positive opinions about STEM (Positive), Self Efficacy for Problem Solving and Technical Skills (Self), and Gender Equity (Gender).

Girls participating in FEMME programs have been found to have significantly more positive attitudes toward STEM, particularly engineering, and significantly more knowledge of engineering careers compared to other students (both male and female) from similar backgrounds [35, 37]. Many young girls who attend a FEMME program return for multiple summers and results of pre-post attitude evaluations using the MASTEM have shown the girls' more strongly agreed with the notion that "girls are just as good as boys in the areas of mathematics and science" and disagreed more strongly that "boys are better at engineering than girls" after attending one of the FEMME programs.

B. Single Gender Programs for Boys

More recent single-gender research focused on boys suggests that the climate in all-male classrooms is much different than all-female classrooms [26, 38]; increased use of technology, more opportunities for physical activity and the presence of male role models is beneficial for the boys' learning [39-40]. But is the single-gender atmosphere or the altering of the classroom structure (e.g. using more active lessons to teach the same curriculum) responsible for the benefits?

Offering mixed gender programs and all-female programs meant that approximately 70% of the students accepted into summer enrichment programs at the Center for Pre-College Programs were female. This and a marked increase in applications from 4th and 5th grade boys prompted the addition of two all-male programs during the summer of 2012. The programs were identical to FEMME 4: Environmental Science and Engineering and FEMME5: Aeronautical Engineering and the equivalent 4th and 5th grade mixed-gender programs. Each of the programs accepted 23 to 25 students such that across all six programs there were 141 students. A semi-qualitative and objective evaluation was planned to examine differences in classroom climate, changes in students' attitudes toward STEM, increases in content knowledge and changes in students' perceptions of what engineers actually do. Students completed the MASTEM, separate grade-appropriate content knowledge tests of engineering, mathematics, computer technology and communications and the Draw an Engineer Test at the beginning and the end of the program.

C. The Draw an Engineer Test

The Draw an Engineer Test (DAET) [41], which has been adapted from the Draw a Scientist Test [42], was developed as a tool to more fully evaluate young students perceptions of who engineers are and what they actually do [43-44]. Students are asked to draw a picture of an engineer at work and provide a short sentence to describe what the engineer in the picture is doing. A checklist has been developed to quantify the appearance (gender, color, etc.) and location of the engineers in the picture, as well as to summarize other objects and/or people in the picture and inferences of action [45]. Previous research has found that purely quantitative measures derived from surveys such as the MASTEM are not always sufficient to capture cognitive changes in students' perceptions about engineers and a more qualitative measure such as the DAET can be more informative [36, 46].

The mathematics, science and engineering classes for both post 4^{th} grade single-gender programs (male and female) were taught by the same teacher as were both the post 5^{th} grade single-gender programs. Although the mixed gender programs were taught by a different teacher, the curriculum (lessons, activities, field trips, etc) was exactly the same. Field trips were attended altogether, chaperoned by all teachers. Other classes such as computer lab and communications were taught by different teachers within each subject, i.e. in computer labs all students in all programs were taught by the same teacher. No changes in teaching were made to accommodate either gender. All of the teachers had taught either the all-female or mixed gender programs previously and as such were familiar with the curriculum.

III. RESULTS

Teachers were interviewed to collect qualitative information about possible differences in classroom climate and student behavior among the three types of classes; single-gender male, single-gender female and mixed genders. The mixed-gender classes were approximately 42% female and 58% male. Although there were 141 students enrolled across the six programs (three gender groupings across two grades), only 134 completed both the pre and post measures.

Three-factor repeated measures analysis of variance techniques were used to test for changes in students attitudes toward STEM and increases in students' content knowledge as measured by the MASTEM and program specific content knowledge tests which included mathematics, engineering, computers and communication. Two between subject factors, gender and type of class (single-gender vs. mixed gender) and one within subject factor (time from beginning to the end of the program) were used to test for differential effects due to gender or type of class.

The extensive scoring protocol and analyses required for all aspects of the Draw an Engineer Test have not been completed to date and as such are not included in the current paper but, aspects related to the gender of the engineer in the picture have been completed and relevant analyses follow.

A. Classroom Climate

The teacher who taught both of the two single-gender post 4^{th} grade classes described the girls in the FEMME program as cooperative and communicative with much less physical activity than in the all-male group. The boys were much more active and less cooperative, requiring more discipline and suggestions to stay on task than the girls. This teacher had taught for the mixed gender and FEMME program during previous summers and reported the cooperation during group activities and other classroom behaviors to be very different than those experienced during mixed gender programs.

The teacher who taught both of the single-gender post 5^{th} grade classes described the girls in the FEMME program as much more task-oriented and less competitive than the boys in the all-male group. The girls' solutions to problems were not necessarily better than the boys', nor did they appear to complete tasks more quickly than the boys. The teacher just described the girls as more serious and very focused. The girls were much less competitive and more willing to share and help each other than the boys. This teacher had also taught for the mixed gender and FEMME program for several years and agreed that the classroom atmosphere in each of the single gender programs was very different than in the mixed gender groups. In the mixed-gender programs the girls tended to focus more on the task rather than interacting with the other girls and boys, where as in all-female groups, even though the girls remained focused, they interacted more with other members of the group. The girls appeared to have distanced themselves somewhat during group activities in mixed gender groups.

"Comparing notes" about identical classroom lessons or activities with the teachers who taught the mixed gender programs suggested less personal interaction during group work in mixed gender groups and a lower level of class participation from girls in the mixed-gender programs.

B. Content Knowledge

All students in each of the six programs showed significant and substantial increases in all areas of content knowledge from the beginning to the end of their respective programs. Within the single-gender and the mixed-gender programs there were no significant differences between the content knowledge scores for the males and females nor where there any differences between scores among the single-gender and mixed gender programs. All students, male and female performed equally well in all programs. See Table I for a summary of mean responses.

C. Attitudes toward STEM

In general no significant changes were found in students' attitudes toward STEM in terms of Interest in engineering: (stereotypic and nonstereotypic), Negative opinions of STEM; Positive opinions of STEM; or Gender equity. See Table 1 for a summary of mean responses. Although this might seems disappointing it is not surprising, the students' attitudes toward STEM were already very positive before beginning the programs as is typical of students who attend enrichment programs [36, 46]. But significant differences were found in Self Efficacy.

For both the male and female students in the single-gender programs the mean Self-Efficacy scores increased significantly from the beginning to the end of the program ($p<.01$, see ** in Table I). And for both males and female students in the mixed-gender programs the mean Self-Efficacy scores decreased, $p<.05$, see * in Table I).

TABLE I
MEANS AND STANDARD DEVIATIONS FOR THE ATTITUDES TOWARD STEM SCALE AND SUBSCALES AND CONTENT KNOWLEGDE TESTS

CONTENT KNOWLEDGE			Beginning Mean (SD)	End Mean (SD)
Engineering				
	Single gender:	Males	51.4 (13)	89.8 (11)
		Females	53.1 (15)	90.7 (10)
	Mixed gender:	Males	58.0 (11)	92.5 (5)
		Females	52.5 (14)	91.8 (6)
Communications				
	Single gender:	Males	65.0 (13)	78.3 (15)
		Females	64.9 (15)	78.8 (14)
	Mixed gender:	Males	71.7 (16)	81.0 (17)
		Females	58.9 (14)	81.1 (17)
Computers				
	Single gender:	Males	52.9 (18)	86.6 (13)
		Females	53.6 (15)	89.0 (14)
	Mixed gender:	Males	48.9 (17)	94.6 (16)
		Females	50.1 (18)	93.8 (17)
Mathematics				
	Single gender:	Males	59.9 (13)	77.5 (14)
		Females	57.5 (15)	78.2 (16)
	Mixed gender:	Males	55.8 (14)	77.0 (13)
		Females	59.7 (13)	77.5 (14)
OVERALL ATTITUDES				
	Single gender:	Males	3.8 (.6)	3.9 (.6)
		Females	3.6 (.5)	3.6 (.6)
	Mixed gender:	Males	3.7 (.5)	3.7 (.5)
		Females	3.3 (.6)	3.4 (.6)
Subscales				
Positive				
	Single gender:	Males	3.6 (.9)	3.7 (.9)
		Females	3.5 (.7)	3.5 (.7)
	Mixed gender:	Males	3.6 (.7)	3.5 (.7)
		Females	3.1 (.9)	3.3 (.9)
Negative[a]				
	Single gender:	Males	1.9 (.6)	2.0 (.6)
		Females	1.8 (.5)	1.8 (.5)
	Mixed gender:	Males	1.8 (.5)	1.7 (.4)
		Females	1.8 (.8)	1.8 (.8)
Interest Stereotypic				
	Single gender:	Males	3.6 (.9)	3.6 (.9)
		Females	2.6 (1.0	2.8 (1.0)
	Mixed gender:	Males	3.2 (.9)	3.2 (.8)
		Females	2.3 (1.0)	2.3 (1.0)
Interest Non-Stereotypic				
	Single gender:	Males	3.7 (.9)	3.9 (.9)
		Females	3.6 (.8)	3.6 (.8)
	Mixed gender:	Males	3.3 (.7)	3.5 (.7)
		Females	3.0 (1.0)	3.2 (.9)
Gender				
	Single gender:	Males	4.1 (.9)	4.1 (.9)
		Females	4.3 (.6)	4.3 (.7)
	Mixed gender:	Males	4.0 (.8)	4.0 (.9)
		Females	4.1 (.9)	4.2 (.9)
Self Efficacy				
	Single gender:	*Males*	*3.8 (.8)*	*4.1 (.7)***
		Females	*3.7 (.7)*	*3.9 (.6)***
	Mixed gender:	*Males*	*3.7 (.7)*	*3.6 (.6)**
		Females	*3.8 (.8)*	*3.6 (.7)**

[a] Subscale items are phrased negatively, so a lower mean is desirable.

These results coupled with the differences in classroom climate and communication suggest that although single-gender programs such as these may not always significantly increase learning of content knowledge they appear to have a significant positive effect on self-efficacy, which is important.

D. *Preceptions of Engineers through Drawings*

Previous research using the Draw an Engineer Test has found the DAET to be a useful tool in more fully exploring young students' perceptions of engineers, what they believe engineers actually do, and how their perceptions may have changed as a result of attending a summer enrichment program at NJIT [36, 46].

Students' drawings of Engineers at Work are summarized using the DAET checklist [45]. The checklist begins with an examination of the engineer to check the species (i.e. Human?), actual presence, gender, skin color, and other attributes, like glasses, lab coats, crazy hair or other clothes. Then the location of the engineer (inside, outside, in space, underwater) is coded and there is a list of inferred actions that can be indicated, like fixing vs. designing, or teaching, or even NO action can be indicated. The types of other objects in the drawing are also coded, for instance, the presence of other people, animals, symbols that would indicate math or chemistry, airplanes, computers, car, trains, signs of thinking, etc. The wearing of a hat has been added to the attributes, "signs of communicating with others" has been added to the list of actions and more specific details about the species and gender of the engineer are also being explored to more fully understand students' perceptions and how they change.

For the current paper the characteristics of the engineer including gender were examined in relation to students' gender and type of program, all-male, all female, or mixed-gender. The physical characteristics of the engineer were examined for signs of gender including long hair, the wearing of a dress, facial hair, name badges, etc and verbiage in the sentence describing what the engineer is doing was checked for the use of He, She, it or "the engineer". Often the engineer students draw, particularly before attending the programs, is a stick figure with no gender or a mechanic\worker with only legs protruding out from under a rocket or car. When a stick figure, androgynous person or partly hidden person is described as "it", "my engineer" or "the engineer" in the sentence then the gender of the engineer is coded as unknown.

All students' beginning and ending drawings were examined and the engineer was coded as Male, Female or Unknown. Table II is a summary of how many engineers were coded as male, female or unknown for the single-gender male programs, the single-gender female programs and the mixed-gender programs with the responses from the male and female students in the mixed gender programs listed separately. None of the male students in either the single-gender or mixed gender programs drew female engineers at the beginning or the end of the program. Only about one third of the female students in the mixed-gender programs drew female engineers at both the beginning and the end of the program. At the beginning of the all-female program, about 25% of the girls drew a female engineer and at the end of the program over 50% of them drew a female engineer.

TABLE II
SUMMARY OF GENDER ATTRIBUTIONS FROM THE DRAW AN ENGINEER TEST

Engineer's gender is.......	Male	Female	Unknown
Single gender males			
Beginning	32	0	16
End	31	0	17
Mixed gender males			
Beginning	11	0	17
End	12	0	16
Mixed gender females			
Beginning	7	6	6
End	1	5	13
Single gender females			
Beginning	12	12	21
End	7	26	13

IV. DISSCUSSION

Overall, the results suggest that although there were no significant differences in the learning of content knowledge or changes in students' attitudes toward STEM among the single-gender and mixed gender programs, there were significant differences in self-efficacy. Both the male and female students in the single-gender programs showed significant increases in self-efficacy while students in the mixed-gender programs showed decreases in self-efficacy. Increased self-efficacy is important for continued learning and persistence when learning becomes more complex or students have difficulty.

Further, only girls in the all-female program changed their image of an engineer from a male or a person of unknown gender to a female. This seems to contradict the fact that there was no change in the girls' average response to the gender equity items on the MASTEM. And although the girls' average responses to the gender equity items were slightly higher than for the boys there were no significant differences between the boys and girls or among the different types of programs. For example, girls' did not disagree more strongly with the statement "Boys are better at being engineers than girls" at the end of the program than they did at the beginning, nor did they respond much differently than the boys overall.

Increased self-efficacy and an increase in girls' perceptions that women can be engineers suggest that there are benefits to single-gender programs for both male and female students, although boys' images of engineers should include females. Future male-only programs should address this problem.

Insignificant changes in students' attitudes toward STEM, like those found in the current study using the MASTEM have been found before with high-achieving students such as those who attend enrichment programs [35-36, 46]. Results from the current study further support the suggestion that more qualitative measures like the Draw an Engineer Test are better measures of changes in students' cognitions and\or perceptions as a result of enrichment programs than more objective types of measures like the MASTEM which are typically used to evaluate new programs or changes in curriculum.

Continued coding and analyses of the other attributes of the students' drawings of engineers will further examine students' perceptions of engineers and attempt to quantify relationships between scores from the MASTEM and summary statistics from the DAET checklist. For example, a relationship does not appear to exist between the Gender equity items on the MASTEM and the gender of the engineers in the drawings although one was expected.

Further analyses will examine correlations among other attributes of students' drawing and individual items on the MASTEM like "engineers spend lots of time working on computers," or "Engineering has nothing to do with real life."

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Special Session: The CS2013 Computer Science Curriculum Guidelines Project

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***Abstract*—The ACM/IEEE-Computer Society CS2013 Computer Science Curricula task force is working to update the previous curricular guidelines published in 2008 and 2001. The CS2013 guidelines are scheduled to be published in the latter half of 2013. This special session is devoted to exploring the guidelines with an emphasis on migrating current curricula to curricula aligned with the new guidelines. A number of significant changes from the 2008 and 2001 guidelines have been made, including the addition of new knowledge areas (including Parallel and Distributed Computing and Security and Information Assurance) as well as the reorganization and refactoring of previous areas to create a Systems Fundamentals area and a Software Development Fundamentals area. These changes are intended to identify significant changes in the computing field over the past decade, look forward to future changes, provide greater flexibility in the design and implementation of Computer Science curricula, provide stronger guidance with respect to student outcomes, and provide diverse examples of fielded curricula.**

Keywords-computer science education, computing, curricula, CS2013.

I. INTRODUCTION

For the past 40 years, ACM/IEEE-CS Computing Curricula volumes [1][2][3] have helped to set international curricular guidelines for undergraduate programs in computing. The next complete curricular volume in the series is targeted for publication in 2013. The goal of this session is to continue the lively and engaging discussions with the computer science education community and other stakeholders about the ongoing work of the ACM/IEEE-Computer Society CS2013 Computer Science Curricula project. Since the CS2013 guidelines will be in the final stages of editing, the session will focus on the changes from previous guidelines and how programs can migrate existing curricula to curricula aligned with the CS2013 guidelines.

The development of guidelines for Computer Science is challenging due to rapid changes, expanding diversity in the computing fields, the integration of computing with other disciplines, and the need to balance the growth in possible topics and the need to keep recommendations implementable in the context of undergraduate education.

Building on the principles articulated in the CC2001 and CS2008 reports, the Steering Committee established the following principles to guide its work. A complete statement of these principles can be found on the project website at http://www.cs2013.org.

- CS2013 will identify the essential skills and knowledge that should be required of all graduates of Computer Science programs.
- CS is a rapidly changing field, drawing from and contributing to many disciplines, and requires undergraduate programs to prepare students for lifelong learning.
- CS2013 serves many constituents, including faculty, students, administrators, curricula developers, and industry.
- The curricular guidelines must be relevant to a wide variety of institution types including large and small, research and teaching, public and private, 4-year and 2-year schools. The guidelines will be used internationally as well as in the US.
- CS2013 will provide guidance regarding the level of mastery for topics and show exemplars of fielded courses covering the topics in the curricular body of knowledge.
- The curricular guidelines will provide realistic, adoptable recommendations that support novel curricular designs and attract the full range of talent to the field.
- CS2013 will include professional practice (e.g. communication skills, teamwork, ethics) as components of an undergraduate experience.

II. CS2013 BODY OF KNOWLEDGE

The Ironman draft of CS2013, available in spring of 2013, focuses primarily on updating the Body of Knowledge in computer science, organized around 18 Knowledge Areas, outlined below:

- Algorithms and Complexity (AL)
- Architecture and Organization (AR)
- Computational Science (CN)
- Discrete Structures (DS)
- Graphics and Visual Computing (GV)
- Human-Computer Interaction (HC)
- Information Assurance and Security (IAS)
- Information Management (IM)

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- Intelligent Systems (IS)
- Networking and Communications (NC)
- Operating Systems (OS)
- Platform-Based Development (PBD)
- Parallel and Distributed Computing (PD)
- Programming Languages (PL)
- Software Development Fundamentals (SDF)
- Software Engineering (SE)
- System Fundamentals (SF)
- Social Issues and Professional Practice (SP)

III. Summary of Changes from CC2001 to CS2013

A. *Other curricular volumes*

It was recognized during the creation of CC2001 that computing had expanded into a family of disciplines. In addition to Computer Science, the ACM and IEEE Computer Society have now published curricular guidelines for Computer Engineering in 2004 [5], Information Technology in 2008 [6], Software Engineering in 2004 [7], and Information Science in 2010 [8].

B. *Reorganization of volumes*

Two substantial reorganizations in the Body of Knowledge for Computer Science include introductory programming and systems. In the area now called Software Development Fundamentals (previously called Programming Fundamentals), we have extracted fundamental software development concepts, including topics in algorithms, design, programming, and software development processes. In systems, we have identified common themes among operating systems, networking, and computer architecture that are captured in a new area called Systems Fundamentals. Additionally, specific developments in the field in the past decade (such as the pervasiveness of parallel computing and the need for better understanding computer security) have given rise to the development of knowledge areas in Parallel and Distributed Computing, Information Assurance and Security, and Platform-Based Development.

C. *Core Tier 1, Core Tier 2, and Elective*

Earlier curricular guidelines had only "Core" and "Elective" with every core topic being required. However, many strong computer-science curricula were missing at least one hour of core material. It is misleading to suggest that such curricula are outside the definition of an undergraduate degree in computer science. Further, as the field has grown, there is ever-increasing pressure to both grow the core and to allow students to specialize in areas of interest. This is simply not possible in the context of an undergraduate degree, particularly from those programs where expanding the degree requirements is not possible.

CS2013 provides greater flexibility on coverage of core topics by identifying Core Tier 1, Core Tier 2, and Elective topics. Core Tier 1 topics are fundamental to the structure of every computer science program. A curriculum should include all of these topics and ensure that all students cover this material. A curriculum should include all or almost all topics in the Tier-2 core and ensure that all students cover the vast majority of this material. By retaining a smaller Core Tier-1 of required material, we provide additional guidance and structure for curriculum designers. In the Core Tier-1 are the topics that are fundamental to the structure of any computer-science program.

A curriculum must also include significant elective material: Covering only "Core" topics is insufficient for a complete curriculum. This enables curricula and students to specialize if they choose to do so.

D. *Levels of Mastery and Outcomes*

Previous volumes listed topics for inclusion in curricula. In CS2013, we provide additional advice on the level of mastery programs should achieve for core topics. There are three levels of mastery, defined as:

Familiarity: The student understands what a concept is or what it means. This level of mastery concerns a basic awareness of a concept as opposed to expecting real facility with its application. It provides an answer to the question "What do you know about this?"

Usage: The student is able to use a concept in a concrete way. Using a concept may include, for example, appropriately using a specific concept in a program, use of a particular proof technique, or performing a particular analysis. It provides an answer to the question "What do you know how to do?"

Assessment: The student is able to consider a concept from multiple viewpoints and/or justify the selection of a particular approach to solve a problem. This level of mastery implies more than using a concept; it involves the ability to select an appropriate approach from understood alternatives. It provides an answer to the question "Why would you do that?"

E. *Exemplars instead of stylized courses*

CS2001 took on the significant challenge of providing descriptions of stylized courses incorporating the knowledge units defined in that report. While this was a valiant effort, it was felt in retrospect that such course guidance did not have much impact on actual course design. As a result, CS2013 takes a different approach: identifying existing successful courses and curricula as fielded exemplars of how relevant knowledge units can be addressed in actual programs. This bears similarity to the report by CRA-E [4], although that report focused on preparing students for research careers. CS2013 includes examples of actual fielded courses—from a variety of universities and colleges—to illustrate how topics in the Knowledge Areas may be covered and combined in diverse ways. Importantly, we believe that the collection of such exemplar courses and curricula provides a tremendous opportunity for further community involvement in the development of the CS2013 volume.

F. *Changes in the Body of Knowledge*

As should be expected for a maturing field, the body of knowledge for CS2013 has a great deal of overlap with previous volumes; but it also has significant changes, as should be expected for a vibrant and dynamic field. These changes include:

- The topics related to systems and networking have been substantially reorganized to recognize the fundamental principles common among operating systems, networking, and distributed systems.
- Similarly, foundational topics related to software development have been reorganized to produce a more coherent grouping and encourage curricular flexibility.
- Digital logic and numerical methods are not emphasized. A fundamental coverage of digital logic can be found in Systems Fundamentals, but more advanced coverage is considered to be the domain of computer engineering and electrical engineering.
- Numerical methods are elective material in the CN knowledge area and are treated as a topic geared towards a more selected group of students entering into computational sciences.
- There is expanded emphasis on Parallel and Distributed Computing.
- There is a significant new emphasis on Security, Privacy, and Reliability.
- There is no distinguished emphasis on building web pages or search engine use. We assume that students entering undergraduate study in this decade are familiar with internet search, email, and social networking, an assumption that was not universally true in 2001.
- The Programming Languages core in CC2001 had a significant emphasis on language translation. The CS2013 core material in PL is more focused on language paradigms and tradeoffs, rather than implementation. The implementation content is elective.
- The Social Issues and Professional Practice (SP) knowledge area has changed to great degree, particularly with respect to modern issues.

IV. Description of the Special Session

The goal of this panel is not simply to provide an update on the state of CS 2013, but to actively engage the community in work that will eventually manifest in the migration of computer science curricula to meeting the expectations described in the Guidelines. Holding this panel at FIE is an important step in further engendering that engagement in a broad forum.

The desired outcomes of the session include

- Increased awareness of the CS 2013 curricular guidelines among the computer science community;
- Increased understanding of the changes between CS2013 and previous versions of the guidelines;
- Action plans for the revision of curricula at participant institutions.
- Understanding of mapping individual course syllabi to CS2013 knowledge areas

The session will start with a brief overview of CS2013 and model curricula and exemplars. Participants will then break out into small groups based on their areas of interest to review sections of the Guidelines with an emphasis on migrating curricula to meet the CS2013 recommendations. Members of the Steering Committee will facilitate these discussions.

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Engineering Education in Countries of Portuguese Language

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***Abstract* — *The Portuguese-speaking countries are home to more than 240 million people located across the globe but having cultural similarities and a shared history. The CPLP (Community of Portuguese Language Countries) nations have a combined area of about 10,742,000 square kilometers (4,148,000 sq. mi), which is larger than Canada. The proposal of this paper is to show and discuss with some details how engineering education is developed in countries of Portuguese languages due to the peculiarities in the historic development of the countries.*

***Keywords* — *Bologna process; policy makers; public school; polytechnic schools; university schools.*

I. Introduction

The discussions about engineering education in different geographical parts of the world are of great importance. This is a way to promote and increase awareness of contemporary engineering education efforts and, simultaneously, to explore the views of young people, teachers, engineering lecturers and policy makers from other parts of the world. The organization of such panel Engineering Education in Countries of Portuguese Languages is important to bring teachers, researchers and engineering lecturers together to discuss and think over the different ways engineers are formed. It will contribute for the development of innovative engineering curriculum in order to increase the numbers of young people entering engineering courses.

Hereafter we present texts about education in the countries with the objective of briefly informing about how education has developed in countries separated by the sea but sharing common cultural roots, the issues faced by countries and the perspectives for the future.

The real discussions will be developed during the panel session that counts with high level lecturers, very well informed and involved with engineering education in their respective countries. They will bring updated information and the framework adopted to defeat the present obstacles and demands in order to face the 21st century's educational crisis. A number of questions about the systems of present are expected to be raised, mainly the ones related to the Bologna Process in Europe, as it is reshaping higher education in the member countries. Regarding the Portuguese ex-colonies countries, the education has still without any doubt a lot of Portuguese education style mixed with new world people and natives.

II. Portugal: History and Nation

Portugal is one of the oldest nation states in Europe: its foundation in 1139 predates that of its neighbor, Spain, by nearly 350 years. The Romans who arrived in 216 BC called the whole Peninsula Hispania, but the region between the Douro and Tagus rivers was called Lusitania after the Celt Iberian tribe who lived there. When the Roman Empire collapsed in the 5th century, Hispania was overrun first by Germanic tribes, then by Moors from North Africa in 711. Military reconquest by the Christian kingdoms of the north began in earnest in the 11th century and it was during this long process that Portucale, a small country of the kingdom of León and Castille, was declared independent by its first king, Afonso Henriques. It is a sophisticated society present in many parts of the globe, helping to shape the world's civilization. Let us point out some facts brought by Martin Page in his book:

Portuguese Jesuits lived in Japan for generations before our ancestors were aware of the introduction of words in the Japanese language, e.g. "irrigate" which means "thank you." They brought the recipe for tempura. They introduced the technique for manufacturing weapons. The Portuguese also taught the Japanese how to construct buildings to withstand earthquakes and artillery attacks. The pepper plant was brought to India allowing "curry" to be invented.

Portuguese is the third most spoken language in Europe (English, Spanish and Portuguese) even before French and

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German. It is the language of cattle ranchers in Northern California and fishing communities along the coast of New England. With over 210 million native speakers, Portuguese is the fifth most spoken language in the world..

III. Antecedents of Engineering Education in Portugal

Until the nineteen seventies, the following aspects characterized technical teaching in Portugal:

- Exclusive State responsibility, that centralized, funded and defined course programs;
- Weak specialization in technical university courses, with a strong common training component verified in all courses;
- Reduced dimension and concentration of Engineering Schools, which only existed in Lisbon and Porto;
- Dichotomy teaching, based on a hierarchical and exclusive model (since it defined who could be and who could not be an engineer) and by the fact that its output resulted in an inverted labor force pyramid.

New engineering university courses were established in Coimbra, Braga, Aveiro, Lisbon and a few other places from 1972 onwards.

In 1986, a binary separation of the higher educational system was established in Portugal, through the Education's System Basic Law, which integrated higher education engineering institutes into polytechnic teaching in 1988.

In 1988, the Law concerning University Autonomy was also approved. Through this Law, universities were defined as centers for the creation of culture, science and technology transmission and diffusion, which, through their expression of study, teaching and research, enabled them to perform their role in society.

The evaluation of the science and technology system, carried out in 1996 and 1999, confirmed the need to promote connections between research centers, civil society and companies, as well as the need to promote scientific cooperation at the level of national and international mobility [1].

IV. Some Remarks about the Bologna Process

When analyzing engineering education today in Portugal, (and in Europe) the Bologna process must be mentioned. It is likely to be a unique chance for Europe to modernize its higher education, according to the same principles, with a perspective of reaching a new level of understanding and readability. It has touched off an impressive set of reforms. Nevertheless it must be admitted that the Bologna process may give rise to various criticisms:

- It implicitly links itself to a singular model of higher education (following the same rationale and being directed by the same values);
- It has been designed without considering the reality of the job market (top-down policy);
- It seems to have taken its inspiration from the North American model, which could provide a certain guarantee, but appears indeed to be following a very different path.

For these reasons, which should inform an open and critical debate, the application of the Bologna principle should remain very pragmatic and open to other dimensions, such as:

- The importance of having a limited number of universities in a position to be competitive at the world level;
- The importance of placing some universities, with credible expertise and know-how, in some fields – the so-called technological clusters;
- The importance of keeping a high level of flexibility and response, to launch new types of programs [2].

V. Higher Education in East Timor

As a new nation, East Timor is working to develop in several sectors and the education sector has been identified as a top priority by the government of the Democratic Republic of East Timor.

Of the 14 institutes listed, only Universitas Nasional Timor Lorosa'e (UNATIL) is a government university. UNATIL has been receiving 70% of its funding from the government; professors are paid by the government as civil servants. The institution has also received educational infrastructure and other material support to rehabilitate the campus, and for chairs, desks and library facilities from East Timor's government, as well as from other countries including Portugal (Agriculture and Teacher Training), Australia (Economics and Social Sciences), the United States (building reconstruction) and Japan (Technology).

Many private higher education institutions have been opened, in general with the same goals of enabling high school graduates to continue their education and developing East Timor's human resources. The first goal is probably already met. During the UNTAET transitional period, East Timor already had two universities, UNATIL and UNDIL, but they did not have space for all the high school graduates seeking higher education and the students who had their studies interrupted in 1999. UNATIL evolved from Universitas Timor Timur (UNTIM), the public university under the Indonesian occupation. That university was destroyed in 1999 by the Indonesian military and militia violence, and most of the professors, who were Indonesian, left East Timor. Under UNTAET, it was rebuilt and renamed UNATIL, which has become a public university under the now-independent government.

The Higher Institute of Economics and Management (Instituto Superior de Economia e Gestão, ISEG), a private higher education institution focusing on economics, was formed in 1998. Under UNTAET this institute used existing facilities in Balide, Dili. After independence, ISEG evolved into a full university and became UNDIL [3].

VI. About Education in Brazil

Brazil's Higher Education has a history of success that has been facing some problems of both social and financial order. It starts with the creation of Public Universities in the many states of the country, which have worked very well for many years; the Country has achieved and has built a solid reputation even abroad also creating generations of Brazilian scientists and educators. In that aspect, there is still a long road to travel, involving three agents: the State, that has to generate and to apply public politics of science and technology, besides funding them; the University, which responsibility is to form qualified personnel and to create basic science; and the Industry, that should invest in technology creation, besides accomplishing applied research, to incorporate qualified personnel and, therefore, to win competitiveness.

With the creation of Public Universities in many states of the country, which have worked very well for many years, the country has achieved and has built a solid reputation even abroad also creating generations of Brazilian scientists and educators [4]. Despite all problems, professionals and educators of every field of science and technology have been discussing the destiny of education in the country, taking into account the historical moment of the world. Certainly some of these discussions have generated some practical actions at governmental level as a response to the society that considers itself as the most interested party in the issue. In Brazil, the situation is very delicate for engineering and technological fields. Although the proliferation of private universities all over the country expanded the number of 3rd grade students, it does not assure the increase of students in engineering and technology areas.

VII. The Role of Engineering in Science and Technology in Brazil

Brazil is five hundred years old with a history of races meeting towards the construction of a peoples' identity marked by diversity and cultural richness. Five hundred years which bring the challenge of starting this new millennium building up a new Brazil, a Country where quality of life in daily basis is a concept of its 166.113.000 inhabitants and not only of a minority. Considering the present history of humanity, the importance of engineering and engineers in the development of science and technology is noticeable, they have shaped a new social world order having as a straight consequence the new life style and therefore a new way of thinking.

Recognizing the importance of engineering in the world scenery, Brazil has been working to get the competitiveness of national goods and services by means of incentive to create projects of qualification of professionals through continuing education, for example, and others. Many representative groups, leaderships and agencies have been implementing programs to prepare engineers to increase the efficiency of research system, experimental development, engineering, producing system and market [5].

All these efforts have been having a kind of smooth effect once it is one of the most difficult and also expensive programs of College level, which does not help considerably the inclusion policy. However some Colleges have opted for a softer engineering program offering them in the evening. These programs are lighter and more focused in technical knowledge and less focused in basic sciences. The students in general work all day and choose engineering programs because it is a way to be promoted at work. A third degree diploma opens some doors, it means not only the possibility of earning more money but also of reaching an upper status, socially speaking. It is a fact that, even being a lighter program for the students, it is very hard and in general it takes them more than five years to finish it. The diploma has the same value of a program that prepares engineers of conception. In a certain way, it helps the inclusion policy of education although the number of engineers has been decreasing considerably in the last 10 years [6].

VIII. Final Remarks

It is important to point out the fact that engineering is now of the interest of countries and governments, so engineering education is also of great interest. It is important to know more about the development of policies and actions in different countries, in order to understand the global educational demands. The search for changing to train the professional engineer for the present labor markets as well as the search for the best system in all the countries is clear now.

It is possible to notice that even with the colonization process in Portuguese speaking countries, due to the several other sources of influence because of the immigration waves, the fight for excellence is an ongoing process with peculiar aspects. It is clear that even nowadays, the importance of a language as identity is very high and so is the way it reflects on education.

The knowledge about these countries' engineering education systems will contribute for the reflection about engineering education in a larger spectrum not only centered in west north hemisphere regions of the world. Moreover this overview is a glimpse of education in some corners of the world that can contribute for the global perspective of higher education that is, now more than ever, important for the development of programs such as Engineering Programs.

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STEM Literacy and Textbook Biases in K-12

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Abstract— **Textbooks are a common source of science information in K-12 science education. Science literacy is a major challenge of students in K-12 and this dramatically affects students' achievement. Biases in textbooks negatively influence students' interest and achievement in science and engineering.**

This study explores types of biases in K-12 science texts. These biases primarily relate to gender, race and ethnicity. Textbook biases negatively affect students' views of science as a field, as a career and as a college major. Achievement may also be affected by such biases. Accordingly, this research study explores the biases in K-12 science textbooks. The textbooks were analyzed using a multidimensional rubric and accompanying scoring checklist. Results of these analyses revealed dramatic biases in textbooks particularly for early elementary and high school texts. Both print and photographic biases were noted in the textbooks. In particular, the books that focused on biological sciences were found to contain significant biases especially related to gender. These biases may influence how students feel about careers in science, technology, engineering and mathematics (STEM) areas and therefore may impact future workforces in STEM fields.

Keywords—science literacy; achievement in K-12; science textbooks.

I. INTRODUCTION

Engineers and scientist utilize the principles and theories of science and mathematics to design, test, and manufacture products that are important to the future of our nation and the world.[1] The percentage of college students seeking degrees in math, science and engineering disciplines has been declining for the past two decades. This is in part because fewer potential science, technology, engineering, and mathematics (STEM) majors are completing rigorous college preparatory programs that would enable them to be accepted in undergraduate engineering programs after high school.[2] The number of people from racial and ethnic minority groups and women are especially sparsely represented in science and engineering fields. This shortfall has raised concerns among leaders in STEM fields regarding future STEM workforces.[3]

To meet the changing demands of the nation's science and engineering labor force, recognition of the importance of pre-college education and implementation of challenging curricula that captures and sustains students' interest and addresses their academic achievement in science and engineering is critical. Textbooks are a primary source of scientific information in K-12 science education. Science literacy is a major challenge of students in K-12 and this profoundly impacts students' achievement. Biases in textbooks negatively influence students' interest and achievement in science. This is of particular concern for women and underrepresented minority groups. When students are not represented positively and equitably in books, they are less interest in engaging with them and this limited engagement in turn leads to poor reading achievement.[5] This is of particular concern in subject areas where content is challenging because difficult subjects require deep engagement with vocabulary and comprehension to fully understand the content. Essentially, if students are "turned off" by texts, they will disengage and learning will be compromised. This could be devastating for K-12 learners.

Content area literacy is particularly difficult for learners whose primary language is not English. The United States has the greatest number of minority students in the country whose primary language is not English (over 1.5 million, 25% of total school population). Ironically, these students are often most underrepresented in photos and graphics in K-12 science textbooks. Under No Child Left Behind[6] schools must ensure that English learners (ELs) show significant yearly progress in developing English skills as well as meeting grade level standards in all academic content areas. According to the latest report card on the implementation of NCLB, schools are falling far short of meeting the academic needs of their English Learners.[7] These students struggle to develop the cognitive academic language proficiency (CALP) necessary to comprehend content-area textbooks particularly in science. Chall, Jacobs, and Baldwin[8] note that the breakdown in academic achievement in STEM content areas as particularly significant. Content-area texts contain a large number of content-specific vocabulary words and concepts that are beyond the students' English language abilities. Students need to be taught how to read content-area texts as well as to develop the academic language and discourse associated with each content area, particularly as they proceed through cognitively demanding curricula such as science. As such, if students are disengaged because they see that texts do not represent them equitably, their engagement and most importantly their achievement may suffer.[5] In other words, textbook biases effect both engagement and achievement as it relates to literacy.

II. Review of current research

A. Textbook Bias in General

Importantly, textbook bias is not a new area of research persay, as it has been studied for the past two decades. Unfortunately, much of this research has been conducted in early childhood education and has not addressed the scientific disciplines.[9,10] Within studies of bias, research that investigates the presence of bias in textbooks focuses primarily on gender bias. Several scholars have undertaken a quantitative approach of analyzing the content of textbooks. Such studies provide a foundation for similar research, yet they are different from the present study, which has as its purpose to specifically identify the biases in science textbooks that may interfere with students' science interest and ultimately, their achievement in STEM disciplines.

B. Textbook Biases in Various Disciplines

Various researchers have studied textbook biases disciplinarily. Peterson and Kroner[11] investigated the presence of gender bias in psychology and human development in university textbooks. These researchers developed two coding schemas to categorize the types of biases that they observed in the texts in their study; one that was used to analyze introductory psychology texts and the other that was used to analyze human development texts. The authors' research goals were to (a) develop a measurement tool for evaluating gender bias in textbooks, (b) to determine how much change had occurred since the American Psychological Association's guidelines for non-bias text had been issued, and (c) to evaluate the current level of equity of gender representation in texts. The researchers found gross inequity in gender representation in the textbooks that they analyzed. Women were often portrayed as "passive participants" rather than "active agents" in the texts. Peterson and Kroner also suggest several useful guidelines for creating more inclusive texts derived from a careful review of photos and character description in the texts. Similarly, Campbell and Schram[12] reviewed psychology and social science texts for gender bias. They searched for examples of "nonsexist" language and "profeminist" language. Using both qualitative and quantitative analyses, Campbell and Schram[12] found results similar to Peterson and Kroner[11] illustrating that the reviewed texts included sexist language.

C. Textbook Biases in Science Texts

Garcia[13] undertook one of only a handful studies that focused on racial bias in texts. He analyzed high school science texts for the presence of a "Hispanic perspective." While the research is useful as it is one of the first studies to focus on Latina/o representation in science textbooks, the study is quite dated.

In a more recent and somewhat related study, Ndura[14] investigated cultural bias in high school textbooks for the potential impact on English learners. Ndura analyzed texts by focusing on three important themes: (1) stereotyping, (2) invisibility, and (3) non-reality. Ndura argued that both teachers and students needed to be trained to analyze textbooks utilizing a critical lens as a means for addressing bias in classroom.[14] As such, with this recommendation, even when stereotyping or invisibility occurs, students are able to dialogue about the problems in texts that they are reading, thus addressing biases head on, while making connections to larger social issues of biases. This study prescribed an intervention associated with confronting biases in texts in addition to an analysis of texts that may be applied in diverse K-12 settings.

Wilkinson[15] undertook a quantitative analysis of physics textbooks for the emphasis on specific components of science literacy. The textbooks he analyzed were chosen from a twenty-year publication timeframe. Wilkinson wished to understand what particular content was emphasized in physics texts within four themes that had been previously used in other science text analyses: (a) knowledge of science, (b) the investigative nature of science, (c) science as a way of thinking, and (d) the interaction between science, technology, and society. Wilkinson adapted an instrument for his analyses that was previously designed to uncover text biases in other areas. The instrument utilized a checklist, which described the four themes. He found that all four thematic areas within the physics textbooks contained biases.

Eide and Heikkinen[16] investigated the inclusion of multicultural material in middle school science teachers' resource texts. Noting that teacher resource texts (often referred to as teachers' editions) are highly used instructional resources, the authors analyzed the extent of multicultural content in twenty-one teachers' editions of middle school science texts. The authors did not focus on illustrations and images in their analyses. Rather, they designed a systematic arrangement for classifying units of communication from the printed material in the texts and transformed the print quantitatively by assigning numeric codes to categories of content within text. They found that multicultural content was present in only small amounts in middle school teachers' editions. This finding led Eide and Heikkinen[16] to recommend additional inclusion of this important material in the science resource texts. They posited that it would be very difficult for teachers to teach multiculturally using their resource books given the sparse representation of this content.

Similarly, Delgato[17] reviewed biology textbooks for the presence of multicultural science educational material. Delgato[17] assessed the portrayal of minority groups, in both image and text, with an emphasis on "indigenous people" and "indigenous knowledge." The results of this study indicate that

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minority groups were often portrayed as undereducated. Delgato[17] recognized a stark need for text rewrite in his study as the vocabulary presented in the texts that was examined were from dominant groups and not often representing the perspectives of indigenous groups.

As described in the review of the research above, significant gaps in the literature on textbook biases have been identified. The bulk of research on textbook bias utilized content analysis to uncover and empirically categorize instances of bias. Checklists and unsystematic analyses dominate this literature. Few studies have explored texts across broad grade levels with the intention of recognizing trends in textbook biases. Additionally, multidimensional rubrics have not been used to systematically and empirically analyze features of bias in texts. Such instruments are useful because they have potential to make results of bias analyses accessible for teachers, students, and parents who are interested in recognizing and addressing biases similarly as was described as an intervention by Ndura.[14] Additionally, biases discussed in contemporary research most commonly identified gender at the exclusion of other types of biases including race, class, and sexual orientation. Accordingly, further analyses of textbooks must include attention to other groups that have been traditionally affected by bias in society and in education.

III. Research design and approach

The present study attempts to address some of the gaps in the research described above with particular attention to multiple types of biases in K-12 science textbooks across grade levels. Potential biases of focus in this study include gender, race and ethnicity in science texts in addition to socio-political biases. Each of these biases can negatively impact students' views of science as a field, as a career and as a college major. Accordingly, these biases have potential to limit options for future scientists and engineers. Additionally, as previously described, K-12 students' achievement may be impacted by such biases, so the need for their identification and alleviation is rather urgent. As such, the purpose of the present study is to identify the types and to determine the prevalence of biases in science textbooks across K-12 grade levels. Therefore, this study answers two important research questions:

- What are the nature and prevalence of biases in science textbooks in K-12 education?
- What types of text biases are present in the science disciplines and at what grade levels are they most prevalent?

The study employs anti-bias theory as a framework for the text analysis. Anti-bias theory builds upon the work of Ndura,[14] Derman-Sparks and Hohensee,[10] (described above) utilizing an activist approach in which one challenges prejudice or biases, links these biases to societal challenges, and proposes change for societal improvement. In this paper, an attempt is first made to identify the type and prevalence of textbook bias and then to propose recommendations for changes in practice to address the biases utilizing an anti-bias approach similar to that which is described in Ndura's research.

A. Instrumentation

This study employed a multidimensional scoring rubric with a checklist addressing each rubric dimension (listed below). The rubric facilitates both a granular and holistic investigation of science textbook bias. The rubric includes four important dimensions that are aligned with anti-bias theory:

- Visual content bias: Visual content is important as science texts contain many visual images that are either photographic or graphic. These images can be analyzed for how underrepresented groups are presented or misrepresented.
- Written content bias: Written content bias refers to the way underrepresented groups are described or depicted in writing. Word choice and written language use is a necessary part of this bias dimension.
- Author's perspective bias: This bias dimension refers the author's hidden message he/she is sending via the text.
- Omission as bias: The omission as bias dimension refers to when particular groups are omitted from texts as an means of exclusion of representation.

The multi-dimensional rubric is structured such that on one half of the rubric there is an element checklist aligned with the four dimensions of bias (described above) and on the second half there is a holistic scoring schema (using a 4-point scale). The four-point scoring schema utilizes a continuum to determine the "level" or prevalence of bias in each of the four analytical dimensions. Inclusion criteria with examples for each of the four points on the continuum are included in the textbook scoring rubric as a guide for determining where the particular element of bias is best represented in terms of "level."

B. Instrument Validation

Group calibration techniques were used to determine the rubric's construct and content validity in addition to its internal consistence.[18] As an initial rubric calibration procedure (recommended by Mark Wilson[18] for sound measurement and in particular item response theory; IRT) , raters were provided with examples of textbook bias that fit into the different dimensions and bias levels (1-4) and were asked to rate each example using the rubric independently. They were then asked to share their ratings and build consensus in their results as a means of calibrating the rubric. Examples were then rescored after discussion of the initial individual example ratings, and once an accurate and acceptable calibration (~ .5 standard deviations from the mean) with the example biases was reached, the criteria on each dimension and level of the rubric was adjusted in accordance with the raters' calibration.

C. Data analyses

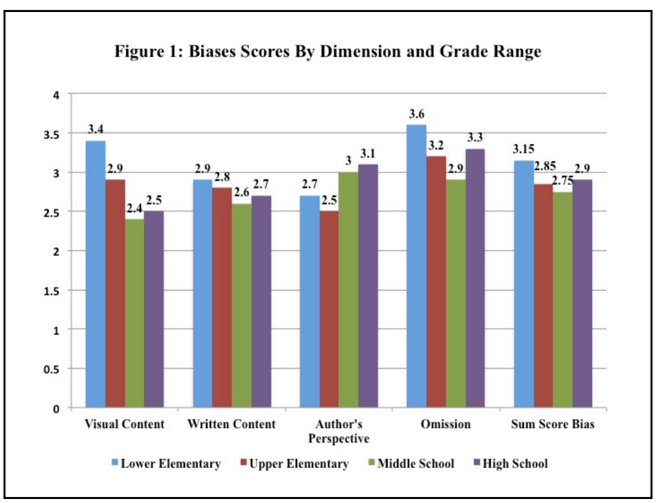
All textbook data (print, visual elements, etc.) was analyzed according to the four dimensions of the multi-dimensional scoring rubric (described above). Notes were taken on each on the rubric related to the dimensions for each analyzed text and these notes were categorized in accordance with the four dimensions to provide rationale for scoring on the rubric. In turn, the checklist portion of the rubric was used only to determine the existence of a particular type of bias within the four dimensions for which notes could be taken and categorized, thus forming evidence for scoring the text on each bias element in accordance with the rubric criteria.

D. Textbook Selection

A total of forty-three science textbooks were analyzed for this study. Approximately 20% of the texts were used in elementary school (grades K-5) , 20% were used in middle school (grades 6-8) and the remaining 60% of the texts were high school texts. The textbooks were chosen from a broad selection of science textbooks commonly used in three of the largest school districts in the western United States. Importantly, the greatest number of the analyzed books were high school texts because of the diverse subject areas within high school science. These included various advanced placement (AP) and honors science course textbooks.

IV. Study Results

Each of the forty-three analyzed texts were found to have biases in each of the four dimensions of the multi-dimensional scoring rubric to a lesser or greater degree. Figure 1 illustrates the distribution scores of the texts by rubric dimension and categorized by grade range. The ranges are divided as lower elementary (grades K-3), upper elementary (grades 4-5), middle school (grades 6-8) and high school (grades 9-12) to illustrate the range and prevalence of text biases.



The results of these analyses are interesting and diverse. The lower elementary texts had the greatest bias noted overall (M=3.15, SD=.79) followed by the high school texts (M=2.9, SD=1.01). In terms of the greatest bias prevalence, the dimension with greatest noted bias was that of omission of a traditionally underrepresented group, (M=3.25, SD=.91), although there was definitely a broad distribution across the four dimension of the rubric. These descriptive findings indicate that much work needs to be done to equitably and accurately represent historically underrepresented students in science majors and careers in K-12 textbooks.

That which is not fully represented in the numeric values in the bias scores is the hidden messages behind the bias dimensions in the analyzed texts. Accordingly, examples of these biases are provided herein. The omission dimension is not possible to fully depict in this paper because omission, by definition refers to a group "not present" in the analyzed text. Omission typically was represented by underrepresentation of people of color and or women as scientists or engineers in the textbooks that were analyzed. Additionally, when inventors were discussed in the texts, historically underrepresented groups were omitted. To determine authors' perspective in K-12 informational texts, it was important to review the backgrounds (educational and otherwise) of each of the contributing authors and editors and then to determine where and in what ways in the text that these backgrounds influenced the textbook message choices. This was somewhat different than that which is often found in a fictional text where authors' voice is often overt.

Photos and illustrations (the visual dimension) were quite marked with biases in the science texts across grade ranges and science subject areas. These were especially prevalent in the life science, biology and physiology texts that were part of the study, where the study of human life and organisms were presented. However, even in non-life science type texts, bias was present in visual images within the textbook. Figure 2 (below) illustrates such bias.

In this photo, (Figure 2), one would note that only males were featured in this photo of a scientific experiment in progress. Not only are only men depicted in the photo (above), the photo does not represent any ethnic diversity. While at first glance one might think that this visual depiction the norm in the scientific world, if the desire is to "change the face" of science nationally and world-wide, one must not only be to sensitive to the hidden messages sent by textbook photos, one must also make deliberate efforts to diversify scientific images in texts in order to positively influence diversity in future science workforces.

Words in science textbooks often have as many hidden messages and meanings as visual images. They can present scientific history in a highly biased manner. This has most recently been portrayed in the following ways. A science textbook may feature a glossy pullout of female scientist, however include precious little text-based narrative of the scientific contributions of women. As an example of this, the following quote was uncovered during analysis of a middle school science text in the study: "Businessmen are now looking for entrepreneurial thinkers that can take the place of the traditions of the American scientist." The word "men" in the first phrase of the sentence sets the stage for a gender-biased text excerpt. Indeed not all business people are males. Secondarily, the statement is American-centric, as it refers to the traditions of American scientists, thus potentially setting up omission of contributions of non-American scientists.

While some may view these two examples as singular, these types of biases have been found via the present study to dominate K-12 science textbooks. Putting an end to such biases may contribute to building an anti-bias framework in K-12 STEM, thereby increasing equity is science fields long term.

IV: Discussion and Future Directions

This research represents a starting point for exploring and ultimately ending both the negative influence of science text bias on academic achievement and decreased interest in science for girls and other underrepresented minority groups. The textbook biases present across the K-12 lifespan are quite alarming. This is especially evident in visual images and in the life science related subject areas. The finding that the greatest amount of bias was found in early elementary level textbooks is quite alarming because the message sent by informational texts to young children could have lasting adverse effects on the choices that they make career-wise. Additionally, this could affect our world's most vulnerable children's interest and motivation to read science texts, which could ultimately negatively impact their science literacy and achievement. This can inform the future of science and engineering fields.

To carry this research forward, future research should be conducted in which K-12 learners are interviewed as to their thoughts about representation and biases in science texts. Teachers should also become a part of such research to determine the impact that these texts have on teacher instruction and associated biases. Once these interviews are conducted, students and teachers from diverse groups should engage in exercises that explore the relationship of such biases to societal issues in broad scientific and engineering contexts. Solutions for ending such biases could be posed by K-12 learners, thereby providing content and context for anti-bias curricular reform in K-12 STEM education.

Additionally, research should be conducted that explores the relationship between textbook biases and science achievement longitudinally in students who have been historically underrepresented in the science fields. Finally, interventions should be developed in K-12 science classrooms in which students themselves analyze their texts for biases and use these identified biases as a means for activist projects that focus on confronting and changing biases in STEM fields. In that way these biases can be called out, discussed, and processed by those who may be most affect by them. Change can start on the grassroots level with the future of STEM workforces at the helm of curricular change.

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Project Based Clean Tech Curriculum for High School

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***Abstract*—United States renewable energy businesses require well trained high school and college students to fill key positions as technicians, engineers, and other high paying jobs. Project based learning programs offer a way to train students in these emerging fields with realistic, intensive student-designed and built projects. This paper reviews the challenges and some of the lessons learned in developing a four year high school curriculum in renewable energy and clean technology. A primary challenge in developing this kind of program is the time and complexity of gathering relevant technical material in this field and adapting it for high school students. Related to this challenge is the selection of projects that the students pursue. We've learned that these two challenges require a content area expert and substantial technical support to insure that student design projects are age and skill appropriate, safe for the class, but also keep students engaged. One key learning from this program has been the successful introduction of novel, table-top scale "minisystems" that emulate full scale projects such as electric vehicles. These minisystems are also low-cost enough so that a typical class can to assign one minisystem to a two person team. The renewable energy focus also enables the discussion of key environmental and economic challenges. Student designed and built thermal storage units mimic residential-scale systems. Energy arbitrage, the differential in peak and low demand prices for electricity, helps the students understand why and when these systems can be economical to operate. Other projects in biofuels also facilitate discussion about the sustainability of using food or other renewable natural resources for energy. Each course contains six to eight projects. Projects topics are developed through an interactive brainstorming session including leading teachers in the State and representatives from prominent local industry. The project topics are further refined to focus on a key problem area. This curriculum is currently in the pilot phase at numerous high schools in the Southeast.**

Keywords: renewable energy, energy efficiency, clean technology, fuel cells, thermal storage, biogas, biomass, water efficiency

I. INTRODUCTION

Advanced Careers™ is a multi-state initiative created by the Southern Regional Education Board (SREB) to create a new high school curriculum that prepares students for entry into the workplace and into science, technology, and mathematics intensive college programs. This program is a direct descendent of Project Lead the Way (PLTW) but deviates from PLTW in several important ways. This paper reports from a curriculum development and deployment perspective how science, mathematics, and literacy are embedded in a project and problem based curricula that is focused on a specific application area- clean energy. Examples of projects are used to illustrate challenges and opportunities in curriculum development, teaching, and standards implementation. While AC is a new program, its predecessor is studied for clues about how AC might succeed in the education marketplace. Suggestions and next steps for improving project based learning are included.

Advanced Careers™ is targeted at the unique skill requirements of specific states . Currently more than ten states are actively developing AC curricula- each targeting the needs of a specific industry or application area. This chapter focuses on the development of one of those states: a four year curriculum targeting clean energy technology (CET), a key area of investment and job growth in the state of South Carolina. As the lead curriculum writer for this program in South Carolina since its inception in 2010, I bring a perspective on STEM curriculum development that is both current and still evolving, but narrowly based on a single field of application.

For readers not familiar with PLTW or project based learning, SREB's Advanced Careers program is attempting to do for career/technical training what Advanced Placement courses have done for academics. The AC program focuses heavily on creating intellectually demanding, industry relevant coursework coupled with extensive hands-on application of the technical skills taught in each AC course of study.

II. OVERVIEW OF THE PROGRAM

The AC curricula for Clean Energy Technology is a four year program of study. The first year of CET focuses primarily on introducing students to fundamental science, physics, and engineering concepts within the context of existing clean energy challenges. The second year program applies these concepts to more challenging projects. Each of the projects introduces students to one element of renewable energy, fuels, or energy storage. A brief introduction to nuclear energy and physics is discussed, but within the context of nuclear batteries, the primary power source for satellites. The third year program advances the education bar a bit further by adding more complex math, software programming, and science content. The fourth and final year is focused on original student research, a problem-based learning paradigm, in one of several pre-selected categories under the general aegis of CET. While

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local industry and government participation is used in the first two years, the final two years rely heavily on the direct involvement of local industry, government, and nonprofits as direct advisors and consultants to the student project teams.

Embedded within the project format are State Common Core standards for math, literacy, and science. Curriculum and content development for each project is subjected to intensive review in the three core standard areas and also subject to overall "go/no go" approval. Common core, twenty-first century, and state level standards taught in the projects are documented at the beginning of each project. The exact frameworks employed, internal methodologies, and method of implementation is outside the scope of this writing.

Within each year long course, the unit of study is a single, hands-on project. A typical course may have 6-8 projects, with each project consuming 20-30 educational periods. Most of the work in each project is team-based while a smaller portion of class time is spent in individual learning. The scenarios that initiate each project describe the problem or challenge Students must will then follow either a "Science as Inquiry" or "Science as Technological Design" process- the two key process oriented components of the current national science standards. In general, inquiry-based science projects are introduced "gently" in the first two years and become more challenging in the latter two years of study to align with the student's expected progress in the math courses offered by the school.

Ensuring the authenticity of projects developed by States and their curriculum writers is an area of concern in the AC program. SREB uses research from the work of Newman and Secada at the University of Wisconsin to critique the individual projects [1]. The SREB multi-disciplinary project editing team provides detailed feedback to curriculum developers on each project prior. Projects must pass an SREB review prior to being taught at the high school.

The AC program departs sharply from previous programs such as PLTW in several areas. While hands-on projects are a requirement, the socio-environmental impacts of science and engineering are integrated into the projects. For example, a project on bio-diesel also incorporates several known economic externalities associated with converting food crops into motor fuel. Students explore the conflicting claims in the ongoing "food vs. fuel" debate. This kind of student engagement also helps develop critical thinking and writing skills.

Secondly, the projects are open-ended. This allows the student teams to investigate different methods and materials of assembly. No two classes studying Course 1 for example will produce exactly the same final product. A typical first year project requires the student teams to build a 10 to 40 watt solar panel from polysilicon solar cells and basic construction materials. Solar panel assembly is rife with potential problems, driven heavily by the need to physically mount and electrically interconnect the brittle silicon solar cells. Circuit design basics like Kirchoff's laws are taught in a just-in-time (JIT) method to teach students how to interconnect the solar cells to achieve a desired voltage or current output. Students may produce very different sized solar panels in each class and employ a wide variety of mounting and assembly materials.

Finally, the projects are evolving over time as students and teachers gain more familiarity with the diverse materials, sensors, electronics, and science concepts used in the projects. Students found in the previous solar panel project through trial and error how to use non-conducting conformal coatings to protect the backside of the solar cells and to make the solar panels more light-weight and lower cost. This has lowered the cost of the projects, and lead instructors to incorporate other ideas and other directions. In another project, an air-to-air geothermal heating and cooling system using a low cost Styrofoam cooler was initially developed by one of our teachers. The project has since evolved to a liquid-air system by using low-cost personal computer cooling pumps and heat exchangers.

The role of economics in driving technology choices is taught throughout the program. Technology choice such as fuel cells versus biomass as an alternative energy source is driven by more considerations than simple comparisons of overnight costs or operating costs. Throughout the projects, opportunity costs are integrated into the projects.

One second year project begins with the students studying a combined solar pump/storage drip irrigation system developed in equatorial Africa for small land-holders [2]. Student teams are challenged to identify ways to improve this system. The teams use commercially available energy modeling software called HOMER™ to model the system's performance. HOMER allows students to configure and compare many different implementations. One of the first questions students face is: why not use a diesel powered generator, rather than solar to power the pump? Through investigation and research, students learn that diesel supply in the more rural parts of equatorial Africa is spotty at best, and fuel prices are often inflated by middle-men to a level that small farmers simply cannot afford. HOMER allows the students to iterate on the cost of fuel so that the levelized cost of electricity (LCOE) between a diesel-fueled system and solar system is at breakeven. This breakeven price of diesel is the point of departure for adding the cost and complexity of energy storage systems and other technologies needed to assure availability of electrical power in a remote off-grid setting.

One of the most radical departures from existing science education is the project and problem based methodology. AC uses much of the pedagogy from the Buck Institute's research and practice on project and problem based learning[1]. Teachers become facilitators rather than instructors, aided by external experts from industry and government that volunteer their time to assist in the projects. Students are the "doers", performing the vast majority of the work, while teachers advise and monitor the student team's progress. The absence of "row-seat" instruction and well-developed texts suitable for high school students presents some major challenges for content developers and conceptual challenges for teachers. Just-in-time instruction that is context specific, such as the by-products and economics of bio-diesel production, must be developed and presented in a way that enable teachers to quickly grasp the essential elements but also transfer much of the learning onto the students. This requires content specialists or experts to

[1] The Buck Institute for Education

train a cadre of teachers in advance and to insure the content is both industry relevant but also contains enough science and math content to warrant inclusion into the project.

Overall, the AC program attempts to integrate multiple standards into a multi-year curriculum that is framed by the key job skills that industry expects from state high school and college graduates. The focus is project and problem based- putting the student in a role of directly of much of the learning. The program is pedagogically rigorous, with State Common Core math, literacy, and science standards embedded throughout each project. Cross-cutting concepts such as creative thinking and entrepreneurship are used to help students develop more depth in their understanding of the industry challenges. By allowing states to develop their own area of focus, clean energy technology in the case of South Carolina, SREB is essentially creating a large catalog of contemporary industry-relevant curricula.

III. History and Lineage of The advanced Careers program

Advanced Careers draws upon many excellent and well managed programs for its inspiration. As an example, AC includes Project Lead the Way (PLTW) as one of it's predecessors. PLTW was developed in the New York State school system. The initial goal of the PLTW program was to increase enrollment in STEM college programs in New York [3]. PLTW is currently the premier pre-college engineering program in the United States with more 400,000 students [4]. The widespread adoption (all 50 states have some PLTW adoption) suggests that the program fits well within the existing public education system in the United States.

IV. Key Facets of Project Based Clean Technology Curriculum

One of the most radical departures from existing science education is the project and problem based methodology [5]. Teachers become facilitators rather than instructors, aided by external experts from industry and government that volunteer their time to assist in the projects. Students are the "doers", performing the vast majority of the work, while teachers advise and monitor the student team's progress. The absence of "row-seat" instruction and well-developed texts suitable for high school students presents some major challenges for content developers and conceptual challenges for teachers.

Technical, safety, scale, and cost challenges abound with this strategy. Creative solutions are needed to keep the cost of the projects within reach of a majority of high schools while not sacrificing realism and relevance. Building and erecting a functional wind turbine with a six foot rotor might be realistic but presents many challenges . An alternative to this approach developed in this program was to focus on table top system from KidWind as the learning platform. The bulk of the project has the students focusing on optimizing turbine blade design while learning the science and engineering principles that derive from the blade design

The wind energy project (blade design) project is much more than simply cutting wood or plastic and mounting to a table top wind turbine assembly. The competitive nature of the project, where 2 person teams attempt to design the most efficient blade, requires a metric and also creates a measurement problem. Tip speed ratio (TSR), a key figure of merit for blade designs, requires calculation of angular velocity of the tip of the rotor.

Calculation of the angular velocity requires knowledge of the rotational speed of the shaft. At this point, we ask the student's to recall earlier training in motors and generators to determine how to measure the shaft speed by examining the voltage output of the turbine. A three pole generator will produce 3 voltage peaks per revolution. Students employ National Instruments LabVIEW™- an industry standard data acquisition hardware and software system, to measure the motor's output and calculate the frequency. From the frequency, students can then complete the task of calculating the angular velocity and TSR.

In a simple task like blade design, a project-based learning exercise can employ all three dimensions of the next generation science standards: science and engineering practices, cross-cutting concepts, and disciplinary core ideas. Within science practices, students collect and analyze the data in the frequency domain and use this data and their knowledge of trigonometry and geometry to calculate a key figure of merit for turbine blade. Cross cutting concepts include the use of energy flows to explain why there is a limit to the amount of energy that a turbine blade may extract from a moving air mass, formally known as the Betz limit. Finally, the core disciplinary ideas include elements from physical sciences (why moving air causes the turbine to spin), earth and space sciences (what causes the wind), engineering/technology and application of science.

Some of the simplest sounding projects can enable teaching of a wide variety of science topics. An essential concept within career and technical training is heat transfer: conduction, radiation, and convection. We found that the design and testing of a passive solar collector is a great way to teach all three components in a single project. The context of the project is a challenge to develop a low-cost, passive solar hot water heater for the developing and underdeveloped world. By shrinking the size of the student built collectors to approximately one foot square, we could use a low-cost thousand watt halogen lamp to simulate the sun. Halogen lamps have a different frequency distribution than solar energy but it is close enough for most basic laboratory work. Students experiment with coatings and materials optimize heat gain in passive collector.

Utility grade renewable energy projects that students often hear about in the news require careful analysis and site planning to optimize energy production and to maximize return on investment. Extensive simulation and modeling is performed before these projects ever break ground. The projects in the CET curriculum leverage many of the same commercial-grade simulation, analytical and web-based data collection software used by utilities, consultants, and contractors. The software and web-based applications dramatically extend the reach of teachers and hide much of the underlying complexity.

Students might be asked to determine whether solar or wind is a good solution to drive an energy storage requirement. A JIT-based module on wind introduces the students to the underlying factors that create the diurnal variation in wind speed. Students are directed to, or must find on their own, one of many websites that allows access to hourly wind speed data. To apply the theory, students can download the wind speed hourly data and then create a simple plot of wind speed by hour. Geography lessons abound, as a comparison of different sites can illustrate why wind driven energy storage might be better suited one location rather than another, or might have a strong seasonal component. Rather than lecture students about why wind energy cannot be used everywhere, students can employ critical thinking skills to answer open-ended questions. Through dialog, peer-review and feedback, students can deduce pretty quickly why some locations are better suited for wind.

A software program mentioned earlier, HOMER™, can be used in a similar way. HOMER can import detailed climate data for many areas of the world. Internally, the program will calculate solar insolation and average wind speeds by hour and month. Students can then use the program's simulation features to develop their load profile and specify the configuration of the renewable energy equipment used. HOMER will then simulate operation of the student-designed system to calculate the levelized cost of electricity. By closely examining the graphs created by HOMER, students can tailor energy storage and load profiles minimize the cost of electricity produced.

Opportunities for cross-cutting learning exist in this project also. Developing a solar irrigation system near the equator can create many challenges. Students may start their investigation with a standard load profile- electricity is needed from 9AM to 4pm to power irrigation pumps. It's a pretty a simple task to then configure a pump and solar panel to provide this electricity. However, simulations will show errors; that not enough electricity is available. Students can dig into the monthly insolation graphs but will find that twice a year, the solar insolation is only at 10% of the level needed to power the pump. As students investigate this more deeply, they learn that this part of the world experiences two monsoon seasons per year. Obviously during the monsoon, there is no need to irrigate. But more importantly, this kind of exercise shows that simplistic assumption such as a standard daily load profile, leads to over-design and inefficient solutions.

One challenge faced in this type of project-based curriculum development is what I call the "mini-macro" problem. Clean energy projects rely on scale, among other things, to achieve financial support. Electric vehicles (EV) are an example of this problem. EVs are a key embodiment of clean technology with a simple electric motor drivetrain and battery energy source. Depending on the application of the EV, a fuel cell may be more appropriate than batteries as an energy source. Batteries have an advantage of maintaining their output voltage over much of the discharge cycle while fuel cell output can very dramatically with load. Most simulation and analytical software available for students in this area is targeted at undergraduate and mostly graduate level automotive engineering programs. How then, can we introduce electric vehicles, drive trains, and fuel cells to 9th and 10th graders in meaningful way so that twelve two-person teams in a typical class can each have their own EV and vehicle test bed?

SREB along with its industrial partner National Instruments created and implemented a concept called the "mini-system" to address this type of challenge (cite SREB website). The mini-system is a low-cost engineered electro-mechanical system that enables student exploration of a specific topic. In this EV project, the industrial partner (National Instruments) developed a dynamometer on a printed circuit board approximately six by ten inches. Mounted on top of the dynamometer, is a remote controlled hobby car. Via the software user interface customized for this mini-system, students can adjust the load on the car and throttle position to simulate driving conditions. Measurement points on the PCB enable students to monitor the input voltage and current to the RC car. The car is powered by 4.5volt battery pack or a commercial miniature PEM fuel cell. The PEM fuel cell is powered through an electrolysis unit.

At first glance, this system is very under-whelming and appears to be more of a toy than an engineering system for exploring electric vehicles. Over several months we developed a project that leverages the mini-system's features to provide the students with a unique challenge. The clean energy project requires students to "drive the car", by adjusting the load and throttle, over a specific route. The goal is to reach the final destination without running out of battery charge or overloading the fuel cells. Since fuel cells can be refueled in minutes with the addition of hydrogen, the time penalty is very short. Battery recharging, though, can take hours. Students are given different routes and distances to allow them conceptual room to explore a longer, flatter route in lieu of a shorter, hillier route. Students calculate distance travelled by measuring the dynamometer rotational speed at each throttle setting. Then, a single measurement of the diameter of the dynamometer roller and the R/C car wheel diameter enables the students to calculate virtual distance travelled at any throttle and load setting.

But this project goes much further. The fuel cell manufacturer provided us with hydrogen consumption data for the fuel cells and also information about the electrolysis unit. With this knowledge, we can lead the students through a discussion and calculation of the efficiency of the hydrogen powered car concept. This leads into more complex discussion and exploration of the so-called "well to wheels" or life-cycle assessment of the transport system. By extension, one can easily lead this discussion to a key limitation of current proton exchange membrane fuel cells- the cost of generating hydrogen and storage of the hydrogen.

Within a single mini-system, we can develop projects with a wide range technical and conceptual difficulty. If these units are purchased for course 2 initially, they can be reused for courses 3 and 4. Because the mini-systems have the vast majority of their features implemented in software, this enables a software developer to make many refinements and improvements to the student and instructor user interface. But the capabilities of leveraging LabVIEW for this application extend much further.

LabVIEW, for the uninitiated, has what can only be inadequately described as a comprehensive and extensive set of built-in measurement, communications, analysis, graphical, computational, and system features. Building a software application on a LabVIEW platform allows developers to use more college/professional level techniques such as fast Fourier transforms (FFTs) implemented in software to calculate the rotational speed of the previously mentioned dynamometer by simply measuring the generator's voltage output. The built-in functions within the software provide the conversion of time based voltage data to the frequency domain. Thus, the user interface (UI) hides this calculation from the student, allowing the instructor to focus on the science and math dimensions of the project.

Limitations of this approach for academia are similar to those found in industry. LabVIEW requires training and practice for proficiency. Data acquisition boards and modules have finite limits on current, voltage, and the number of channels. Distributed measurement systems using wireless technology, which would be a huge benefit for high school programs, is still quite expensive per measurement point. All of these challenges will be overcome at some point in the near future.

While min-systems are suitable for several projects, implementation for others proves problematic at this stage in the program's development. Previously, I mentioned a project involving solar drip irrigation in Africa. There were numerous ideas and a few attempts to develop a mini-system for a growing environment: complete with sun, computer controlled irrigation, and integral soil moisture sensing. Conceptually this approach was quite attractive as the small volume of soil used, about one cup, would enable rapid wetting and drying. This "fast cycle time" would allow the students to accelerate the time base of the projects- not currently feasible with conventional agriculture. However, this approach created a large set of additional problems. Abandoning this approach, we next explored using small integrated indoor greenhouses, about the size of a small bookshelf, so that students could grow real plants. The time requirement for the students to generate meaningful data was beyond the time allowed for the projects.

The current solution to the challenge of simulating a real growing environment in a rapidly compressed time frame was a hybrid solution. Rather than using plant growth as the primary measurement, we focused in on the widespread problem of soil moisture variation. Many farms around the world plan their irrigation needs based on evapo-transpiration (ETo) models. Formally, if one knows the sunlight, the type of soil, the crop, and temperature, the amount of irrigation needed to wet the soil to the specific root zone depth can be calculated. However, ETo models may lead to major swings in soil moisture both above and below what is needed. Soil moisture sensors can be used to augment ETo calculations. Since pumps are used to provide irrigation water, over irrigation leads to higher power consumption and costs. But more broadly, ground water fed irrigation systems that employ ETo can also cause over draughts of the underlying aquifers. This problem, originally centered in Africa to start the project, then takes on a more regional and global importance.

To implement this irrigation project within a narrow time frame, we made several changes. First, we used a simple five gallon bucket filled with commercial topsoil (depth is important) as our field. Next we used our halogen lamp under computer control to simulate sunlight. We purchased a state of the art, blade-type capacitive soil moisture sensor to monitor water in the soil in real time. To simulate the pumping/storage of water, we used a five gallon bucket suspended about 2-3 feet above our "field". The bucket was mounted with a spigot and computer controlled valve. From the valve, quarter inch commercial drip irrigation tubing conveyed water to the soil. A conventional adjustable dripper was used to release water into the soil. Students monitor the volume of water released into the "the field" by measuring the change in the volume of water in the bucket.

We then structured a competition among the student teams to develop a software algorithm to maintain the soil moisture within a close tolerance. Points are awarded to teams based on the least amount of water used and lowest variation in soil moisture at a specific depth. The challenge for the students in this project is managing the interaction between the type of soil, the rate at which water is applied, and the response time of the sensor. Instructors can add stochastic variation to the project by altering the timing and amount of sunlight, adding or modifying the soil depth, or even allowing the students to explore concepts such as no-till planting.

A key component of renewable energy and fuels is the role of biology and more specifically molecular biology and genomics. Integration of engineering concepts with biology is probably a challenge for most teachers, as well as curriculum developers. One bio-project that has gained favor with instructors and students uses a so-called "dirt battery" to generate a small amount of electricity. Like the earlier project that began with drip irrigation in Africa, this project begins with the need to develop the simplest possible form of electricity to power an LED lamp in a rural, underdeveloped country.

We purchased a commercially "dirt battery" and had the students collect "muck" from around the various streams and rivers near a school. The students then add the mud to the device, insert the electrodes and wait. Within 5-7 days, the LED mounted in the top of dirt battery began blinking – an indication that a small electric current was charging a capacitor. During the wait time, students spend several class periods learning about microbial fuel cells.

One clever instructor extended this concept in a different direction. He and his students had several of the dirt batteries operational. He then posed to the students the question of fuel: what do the bacteria consume? Students figured out that sugar might be a good thing to add to the mud. After adding sugar to one of the dirt batteries, the LED indicator began blinking much faster than the rest.

This prior observation about the blinking LED leads inductively to the question: where does the electricity originate? The answer for AP biology students would be obvious- the cell's electron transport system. But this concept is well beyond existing 9th and 10th graders. However, we don't stop the learning because the material is not grade-appropriate. The key concept in biological systems of this sort is the effect of temperature on reaction rate. Analysis of the Arrhenius equation can provide the classic treatment but is taught in upper division classes. For course 1 and 2 students, this relationship can be shown graphically or using a JIT lecture. Observationally, the students can deduce that an increase in the temperature should result in a faster reaction rate.

In the dirt battery example, students learned that rate of electron transport can be visualized with the blinking LED. The faster the LED switches on and off, the faster the rate of electron flow in the biological system. In one high school, first year students put the dirt battery in a student-built temperature controlled water bath (crock pot plus low cost computer controlled power switch) and then began to log the number of "blinks" at a steadily increasing temperature. Sure enough, a graphical relationship between temperature and reaction rate emerged that supported the prediction from the Arrhenius equation.

Finally, a key facet in the design of a project is the use of student engagement scenario at the beginning of the project. To get the students to engage quickly, we've used a combination of real job and environmental problems. In some projects, we introduce the students to startup companies as examples of what can be done in this field. Entrepreneurship coupled with science-based project learning is proving to be an effective way to gain student interest. In other projects, we may put the student in the role of a technician that has been asked to solve an ongoing business or technical problem. In others, students are entering a regional or national entrepreneurship competition such as the Department of Energy's Solar Decathalon.

V. SUMMARY

Overall, the AC program is employing many cutting edge concepts to drive science literacy and attract more students into STEM disciplines. The program does leverage many of the competencies and infrastructure developed for PLTW but takes a very different approach toward learning. The support of industry partners, local business, content experts, and compelling projects enable the teachers to take the role guide and advisor and allow more student-driven learning.

As of this writing (June, 2013), the Advanced Careers program is in the roll-out stage. A number of states have begun fielding their curriculum at select schools. Data collection and detailed observations about the program are currently limited to feedback from teachers and a small cohort of students. However, both AC and PLTW share a common pedagogy- project and problem based learning. Much of the PLTW infrastructure is being leveraged to launch the AC program. The implementations between the two programs within the projects are very different but the previous experiences of PLTW may hint at the challenges ahead for AC.

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Computer Science Widening the STEM Education Spectrum

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Abstract— **Science, Technology, Engineering and Mathematics (STEM) education is slowly becoming an important part of American culture. STEM educators try to promote 'hands on' science, where students can actually interact with and see the results of their work. Unfortunately, not all paths of education for STEM related fields can have exciting, interactive teaching methods. At the Millard Oakley STEM Center, we have taken advantage of the interactive experience in our planetarium show. In this paper, we take an in-depth look at the Definiti Theater System and the software that runs it, Digital Sky 2. This software package is created by Sky-Skan and is considered to be the standard for many new planetariums across the country and beyond. We take the software in new directions by building new elements through the Sky-Skan scripting engine and by also exploring its 3D engine for creating a novel experience. The primary purpose of this paper is to provide a roadmap of observations and enhancements for other educators that wish to improve the learning experience of students and visitors to their planetarium.**

Keywords—STEM, education, planetarium, Digital Sky 2, 3D

I. INTRODUCTION

The goal of STEM education centers is to engage students of all ages enough so that they will find an interest in a STEM career path. The scientists, engineers, and mathematicians of tomorrow are hidden among the children of today. Any moment of a child's life could be that special moment that shapes who they will become. To try to capture the minds and interests of students, STEM programs employ a hands-on technique to their offered programs [1]. This approach sets a STEM program apart from other programs. Instead of students simply learning about the laws of physics, they will learn about them as well as build a rocket with which they experience physics in action. They can then compare and talk about their results, and what they observed and experienced.

It is in this area where programs like astronomy shows tend to fail. As the very name implies, it is a "show". Regardless of how knowledgeable or enthusiastic the program host may deliver the show, it is still the same material. When a student experiences the show, they know their peers will see the exact same thing, outside of the differing questions other students may pose. Few students will talk about their experiences in an astronomy theater with their peers because they all have the exact same experience.

In our previous shows, we used minimal 3D assets and relied heavily upon the speaker to convey what various dots and circles and lines on the screen meant. In shows that did feature 3D models, none of the models were original or custom built to showcase that particular show. The shows were built only around what was pre-existing within the system, and limited the creativity of the developers. Also because a show was 'a show', the thought never occurred to the developers to allow the on-screen action to be directed by the students.

To better achieve the expected STEM experience from our existing astronomy program, a redesign of the previous creation methods was necessary. What we desired was a new program that could support the hands-on approach to learning through a virtual experience. Ideally, the program could involve numerous choices, each with different events and moments. In order to harness their interest and spark conversation outside of the show between students, events needed to be different and interesting – or at least different enough that each student could have his or her own story. Key events would tie back together, so the goal of the educational material would still be achieved, but additional material would be different from student to student.

This paper will discuss the topics associated with not only the discovery process and the angling of the concepts of a new interactive astronomy program, but also delve into the details of the program itself. The topics will include methods of setting up interactive features using Sky-Skan's Definiti planetarium software, Digital Sky 2, to achieve a fully interactive environment [2]. Pitfalls, workarounds, and tips encountered by our team will be discussed at each step. While much of the paper will be covering the Digital Sky 2 software, the basic concepts used can cover a wide variety of software where an educator may be having a difficult time building interactive features for their students. The goal of this paper is to provide a roadmap for transforming a non-interactive presentation into something that will not only further STEM objectives, but also will capture the attention of students.

II. RELATED WORK

For our approach to be useful to others, we researched a myriad of ways to implement the necessary interactive features. However, up until now, little work has been done in this area. We were able to discover some of the simpler features through work by others by reading the private forums associated with Digital Sky 2 purchasers. To the best of our

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knowledge, more complex functionality such as asset creation and implementation has never been fully explained or well documented.

Planetarium web pages across the United States prove they follow a standard approach to their astronomy centers. They tend to feature a scripted planetarium segment and a non-interactive, pre-recorded movie. Generally the show's commentary is prerecorded, occasionally by a person of note within the science community or an author. Any interactive features available by the system are either unused, or used in such a way that there is no dedicated show built specifically around those capabilities.

One such example of this is The Morehead Planetarium and Science Center at the University of North Carolina at Chapel Hill [3]. The shows look spectacular, but the experience is the same for everybody. Since there is limited or no interaction with the audience, the experience is an educational movie.

While most planetariums follow the route of the non-interactive feature, the Lawrence Hall of Science's planetarium at the University of California, Berkeley does provide an interactive experience [4]. They also use the Digital Sky 2 software – the same software that we use at the Millard Oakley STEM Center. In this case, the show is hosted by a real person and the host can answer questions posed to them and direct the screen to whatever object a person may want to see. This type of feature is fully within the operational boundaries of the Digital Sky 2 software, but it still does not fully realize the goals presented in this paper.

In short, to the best of our knowledge, what we are presenting in this paper is novel. For most planetariums the word interactive describes a show run by a live commentator. The commentator controls the system in a pre-existing way, such as to view a certain object. The commentator has control of the *navigation mode* already built into their software. This method is useful, but it will not grab the imagination of an audience and pull them into a different world where they are in the driver's seat. In fact, this interactive method is traditionally how we have used the software in the past. This level of interaction lacks the excitement of what we are aiming to do with our interactive story approach to education. We believe that the Digital Sky 2 software has a great deal of 'interactive potential'. So, our goal is to capture the essence of what 'interaction' means in an educational setting, and refocus it into something that will grab students' attention by literally pulling them into the story.

Through a system such as Digital Sky 2, we have the capability to create a lasting, educational experience. However, the capability to do that is not simply inherent within the software in and of itself. There are certain techniques, which when applied, have helped to move our presentations to another level of excitement, where the student can literally take part in an adventure driven by education.

In other words, our goal is to not just show a movie. We want to surprise the audience with a story where *they* are the author of something exciting. The following is our proposed approach to implementing a truly interactive planetarium show, with detailed steps and examples that will allow other practitioners to do the same.

III. Proposed Solution

A. Storyboard / Event Flowchart

Before beginning to build a show, it is important to answer the following questions: What do you plan to teach? What do you plan to talk about? What do you want to start with and what do you want to end with? Even for practitioners who are not using the Digital Sky 2 software package, this step is critical to any feature event, whether it is interactive or non-interactive. It is easy to skip this step and dive directly into building a vision, but this haphazard approach will often result in a confused, incoherent project. To get around future difficulties, it is good practice to create a *storyboard* at the beginning of development. A storyboard is not a new concept, and is something many people familiar with the entertainment industry will recognize [5].

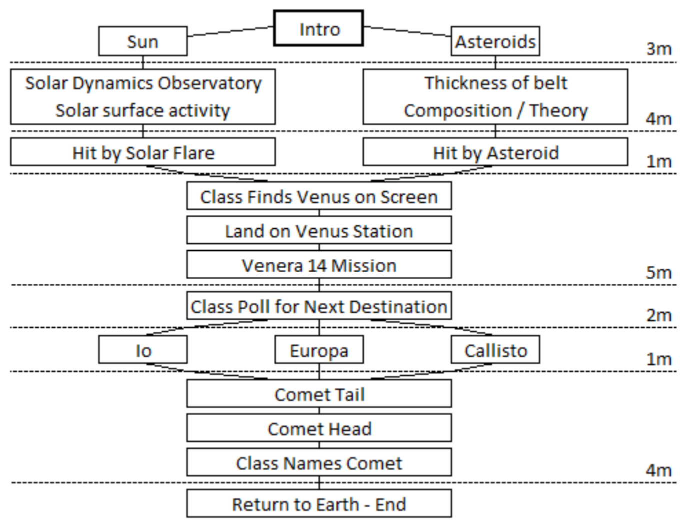

Figure 1: Example Storyboard Flowchart

To implement one's strategy, one must storyboard ideas using a medium that is easy for all to view and edit freely. For our purposes, we storyboard our ideas on large white boards. Ideas undergo numerous changes until brain storming is finished. Our initial storyboard consists of a flowchart of topics we want to cover, and the amount of time we want to take talking about each topic. Lines connect the different branches the feature will take (Figure 1).

Since our feature will have key topics we want to cover, we use a 'diverge and converge' system. Each major topic will be talked about, followed by an ancillary topic the students would choose as a next destination. Those destinations would ultimately return to our main topic again. This initial flowchart storyboard not only gives us a way to 'see' how the show will play out, but it also gives us rough estimates for timing. These estimates can be taken into action for writing the speaking portions of the show.

Additional work with a storyboard may be necessary to achieve the desired look and feel. It may be necessary to draw out individual scenes, complete with timing for smaller events, including the timing for audience participation. For each individual event in the flowchart, we follow the standard method of storyboarding. We draw comic book-like panels of pictures describing what occurs. This helps us further recognize assets we need to create, as well as what we would say and when.

With the storyboard visible to the development team, all creative thoughts and ideas are never lost. Since a 20-minute show may take a year to develop, preserving ideas for later implementation is a critical key to success. The storyboard also provides a convenient metric to measure the completion percentage of the overall presentation.

B. Understanding the Model & Brief History

Creating models is necessary for custom content, and understanding the format of the model file is necessary to create professional looking models. Digital Sky 2 uses DirectX models in the .x format [6]. This is an older and depreciated format, and to the best of our knowledge no fully compatible Digital Sky 2 model exporter exists. For certain features, such as applying *shaders*, additional model editing must be done.

We initially used Blender to export our models to the DirectX format [7]. In our version of Blender, we enabled the ability to export to the DirectX format through the *Add-ons* menu. However, we discovered some issues exporting certain materials, and creating animations was difficult as well. This led us to look for alternatives.

What we use now is Autodesk 3D Studio Max 2012 [8]. Autodesk 3D Studio Max is very expensive to buy, but for students it is free to use. Although we are not able to build DirectX *shaders* compatible with the Digital Sky 2 software using the *shader* creation tools within 3D Studio Max, we are able to resolve animation issues and ease of exportation. Sky Skan also uses 3D Studio Max to create their content, which further justifies our selection of this software. However, between the version Sky Skan uses and the current version of 3D Studio Max, the ability to natively export to DirectX models has been removed.

Therefore, since we did not want to lose the great modeling and animation features present in the newer versions of 3D Studio Max, we had to locate a third party exporter. After a lot of failed attempts, we found Pandasoft's DirectX Exporter [9]. This exporter covers all of the bases, including animation, and even allows for direct export of models with a basic texture map material without the need to edit the .x file.

Digital Sky 2 can be very picky if certain modeling actions are taken. If an object is not modified at the *sub-object level*, it may be deformed in the Digital Sky 2 environment. Translating, scaling, and rotations of objects performed outside of a *sub-level* of editing can all lead to these deformation issues, even if the model looks normal inside the modeling program.

The Digital Sky 2 environment can also support models with a very large file size. The International Space Station model which comes with Digital Sky 2 is a very detailed, large model. The model can be displayed on the screen with no performance loss.

However, it is also important to know that when working with large file sizes, the development team will need to plan ahead on how to load these assets, since it will take time for a larger model to load than a conservatively smaller sized model. If there are also large textures associated with the model, this will also have an impact on file loading times.

C. Landscapes, Flat Surfaces, & Billboards

One of our major goals with the project was to create land-based scenery and events. This was a challenge due to the high field of view of our system. Flat objects were distorted to look curved. This resulted in a fisheye appearance to all of our content, and while it was acceptable for space scenes, it ruined landscapes and anything else we wanted to look 'flat'. Digital Sky 2 is set with a *field of view* associated with the connected display, and for us this editable value is set at around 170 degrees. However, it is a system-wide setting, and cannot be set on a per-scene basis. This led us to the conclusion that adjusting this setting will harm all our previously created shows, and was not an option.

Our billboard graphics, which are .JPG or .GIF images put directly onto the screen, also suffered from the fisheye problem. The further towards the top of the screen we put an image, the more distorted it was. We noted, that if we set a billboard low at the horizon, which was the bottom of the screen, it was flat, albeit cut off by the screen itself.

We discovered ideal ways to combat this distortion. The ideal display to use for billboards is *panoramic*. To shift a billboard upwards on the screen without distortion requires two values on two different lines to be changed. On the billboard setup line, the *Y-Offset* has to be an increasing positive value, and the display line has to keep the *elevation/declination* setting to a value close to zero (Figure 2).

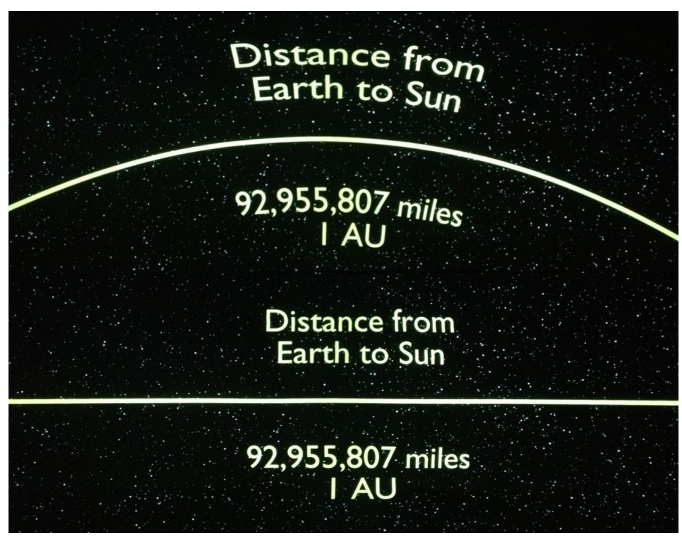

Figure 2: Top – No Y-Offset; Bottom – Y-Offset Used

Each billboard has different settings, since the size of the associated image is different. The *Y-Offset* has a maximum value it works at, so juggling between it and the *elevation/declination* value is required for an optimum image. Discovering that images placed along the horizon have very little bending to them helps to pave the way for landscape creation. If one creates a landscape by placing it at the base of the screen and pointing the camera 'skywards', the landscape will remain flat along the bottom of the screen.

Unfortunately this technique does not meet expectations when we want the camera to look at the landscape itself. When rotating the camera 'side to side', the fisheye effect is not very obvious. However, when rotating the camera 'up and down' the effect is dizzyingly prevalent. Due to the *field of view* setting, the screen is viewing an entire hemisphere.

Once one fully understands how the camera acts because of the field of view, one can come up with strategies to get around it in their models. What we discovered to work best was to create the scene we wanted, and then bend and distort it afterwards. By bending and extending the edges of the model to curve inwards, the camera will not be able to see the end of the landscape. It is also important to bend the model around where camera is to be located.

To build a good centerpiece terrain, it should be modeled from 'strips' of terrain, then overlapped them from the camera's point of view. This gives a good effect for distance. These strips should taper larger towards the edges to prevent them from appearing to shrink as they near the edges of the fisheye camera (Figure 3). This technique provides for excellent panoramic scenes.

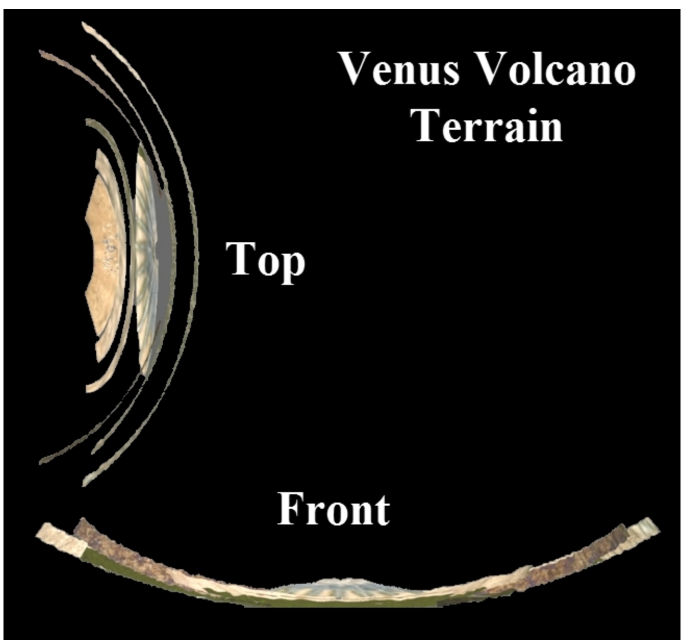

Figure 3: Terrain Bending for Camera Compensation

When building a scene it is important to know how the camera will act and what it will show to the audience. The design of the model will need to be based entirely how it is seen by the camera. Once a scene has camera compensation bending applied to it, going back and making changes can be difficult, and even impossible for complex scenes.

D. Scene Animation

Digital Sky 2 allows for at least two types of animations: *bone-based* animations and the more standard *rotation and translation* animations. Bones animation involves the object being rigged with bones to animate it, and allows for more realistic animation [10]. The rotation and translation type animation allows for full objects to be rotated and translated, and may be useful for solid objects moving from one location to another location. Animations are built by setting *keyframes* for actions, which are fully implemented by Digital Sky 2.

For most complex animations, separating a static background model from an animated model is very challenging using Digital Sky 2 due to its own system complications. The primary reason to have two or more separate models in an animation is due to how the *shader* system works in Digital Sky 2. If a model is animated using bones with a basic bitmap applied to it, the bones will animate as expected. If that same model has a *shader* applied to it, the model will 'break apart' at the polygon level as the bones animate. This means that instead of having the polygons bend and shift to accommodate the movement of the bones, they are instead static and unable to shift, causing the model to literally rip apart at the seams as it animates. What this results in is static models that can have nice looking *shaders*, but any animated model must use only standard bitmaps. Being able to mix an animated, bitmap-only model over a nicely *shader*-enabled static model would be useful, however, actually getting this to work proved to be more of a challenge than we could afford given our time limit for the project. Mixing static and animated models together is possible, but it takes a considerable amount of work, and any changes to the animation or static scene has adverse effects on the Digital Sky 2 settings and positions of the models.

For optimum control over a fully animated scene, it is best to keep the animating objects in the same model as their background. All of the scene objects must also be connected together as a single object, or there may be unexpected results. With a single large object, the only way to animate it is by using the bones system. Surmounting object interaction and positioning is difficult, and using this technique for precision will save countless hours for different animations.

It is important to keep in mind that Digital Sky 2 mirrors everything when it loads it into its environment - just like models. So an animation of something going left will go right inside the Digital Sky 2 environment. This can be circumvented by mirroring the scene prior to exporting.

E. Applying Bitmaps and Shaders

Creating a quality model is a two-part event. First, a detailed model must be developed, and second, good bitmaps and shaders must be applied to it. Digital Sky 2 allows these features with shader support available for non-bones animated objects. Getting a basic bitmap on an object requires nothing more than exporting the bitmapped model with the Pandasoft exporter. Applying a shader to the model requires significantly more work.

To apply a shader to a model, first one must export the model as normal using the exporter software, like Pandasoft. The shader file itself will need to be created separately. Shader files have a .fx extension, and pre-existing .fx files can be found within Digital Sky 2 to use as a starting point [11]. Digital Sky 2 supports many types of *shaders* that are not normally available within the default .fx files, such as self-illumination. These shader additions can be built into custom .fx files if necessary for a particular model.

With either a custom shader or a pre-built shader from another Digital Sky 2 file, one must then connect the shader with the model. This requires editing the .x model file. To best understand how this works, one can investigate the *Shuttle.x* and *StandardFX_ds2.fx* files which come with Digital Sky 2. *StandardFX_ds2.fx* by itself can handle *normal* mapping, *specular* mapping, and *diffuse* mapping techniques.

To apply the .fx file to the model, open the .x file in an editor and search for *MeshTextureCoords*, locate the texture method above that block. If this is a fresh export using the Pandasoft exporter, there will only be the bitmap pointing to an image file. In order to get the *StandardFX_ds2.fx* shader applied within model, replace the entire bitmap block with the contents of the block in the same location as shown in the *Shuttle.x* file. To use custom bitmaps, change the file names pointed to in the *Shuttle.x* block.

If the model is using multiple objects inside of a single file, each object will need to have the bitmap block replaced with the associated shader block. This can become time consuming, but it is possible and it will allow for different objects within a scene to use different shaders. Good usages for multiple objects in a single file would be for such things as a space station and a space ship docked together. Instead of trying to wrestle with the Digital Sky 2 environment for precision, simply merge the two objects into a single file and position them as a single model.

Another important note concerning mapping and Digital Sky 2 is that any model will be mirrored once it is inside the environment. This means that readable text inside the modeling program will be backwards inside of the Digital Sky 2 environment. This issue can be circumvented by mirroring the model prior to exporting.

Figure 3: Self-Illumination Shader Bitmap

We discovered that many 3D-engine specific shader functions work with the Digital Sky 2 engine, such as self-illumination. Self-illumination bitmaps need to have the diffuse bitmap edited to where the light is shining and black where there is no light (Figure 3).

The shader system used by Digital Sky 2 does not provide any documentation. However, we have observed that shader equipped models can be built to the level of current generation graphical expectations. Many of the same concepts used by high profile video game models can be employed within the Digital Sky 2 environment as well [12].

F. Large Project Development

Larger projects have their own development dynamics. Since Digital Sky 2 does not feature any way to speed up or slow down the speed of a show, a developer must sit through the entire segment before they can see the effect of their changes. This issue takes center stage as sound components are added to a presentation.

One way to combat this issue involves creating event-specific buttons on the control program. If a single button controls an exceptionally long segment, one can break that segment up into two or more buttons. Good split locations are most often camera change events. If one copies the last camera change made into the top of the new event button with a time value of zero, the camera will start at the end of the previous segment.

By using this technique, it has cut our own development time considerably. When we add sounds or make small changes to the movement of the camera or an object, we no longer need to wait for 20 minutes before we see the impact of that change. In other words, once editing is complete, one can cut and paste the fragment back into the original button event, and remove the camera position line.

When we develop large segments, we develop them as small partitions from the outset. Once all of the partitions are complete without error, we transfer them to a final button as a single event.

An important element to keep in mind when using this design method is locality. For example if segment 12 is being edited and requires elements from segment 2 to exist, there may be complications due to these missing elements. Ensure that all of the resources a segment requires have been loaded and are in their proper positions for that segment's time frame.

G. *Loading Time and Memory Management*

As a show is running, one hopes that the audience will become immersed in the newly created world. Suddenly, the picture stutters, and the audience is jolted back into reality. Or even worse, one of the computers crashes, and suddenly the audience is watching a Windows desktop. These issues arise from asset loading and poor memory management. For large, ambitious projects featuring considerable custom content, loading times and memory management become a problematic hurdle to overcome.

Currently in Digital Sky 2, when an asset loads, it is loaded in the background. This loading can be almost seamless for small billboard images or sound bites. However, when the system needs to prepare for a scene shift, and a large number of assets are loading, this a noticeable on-screen hiccup. This problem can also occur for a small model if it happens to use *shader*s, since it may have four or more large bitmaps to load before it can be displayed. Hiccups can also occur when loading a large video file for playback. In fact, any large file has the potential to impact the quality of the on-screen frame rate.

One of the best techniques to combat this behavior is to load assets when the camera is stationary. The frame rate will still be impacted, but because the camera is not actually moving the loss of frames will not be noticed. Using a fade to black type transition also makes use of this technique. A fade to black also looks more professional than simply switching from one scene to another instantly.

The least effective method to utilize is to gradually load assets. For instance, in the feature's code, one can add *keyframes* between camera positions which do nothing but load assets. In this case, loading assets one at a time over a period of time may not result in a noticeable frame rate impact. For example, if a camera moves over a 20-second period, adding additional *keyframes* at 3 second intervals will not affect the movement of the camera or how long it takes to move. However, one should also make sure that the final load takes place before the initial 20 second camera movement has completed.

Digital Sky 2 has no automatic memory management features. This means that for every asset loaded, it must be unloaded or it will continue to take up memory until the system is reset or crashes. When a crash takes place, one of the computers usually will shut down Digital Sky 2 and return to the desktop. This problem may arise when playing many concurrent shows, since one of those shows may have a memory leak. A general good rule of thumb is to hit the reset button between shows to prevent any unexpected behavior.

To combat this problem and keep a show running smoothly, assets should be unloaded when they are no longer used. If an asset is used more than once for different scenes, hiding it may be more useful than unloading and reloading it.

At the completion of a show make sure all assets are completely unloaded. Breaking a large feature into segments will make memory management easier to handle, since loading and unloading can take place on a segment-by-segment basis.

H. *Building an Interactive Presentation*

The interactive feature is the reason why we began working on this project. Surprisingly, it is simple to accomplish with Digital Sky 2. Not only are the event buttons useful for creating a single large feature, but they can also be used to control an interactive show.

The buttons can mirror what the storyboard overview depicts. Each button can control that particular segment from the storyboard. The show's presenter will then be able to easily follow the flow of the show from one button to the next.

Helper buttons may also be implemented. We use helper buttons for naming the spacecraft of our show to what the students chose. This involves us needing to edit that button during the show, which contains the code to give a name to an object already loaded on the screen, and then activate that button. The students enjoy seeing that they could really interact with and change what was visually on screen. Being able to give key objects custom names helps to keep the show personal and individualized.

IV. Conclusions

The ending product for our project was very close to our vision for graphical fidelity. Using the techniques we learned, we were able to use Digital Sky 2 to seemingly bring people not only to the far reaches of space, but also to the surface of Venus and Callisto. We were able to create branching events and tie it all together to create a new kind planetarium presentation. Our success was the approval of teachers as well as the interest of the students. Our premier show aired all day long to nearly 300 people, and the show has been added to the regular schedule for schools visits. Using the tools and techniques described in this paper, we have successfully brought student interest into an area that previously had very little interaction.

Measuring the success of a public show, where no grades or surveys are involved, can be a difficult task. However, most educators can recognize the difference between students that are truly interested versus those that are "just attending". Following the premier and consequent presentations of our pilot interactive feature, we observed more inquisitive students than we had previously. There was also more of a buzz about their experiences during lunches, and more activity between "project zones". When the general target audience is middle school children, data gathering can be anything but simple and often inconclusive. We are therefore left to our own observations of the students' reactions, such as smiles and eagerness.

If nothing else, we hope that our own success and direction provided in this paper will help other educators create an exciting educational environment. Even if one is using something other than Digital Sky 2, this paper still holds valuable resources for an educator to outline and create a larger production. It is not easy, but capturing the minds and sparking the curiosity of students and adults alike is a reward only measurable by our future society.

V. FUTURE WORK

With the success of our project, the Millard Oakley STEM Center on the Tennessee Tech University campus is actively looking to continue to create new interactive content. We know there is more tweaking and tricks that can be utilized by the Digital Sky 2 system. For instance, one of the tricks we have been thinking about has been a way to employ a Java program to cause 'on the fly' edits to a script in the Digital Sky 2 system. This can allow for students to interact with the system via a computer set up in the room for them, and it would remove the necessity for an operator to script in whatever custom event a student would build. One of the tweaking techniques we are currently looking into is the reason behind a model breaking during bones-based animation if it has a shader applied to it as opposed to a regular bitmap. We are investigating the impact that other files within the system may be having on this issue. We are also still investigating the unknown object physics that can cause two models to 'collide' with each other and move each other out of position. This appears to happen at random, and as of the writing of this paper, we have been unable to determine how to compensate for this behavior by the system. We are hoping to investigate this problem further and discover a workable solution.

VI. ACKNOWLEDGEMENTS

This project could also have not been possible without Marc Robinson, who was the co-creator of the presentation from conception to giving the show to students. This project would also not have been possible without Dr. Sally Pardue, who has incredible dedication to STEM activities and is always looking for ways to improve student learning and experiences.

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Broadened Perceptions of Engineering in Tenth Grade Students Through a Biowall Design Project

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***Abstract*— Vertical garden and green wall structures have been introduced to the K-12 environment as vehicles for learning as part of a larger green construction trend. This paper considers the design and construction of a biowall as a case study for green engineering design projects in the K-12 setting. The research, conducted in participation with 123 10th-grade public school students, investigates further learning opportunities posed by a biowall design-build project. We claim that the highly visible plant component of the wall makes the project more accessible to students that would have been immediately averse to a "rigid" engineering project, allowing for increased perceptions of competency in engineering through willing practice. Further, we claim that the large-group organizational structure of the project, with students working in multiple specialist sub-groups to complete a larger project, increases students' perceptions that good communication skills are required in engineering. This article provides methods employed and qualitative and quantitative results.**

Keywords— problem-based learning; active learning; K-12 education; engineering design; green case study; green construction; biowall; vertical garden; green wall; living wall;

I. Introduction

In recent years, the US has seen an increasing number of sustainable, or "green," construction projects [1]. A recurring feature in such projects is the "green wall," "vertical garden," or "biowall," a vertical structure supporting plants for aesthetic value, small-scale food production, or indoor air quality improvement, respectively [2][3][4]. This trend has made its way into the K-12 environment in the form of green walls constructed by independent contractors (Sanchez Middle School, San Fransicso, CA and Drew School, San Fransisco, CA) and kits for students to create vertical gardens (Wooly Pocket Wooly School Garden initiative and Green Bronx Machine edible walls) [5][6][7][8]. Such projects are meant to supplement student learning in biology, chemistry, and environmental science but lack the student-driven design component that could, simultaneously, cultivate an understanding of engineering practice.

The green engineering design case study discussed in this paper was conducted with 10th grade biology/chemistry classes at Science Leadership Academy (SLA), Philadelphia, PA. The school, a partnership between the School District of Philadelphia and the Franklin Institute, is described as an "inquiry-driven, project-based school" where "core values of inquiry, research, collaboration, presentation, and reflection are emphasized in all classes" [9]. The project was developed, collaboratively, by two Graduate Fellows from the Drexel University NSF STEM Fellows in K-12 Education Program ("GK12 Fellows") and SLA's two 10th grade teachers ("Teachers") as a culmination of earlier engineering design projects meant to supplement the course goals and increase students' understanding of engineering. The general engineering education goals that were used to inform the choice of the project content were:

(a) increase students' perceptions of their competency in engineering through practice,
(b) emphasize the importance of communication skills in engineering, and
(c) illustrate the interdisciplinary and collaborative nature of large engineering projects.

We hypothesized that the biowall design-build project would help further these goals through (1) its specific content and (2) the organizational framework required to complete it.

Existing work shows general support for cooperative, problem-based learning as an effective method for achieving positive increases in student perceptions and attitudes [10] [11]. Green engineering has been acknowledged as a highly interdisciplinary practice, though disciplinary egocentrism has been observed as a barrier to understanding the complex contributions to interdisciplinary problems at the undergraduate level [12][13]. We choose to proceed with this in mind, leaving an open question as to whether early high school students would exhibit the same discipline-specific mindset as university students.

Biowall design was chosen as the content for the project over other greening topics, such as energy or resource use, because the most visible features of a biowall are the growth, maintenance, and display of plants, tasks not generally associated with engineering [14]. We believed that this overt biology-based subject matter would support the curriculum and encourage the participation of students that may not be as interested in engineering. For example − and without attempting to explain any cause here − women and underrepresented minorities' participation in biosciences and biomedical engineering is greater, in the US, than their

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participation in engineering-at-large [15]. More practical reasons for the choice, over a project such as green roofing, include the ease of execution in the classroom and the structural design element. Additionally, the proximity of Drexel University's biowall at the Papadakis Integrated Science Building and other local projects provide good motivating examples [16].

It is commonly accepted that engineers are viewed as lacking in interpersonal skills, though communication and collaboration are integral to the discipline [17]. The organizational structure of the project was designed to address these stereotypes, as well as demonstrate that engineering may be interdisciplinary. Students were organized into large groups, of approximately 16 students, to design and construct a single biowall panel. Each large group is separated into specialist sub-groups focusing on watering systems; lighting systems; supporting structure; and plant selection, growth, and maintenance. The GK12 Fellows and one classroom Teacher, per class, provided only loose guidance for the project, leaving many decisions to the project groups and forced them to create networks for coordination among the large number of students and specialist groups.

In this paper we describe the implementation of the project over a three-month period, providing the loose project structure and the general practice employed by the GK12 Fellows and Teachers in the day-to-day administration of the project. We provide representative data from student surveys administered before and after the project and discuss the results as they relate to the three goals given above. We found that, over the course of the project, students' perceptions of their potential to become engineers increased at a statistically significant level. Students' perceptions that engineering requires good communication skills also increased. No significant increase was observed in perceptions of engineering as an interdisciplinary practice, though initial responses tended to be in high agreement with such statements. Roughly four of the eight walls were seen to completion, integrating most-to-all required systems.

II. Background

The biowall engineering design-build project ("biowall project") was run with all of the SLA's 10^{th} grade joint biology/chemistry courses. This consisted of 123 students across four separate classes. A single SLA Teacher taught two of the four courses each, for a total of two SLA Teachers. As a public magnet school, the demographic breakdown tends to reflect that of the city of Philadelphia. The project class's self-reported demographic breakdown can be seen in Table 1.

Two Drexel University PhD candidates in engineering worked with all project classes over the 2011-2012 school year as part of the Drexel University STEM GK-12 Program: "Catalyzing STEM Education via the NAE Engineering Grand Challenges" [18]. As part of this program, the GK12 Fellows collaborated with the two classroom Teachers to develop lessons, activities, and projects centered around the NAE Engineering Grand Challenges in order to supplement course curriculum and increase students' understanding of the engineering discipline. The biowall project began in late-January, so the students were familiar with the GK12 Fellows from previous projects meant to incrementally introduce them to the engineering design process.

TABLE I. SELF-REPORTED DEMOGRAPHICS OF STUDENT PARTICIPANTS

Race	Percent[a]	Gender	Percent
Black	37.1	Male	50.8
White	30.8	Female	49.2
Asian	7.5		
Other	24.5		
Hispanic or Latino[b]	14.3		

a. Percentages may not sum to 100 because students may have identified with multiple groups.

b. "Do you consider yourself to be Hispanic/Latino?" was a separate question from race.

The biowall was intended to be a culmination of the classes' study of engineering practice. The GK12 Fellows and SLA Teachers collaboratively generated the general structure, goals, and assessment surveys for the biowall project in the weeks before intoducing the project. A form completed durring the planning process to explain curricular goals, in Understanding by Design format [19], can be found at [20]. Later corrections or deviations from the original structure were made during weekly planning meetings to address problems, teaching opportunities, and time constraints. The project structure presented in this paper reflects these changes.

III. Implementation

The biowall project took place over 14-week period, beginning late January 2012. Each of the four classes spent one one-hour class period per week on the project, though they were occasionally given an additional class period to work when nearing deadlines. The project consisted of a background research and design phase (four weeks); a construction phase (five weeks); and a documentation and reflection phase (two weeks), with field trips and visits by specialists taking place intermittently.

As motivation, the students were taken on a short field trip to see the biowall at Drexel University Papadakis Integrated Sciences Building before beginning the project. This 22-foot by 80-foot biowall is a research platform created to study the effects of root-based microbial communities on indoor air quality, specifically the removal of volatile organic compounds [21]. The students heard from and asked questions of a faculty member from Drexel Civil, Architectural, and Environmental Engineering involved with research on the biowall. The students were given some time to examine the biowall from several floors and were, by all appearances, excited about the trip and the upcoming project.

To begin the project, each class was split into two "project groups" of approximately 16 students that would be responsible for designing and constructing their own biowall panel, for a total of eight project groups across the four classes. Within each project group were four "specialist groups" that would work together on a specific aspect of the biowall: the structural system ("structure group"); watering and nutrition system ("water group"); lighting system ("lighting group"); or plant selection, growth, and maintenance ("plant group"). Classes were originally divided into specialist groups through a "Four Corners"-style game, where students indicated what subject matter they were most interested in by going to a corner of the room, following other questions about their life and interests. This provided a method for the students to, somewhat unknowingly, chose what specialty they were going to work on. After one period of researching the considerations for their specialist tasks, each class-wide specialist group was halved and grouped with others to create the project groups.

The general problem posed to the project groups was to create a self-sustaining biowall panel that serves some function beyond its aesthetic value. Further, it was stated that the panels should be suitable for public display in a to-be-determined location and have dimensions of approximately 4' x 6' in the vertical plane. The specialist group responsibilities follow, with sample considerations that were posed to the groups, either formally or through discussion with the Teachers/Fellows:

Structure group: Design and build a free-standing or wall-mounted structure that can support living plants and the required watering and lighting systems for those plants.

Sample considerations: *What are the benefits and drawbacks of various materials? Are there any options that would be low-cost or recycled? How much weight should the wall be able to support? What can we learn from existing biowall or vertical garden structures?*

Water group: Design and incorporate a watering system into the biowall structure that can provide the appropriate amount of water and nutrition to the wall's plants. This system should require little human maintenance beyond infrequent refilling.

Sample considerations: *Will you circulate water or will the system only be driven by gravity? What nutrients will your plants require, and how will these be supplied? How will you manage water flow rates to supply the appropriate amount of water to the plants?*

Lighting group: Design and incorporate a lighting system that will provide the appropriate amount of light for plant growth.

Sample considerations: *How does photosynthesis work? What wavelengths of light are most useful to plants, and will specialty lighting be required to provide this most effectively? Is it important to turn the lights off for some amount of time? If so, how will this be controlled?*

Plant group: Chose plants, appropriate for indoor conditions, to incorporate into the biowall that will perform some task beyond providing aesthetic value. Care for the plants before including them on the wall, and monitor their condition after they have been incorporated.

Sample considerations: *What are the relevant biological mechanisms that will allow your plants to perform the chosen task? What are the lighting and nutrition requirements for the chosen plants, and what do other specialist groups need to know so that the completed wall can sustain the plants?*

General classroom practice for the Teachers and GK12 Fellows was typical of a problem-based learning environment [22]. The SLA Teachers are well versed in the pedagogy, and the fellows attempted to follow and learn from the teachers' leads over the course of this and previous projects. During these classes, students were given freedom to use the time as they thought appropriate, and teachers and fellows would move through the classroom to assist students and keep them on task. We attempted to guide students towards appropriate solutions by asking questions, rather than make explicit suggestions.

Students worked on the biowall project for one hour each week, and this was commonly called "engineering day." The GK12 fellows were commonly referred to as "the engineers." Where, other days of the week, the teacher referred to the students as "scientists," a point was made to call the students "engineers" on the days in which they worked on the project. This was an attempt to have the students identify as engineers and, possibly, increase their perception that they had the potential to become an engineer.

In the design phase, students were asked to research information relevant to their specialist topic in order to inform their design decisions, with Teachers and Fellows providing prompts similar to those above given. The majority of research was performed using the Internet. Project groups were given three weeks, from the start of the in-class portion, to document an overall design, through descriptive diagrams, and provide requested material lists, including estimated costs. They were given a $100 budget and were encouraged to use found or recycled materials in order to afford costly, but essential, items. It was suggested that, rather than working as a 16-person committee, specialist groups nominate a representative to confer with those from other specialist groups in order to make large-scale decisions.

As a deadline to complete designs and opportunity provide feedback to the students, we arranged for an expert from the Pennsylvania Horticulture Society (PHS) to visit during class time. Each project group was given half of the class to explain their biowall design, receive and discuss feedback, and ask questions. These discussions centered on the choice of plants for the given biowall function and what the groups might not have thought about, in terms of supporting the plants.

Over the two-week period of expert visits, the students were also taken on a walking field trip to the Grumman Greenhouse. This sculptural greenhouse, on the campus of the Pennsylvania Academy of the Fine Arts, is in the shape of a crashed Grumman Tracker II Naval airplane and houses nutritive and medicinal plants within the cockpit area [23]. After viewing the greenhouse, the students were asked to discuss considerations important to displaying a piece of work in public and question why certain elements had been included: for plant care or artistic intent?

Project groups moved on to the construction phase after making refinements to their proposed design, having it approved by the Teacher and GK12 fellows, and submitting a list of requested materials. The fellows acquired requested items to the best of their abilities, using some discretion. The Teachers, Fellows, or colleagues brought in tools that were needed. The fellows advised students on specific tool use and safety, often demonstrating use. Over the course of several weeks, the students attempted to assemble biowall systems. Common construction efforts included:

- *building a wood frame with shelves by fastening with screws;*

- *building a frame of PVC piping, fastening with glued joints and screws;*
- *planting plants in plastic bottles or pots to be mounted on a frame;*
- *drilling holes in a plastic basin to stick tubing or allow water to drip through;*
- *assembling tubing and fasteners with an electric pump to pump water to a desired height;*
- *experimenting with different clip lights and bulbs on a test frame.*

Some specific completion requests were made, such as having the wall in a state that plants could be mounted and sustained over spring break, following the third week of construction. The project groups were encouraged to have their walls complete by Week 12, the fifth week of construction, so that some could be displayed as part of the Philadelphia Science Festival. The Teachers and Fellows chose two biowalls to be displayed as part of the festival's Science Carnival on the Benjamin Franklin Parkway.

The project was concluded with a two-week documentation and reflection phase. Most work ceased on the walls and the students were asked to reorganize their project groups into four new sub-groups, each consisting of a student from each specialist group. These "recap groups" were each asked to produce a different product to either explain their project or reflect on challenges, failures, and lessons learned. Ideally, all of these products would exist together on a web page about the project group's biowall. The groups' tasks were as follows:

- **Video presentation**: A short video overview of the features of project group's biowall, addressing why specific design decisions were made.
- **Assembly diagrams**: Step-by-step diagrams that would explain how to reproduce the wall that the group created. It was strongly suggested that these be in a wordless format such as IKEA, Lego, or K'nex instructions.
- **"Fail blog"**: Similar to the namesake's style of photographic documentation, this would be a weblog that shows humorous photos of mistakes that the group made along the way, with short descriptions of what was learned from these mistakes as well.
- **Informational poster**: This poster would act as an explanation to the public of what the biowall was, including some science and explanation of the biowall's function, and refer viewers to the other web content.

The project groups presented this content to their classmates, Teacher, and the GK12 Fellows in the final week of the project. Through the documentation/reflection phase and the few weeks following, several small groups of students continued to work on the biowalls during extra class time or after school. Though attempts to have the biowalls displayed in other, more-public locations fell through, three wall panels were displayed outside the main office of SLA.

Fig. 1. Student with example biowall project. This biowall held soil and plants in individual pockets. Water was pumped, from the basin at the bottom, into drip tubes that ran through each pocket.

IV. Results

A. Quantitative Results

Quantitative results were attained from survey responses collected before and after the biowall project. The questions were self-created by the Teacher/Fellow team in an attempt to evaluate the project's effectiveness in changing students' perceptions of engineering and gauge their opinions about the project. Additional questions were included, out of interest, in attempt to find out how much students believe they had contact with or consciously observed plants in their environment.

Surveys were issued through an online form during the class period, and anonymous tracking numbers were used to pair a single student's end survey with their initial survey. The initial survey included 36 questions, and the end survey included 51 questions. Of the total 123 unique respondents, only the 98 that responded to both surveys are included in the analysis, except in the case of student opinion and open-ended questions only available in the end survey. All prompts where students were asked to indicate their agreement with a statement were given as a 5-point Likert scale, with options: "Strongly Disagree" (1), "Disagree" (2), "Neither Agree nor Disagree" (3), "Agree" (4), and "Strongy Agree" (5). All p-values given here are the result of a paired, two-sided Student's t-Test. For the sake of brevity, we only provide analysis of questions relevant to the research goals here. The full list of survey questions, with statistics, can be found at [24].

Based on survey responses, the project appears to have been successful in increasing students' perceptions of their competency in engineering (Table 1). This is evidenced by students' increased agreement with the statement "I have the potential to become a scientist or engineer." (p = 0.024) and increased disagreement with the statement "Other factors, besides my abilities and/or determination make it difficult for me to become a scientist of engineer." (p = 0.010). The latter question was intended to be very open to the student's personal interpretation concerning their barriers to becomming a scientist or engineer, and we will leave the interpretation of the result open to the reader as well. We believe that the highly visible, biology-based subject matter of the project kept students that may have been averse to engineering in general from rejecting it quickly. Further, we believe that systematic attempts towards inclusion, such as encouraging all students to try "heavier" assembly tasks with power tools and calling all students "engineers," helped students to realize potential that they might not have had the opportunity to otherwise.

We acknowledge the inclusion of the optional "scientist" term in both statements as a reason to doubt the effectiveness of the project in increasing perceptions of competency in engineering explicitly. Notice that this occurs, with the exception of Prompt 3d, only in questions related to competency/future in engineering. This was an attempt to gauge success of the GK-12 program's broader goal of increasing participation in STEM fields, rather than just engineering. All questions related to the project-specific goals listed above are engineering specific. It is unlikely that removing respondents only identifying with the "scientist" portion of the prompt would bring the results above 5% significance, as the change occurred over the course of a project for which all effort was made to identify as engineering. Some doubt could be cast from no significant change in the response to "I am interested in science or engineering as a career," but no explicit point was made to encourage students towards the discipline over the course of the project, only increase their understanding of the practice.

The project also appears to have been successful in its goal of emphasizing the importance of communication skills in engineering. This is gathered from increased agreement with the statement "Engineers must be good at communicating with others to successfully complete engineering task" (p = 0.016). While there was also an increase in agreement with the statement "Most engineers are good communicators," the result lacks statistical significance at any reasonable level. Though we have not indicated correlation between responses to these prompts, it seems that students differentiated between the need for communication skills and engineers having those skills, at least in stereotype. This distinction strengthens the result because it shows that students appear to understand the fundamental practice and are able to separate it from the practitioner. We believe that the large group organizational structure of the project and the documentation/reflection phase centered around relaying the design and construction process to a wider audience contributed to this result, though it is difficult to isolate either of these factors as playing a dominant role.

The results concerning the project's success in demonstrating large engineering projects as interdisciplinary and collaborative are mixed. Students overwhelmingly increased in disagreement with the statement "Engineers usually work alone" (p = 0.011) and started with high agreement with the statement "Engineers need to know things from many different subjects to successfully complete engineering tasks." (3.93 pre, 4.02 post). This somewhat favorable result shows that the necessity to communicate over the large-group structure of the project was recognized and extrapolated to general engineering practice. However, there were mild decreases in agreement to statements such as, "Engineers often work with doctors, biologists, and other people who work with plants." or "Studying engineering will allow you to become a doctor or biologist," which more explicitly address engineers communicating with people outside their field, rather than possibly only each other.

TABLE II. SURVEY RESULTS WITH STUDENT'S T-TEST VALUES.

Prompt	Pre	Post	Dif.	p-value
1a. I am good at science and/or engineering.	3.77	3.90	0.13	0.118
1b. I have the potential to become a scientist or engineer.	3.71	3.94	0.23	0.024
1c. I would be able to become a scientist or engineer if I work hard.	4.08	4.13	0.05	0.525
1d. Other factors, besides my abilities and/or determination, make it difficult for me to become a scientist or engineer.	2.94	2.68	-0.26	0.010
1e. I am interested in science or engineering as a career.	3.35	3.38	0.03	0.765
2a. Engineers must be good at communicating with others to successfully complete engineering tasks.	3.87	4.09	0.22	0.016
2b. Most engineers are good communicators.	3.44	3.58	0.14	0.127
3a. Engineers usually work alone.	2.57	2.31	-0.27	0.011
3b Engineers often work with doctors, biologists, and other people who work with plants.	3.71	3.58	-0.13	0.107
3c. Engineers need to know things from many different subjects to successfully complete engineering tasks.	3.93	4.02	0.09	0.266
3d. It is important for me to understand science and engineering, even if I do not plan on having a career in those fields.	3.82	3.89	0.07	0.461
3e. Studying engineering will allow you to become a doctor or biologist.	3.20	3.10	-0.10	0.213

Statements intended to gauge student feelings of success and interest in the project show that students were largely dissatisfied or disappointed with the project or the biowalls produced. We see significant decreases in agreement with statements such as, "We will be successful in creating a biowall or vertical garden." when compared to the past tense version of the same statement given in the end survey ("We were successful…" at p = 0.02). Of the 10 related prompts, five showed significantly decreased agreement at, at least, a 97% confidence interval, though we acknowledge that a paired t-test may not be appropriate for comparing different statements. We believe that this general disappointment could have occurred due to the high expectations set for the project. Several of the biowalls were largely incomplete at the close of the project,

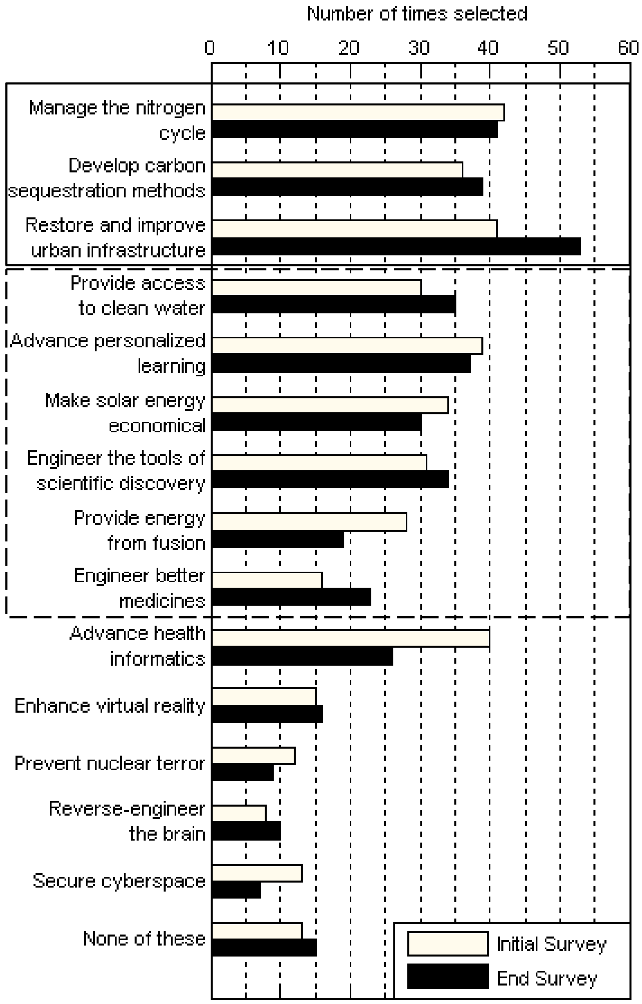

Fig. 2. Number, out of 98, of student respondents that selected each NAE Engineering Grand Challenge, believing it was related to the biowall project, before (white) and after (black) the project. The Grand Challenges within the solid box were indicated as "mostly related" and the Grand Challenges within the dashed box were indicated as "somewhat related" by four GK12 Fellows.

and, where the students were originally led to believe their projects might be publicly displayed outside of SLA, only a few were actually displayed outside the main office for a short time at the end of the year because no formal agreements could be made with other institutions. Other shortcomings could have been due the fact that this was the first time the Teachers and GK12 Fellows implemented the project. Regardless, we are optimistic to see positive results towards the given goals even though the students were not altogether pleased with the physical output, as this shows much of the structure and practice of the project was likely sound.

To assess the effectiveness of the biowall, as it relates to the overall Drexel GK-12 Program objectives, a multiple-selection question on the survey was preceded by the prompt: "The biowall/vertical garden project is related to some of the NAE Grand Challenges of Engineering. Please check any that you think apply." The results are visualized in Figure 2. Four GK12 Fellows, familiar with the project and NAE Grand Challenges, judged the "correctness" of responses. We see a general trend, both before and after, of students accurately identifying more relevant challenges, which indicates that the students had a fair understanding of the project content, likely from the Drexel biowall visit, and Grand Challenges before participating on the biowall project. No clear trend can be observed in increased selection of accepted Challenges or decreased selection of non-related Challenges from the end survey. There are as many increases as decreases in all levels of relation to the project. However, most notable is the increase in correct selection of "restore and improve urban infrastructure." This increase is most likely due to the Teachers' and Fellows' discussion of biowall and vertical gardens' relevance in urban environments. Students also increased their choice of "engineer better medicines" most likely because a small number of project groups attempted to theme their biowalls around medicinal plants.

B. *Observational Data*

We observed that, when students selected specialist groups based on their interests, the structure groups for all classes tended to be heavily male. The imbalance in the structure groups was generally compensated for by more female students in plant and water groups, with one class having two plant groups that were entirely female. Upon observing this trend, we attempted to encourage some remixing, with only mild success due to students' complaints. Throughout the project we attempted to compensate for these imbalances by finding opportunities for female students to get involved in structure assembly. We believe these conscious efforts contributed to some of the quantitative results observed, in terms of perceived competency.

Roughly 50% (four out of eight) project groups produced a biowall for which all requested systems were integrated into the structure. As stated previously, this is most likely due to high expectations and the fact that this was the first time running the project, with little precedent. During the construction phase, most project groups did not appear to have specific design points to follow, so the students tended to design all minor points on-the-fly and were forced to learn from doing. This, of course, caused the construction phase to take a considerable amount of time and require extra materials, which were previously unforeseen by the students. Teachers and Fellows could have prevented groups from moving to the construction phase with incomplete designs, but we felt it would be appropriate, for the sake of time and momentum, for them to continue as long as they had an overall vision for their wall.

V. Discussion

Though not all groups successfully completed the project, we view the project as a success, particularly in light of the quantitative data. The data suggested that the project was effective in achieving the goals of increased student perception of their competency in engineering and their understanding that engineering requires good communication skills. Considering that this was the first iteration of the project, we would hope that the lessons learned would improve the products created in future iterations, while maintaining the same increases in student perceptions of engineering.

Communication about the biowall project with other Teachers and Fellows within the Drexel GK-12 program has spurred interest in similar projects. Another new Teacher-Fellow pair has also implemented their own biowall design project, with an emphasis on urban gardening and maximizing useful area. A third Teacher with the program is attempting to have their school build a green wall within a stairwell, having biology classes select appropriate plants.

The self-created survey used in this research was meant to search broadly for interesting outcomes from this project. Future research should be concerned with selection/design and implementation of instruments that could more rigorously assess constructs of interest, for example: student perceptions of their competency in engineering or, not studied here, student perceptions of barriers to studying engineering.

Returning to the point raised in the introduction, there is some question as to whether forcing students into specialist groups caused students to exhibit specialty egocentrism similar to the disciplinary egocentrism observed in [12]. There is some evidence this occurred. Specialty groups were consistently observed blaming other specialty groups when project group goals were not met. Survey results also show the least support for success of goals related to understanding the interdisciplinary aspects of engineering, though it is difficult to attribute it to this. It would be valuable to repeat this project with smaller project groups (about four students) and do away with specialist groups in order to remove this confounding issue.

This research shows the potential of green engineering design projects to help students improve their perceptions of engineering and themselves as engineers. We believe that the less traditional engineering content provides the opportunity to subvert student expectations and appear more inclusive. When followed with continual insistence that the students are practicing engineering, students may be surprised to realize potential that may have been missed by reluctantly participating. However, it would be valuable to separate the subversive content (in this case, the biowall) from the continual insistence that the students are practicing engineering in order to determine the effects of either alone, i.e., conduct the biowall, or similar, project while rarely stating that it is an engineering project and conduct a stereotypical engineering project while continually referring to all students, even those that are reluctant, as "engineers."

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Hands-On Electricity: An Active Learning Opportunity for High-School Physics

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Abstract—**This paper describes a STEM outreach program for 9-12 grade physics courses. The goal of the program is to provide students with hands-on technologically relevant learning activities for concepts in electricity and magnetism. The three parts of this program include providing schools with the appropriate technology, training the teachers, and developing relevant and sufficiently detailed lesson plans. This program began in the summer of 2011. Being at the beginning of a work in progress, very few results are available so this paper describes the program itself and some of the lesson plans.**

Keywords—STEM; K-12 outreach; physics education; electronic instrumentation; active learning;

INTRODUCTION

Modern technology is starting to bring into common language concepts such as LED lighting, low power electronics for longer battery life, and electric vehicles. To interact effectively with this modern world and solve future problems, students need to know at least some minimal level about this technology. Introduction to the necessary concepts in electricity and magnetism can come in the physical science curriculum in high school. Unfortunately, even for those students that do choose to take physics, exposure has traditionally been very limited due to lack of resources and expertise.

The United States is currently facing a crisis with regard to high-school physics education and in particular with concepts in electricity and magnetism. According to a 2010 report, approximately 400 high-school physics teachers are hired each year, but there is a need for over 1200[1]. As a result of this need, only a third of the high-school physics teachers have a major in physics or physics education, while two-thirds have other science related backgrounds such as biology and chemistry. Another national survey showed that, while physics teachers felt comfortable with Forces and Motion, they felt much less qualified to teach concepts in electricity and modern physics[2]. Due to lack of teacher training, most students have very little, if any, hands-on experience with modern concepts in electricity. Given the state at which modern technology is advancing, students are very naïve about the field, meaning that fewer people will enter the industry or related fields in higher education. Data from the National Science Foundation through 2008 indicates that while enrollment in other engineering disciplines is increasing, enrollment in electrical and computer engineering is falling[3].

The work presented in this paper is an attempt to provide high-school physics teachers with necessary resources and training and the students with motivation and experience. This outreach activity was inspired in part by the NASA Threads program, which provides an entire year's curriculum that is based on the Boe-Bot platform[4]. In contrast, the program described in this paper is more flexible in that the activities can be integrated into any curriculum at any level and at the appropriate time.

In August of 2013, the program will be entering its third year. It has supplied 9 Indiana high-schools with equipment for performing technologically relevant hands-on activities related to electricity and magnetism. More importantly, the program is providing continual teacher training and refining lesson plans, which are both essential in order for the equipment to be used most effectively. This paper focuses on the program's development and current state. Examples of lesson plans are provided. Some student outcomes and teacher responses are included to provide a very preliminary sense of value and impact.

THE ENABLING TECHNOLOGY

Exposing students to more modern technology has traditionally required complex equipment. In order to see time-varying voltages it is necessary to have a function generator to create and an oscilloscope to measure voltages. A variable power supply provides control over DC voltages while supplying larger currents. One set of this equipment could cost approximately $10,000-$20,000, which is well out of reach of most public school systems. Fortunately, cost-effective portable electronic instrumentation solutions exist such as the Digilent Analog Explorer system and the Analog Discovery System. While these devices are not as accurate or powerful as the more expensive equipment, they are more than sufficient for simple experiments. In fact, many of these devices are being used in undergraduate engineering courses.

These instrumentation systems provide varying levels and numbers of power supplies, oscilloscope channels, and function-generator outputs and are controlled by software that runs on a PC. The Digilent Analog Explorer device was chosen for this STEM program because it has a built in prototyping board, user friendly software, sufficient resources for complex

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experiments, and the highest wattage power supply available that could drive small motors and incandescent lamps. A separate PC is required to control the instrumentation, but the cost of a sufficient PC laptop is approximately $300. A single complete instrumentation station that was used in this program cost approximately $600 and consisted of 1 laptop, 1 Digilent Electronics Explorer system, 1 DMM, and a parts kit. For approximately $6000, a classroom for 20-30 students can be supplied with 10 stations.

Development of the Current program

During the development of this program some important issues arose that morphed the original idea into the final program. Through an odd turn of events, this program began with funding that had no plan or proposal. The original plan was developed between Mario Simoni and Glenn Cook to work with teachers on an individual basis. This original plan focused on the Vigo County School Corporation because of its vicinity to Rose-Hulman. As such, regular face-to-face meetings between the engineering faculty and 6-12 grade teachers were possible. The goal was to involve as many middle- and high-school math and science teachers as were interested in a week-long workshop that would demonstrate how the technology could illustrate concepts from the state curriculum map. Because the equipment is so portable, this plan called for mobile sets of equipment that could be moved between classrooms and schools for whichever teachers wanted to use it. A proposal was written and submitted to the Tellabs Foundation in order to keep the funding.

The proposal was accepted by the Tellabs Foundation, and, eventually, the Vigo County school board was involved because of the need for corporate wide participation of teachers and resources. The board saw several problems with this original proposal. First, there were limited resources to move equipment between schools, and it was feared that equipment would be lost or broken in the process. With a lack of clear ownership they feared that the equipment would not be properly cared for. The equipment then had to be permanently located at specific schools. Second, the 6 middle schools and 3 high-schools had to be treated equally, meaning that all 9 schools had to receive the same amount of equipment. The grant was insufficient to do that for 9 schools. It was decided then to focus on just the 3 high-schools. Third, it was stated that there was no room in the math curriculum for teachers to supplement with other activities. The math teachers had been told on a daily basis what had to be covered in class and how to cover it. It was decided then to focus on physical science classes, for which there was only one teacher per high-school. Fourth, because of the teacher union, it was required that we pay the teachers at the standard rate for all meetings attended.

During the first year of the grant, the 2 large high schools (> 2000 students), North and South, were supplied with 10 experimental stations each and the smaller higher school, West, (approximately 600 students) with 6 stations. Initial meetings with the three teachers revealed a diverse set of backgrounds. Two teachers had Physics Education degrees, but the third received a physics teaching certificate from a summer course. One teacher had previous experience with amateur radio and building circuits, another was familiar with basic concepts in electricity and magnetism from college courses but did not feel comfortable enough to go into detail in the classroom, and the third had very limited experience with any technology. The three teachers were very willing to participate in the program, but requested as much training as possible in order to feel comfortable teaching the concepts and using the equipment.

The teachers wanted to be able to understand and perform much more complex experiments than what the students would do. Monthly meetings between the three teachers and engineering faculty began in August before classes began and continued throughout the year. The Physics and AP Physics courses did not begin electricity and magnetism until the spring, so there was time to develop confidence. Each of these monthly meetings lasted approximately 1 to 1.5 hours. They typically began with a discussion of a concept and the physics behind it, which then led to the construction and testing of a circuit on the instrumentation system. The teachers were able to verify their understanding of the concepts and learn how to use the instrumentation under supervision. The discussion then led into how these activities could be adapted for use in the high-school courses. Topics that were covered during these meetings included voltage, current, Kirchoff's laws, time constants, different types of capacitors, inductors and transformers, diodes and LEDs, transistors, operational amplifiers, frequency and waves, and oscillators

The second year's goal was to involve other schools in order to test the program with more varied conditions and begin developing a community of experienced teachers. In the summer of 2012, six additional high-school physics teachers from across the state of Indiana were invited to become part of the program. Of the six teachers, two were chosen from large high-schools, two from medium-sized schools, and two from smaller more rural schools. Each school was given a number of stations according to the size of the school. The teachers participated in a 2 day workshop that was held at Rose-Hulman Institute of Technology. During the workshop, the new teachers were introduced to the equipment and electronic components; exposed to concepts in electricity and magnetism; instructed on practical matters such as how to wind inductors and soldering; and how to use operational amplifiers. During the evening, the teachers were given the opportunity to design their own experiments using the equipment, and were able to generate 4 new experiments that had potential for lesson plans. The workshop ended with a discussion about assessment, but nothing tangible came of the discussion.

After the summer workshop, approximately monthly online meetings were made available to all 9 teachers. These meetings were met with varying levels of success and participation. One challenge was that the software being used, Microsoft Lync, had bugs and many teachers had firewall problems at their school. Despite the difficulties, we still met 6 times during the academic year. Prior to each meeting the teachers were given a circuit to build and test and during the meeting, the circuit and concepts were discussed and any problems or questions that were encountered were addressed. The Lync software permitted sharing of video feeds and computer screens among all participants, which greatly aided in debugging circuit problems or answering questions about the equipment.

THE LESSON PLANS

There are several levels of physical science education in the Indiana Public School system. At the most basic level is the Integrated Chemistry and Physics (ICP) courses for students who have little to no interest in entering science fields. The next level up is the Physics course and then at the highest level are the AP Physics courses. For the ICP and Physics courses the required daily curriculum is provided by the state, but there is a little more flexibility for the AP Physics courses to augment the curriculum. The rigidity of this schedule means that, especially for the lower level courses, any developed lesson plans must apply directly to the state curriculum and not cause the teachers to fall behind the lecture schedule.

There are already many online training materials and lesson plans available for the Digilent systems. However, most of these materials were designed with the undergraduate engineering student and faculty member in mind and assume a certain level of proficiency with the concepts and technology. As such, while the actual lesson plans that were developed for this program may be similar to the ones currently available, the presentation must be altered significantly to account for the audience. In order to prepare the students for the experiments, it was found very helpful to provide them with a photocopy of the breadboard so that they could draw the components on the paper with the proper wiring. This paper could be collected and graded prior to performing the experiment.

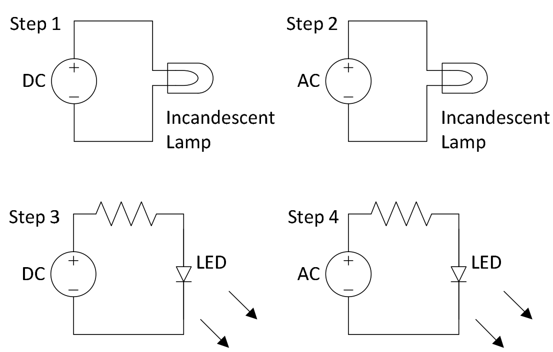

Fig. 1: Schematics associated with a lesson plan.

One of the first experiments that was created consists of a lamp, an LED, and a resistor as shown in Figure 1. In the first part of the experiment, the students connect a single Christmas-tree light bulb between the power supply and ground. The advantage of this equipment, is that students now have control over more variables. The students can vary the voltage while measuring the current and see the results in real time. Then they can record the data and plot the results, tasks which are crucial to high-school curriculum. In the second step, an AC voltage can be connected to the function generator and a low-frequency sinusoidal voltage is applied so that the light is seen to repeatedly turn on and off. Students can gain much intuition by changing the amplitude and frequency of the voltage. For more advanced classes, the lamp can be switched to an LED and resistor. When the same voltages are applied, the students will measure a much lower current, showing that much less energy is required to generate the same amount of light. When an AC source is used to drive the LED, the directionality of diodes can be discussed.

RESULTS AND IMPROVEMENTS

The equipment provided to the schools has been used in all levels of the physical science courses. The simple light-bulb experiment was done in an ICP course. The teacher reported that many students became excited about the technology and wanted to learn more. At the Physics and AP Physics level students performed experiments with time constants and LEDs in series and parallel. Other groups were able to measure Plank's constant by looking at different colored LEDs.

Two key events stand out as somewhat measurable results. At Terre Haute South High School, the average score on the electricity and magnetism portion of the AP Physics test from 2007-2011 was 55%. In 2012, the first year of this program, the average score was 72%. This is a single point of data and there are many variables involved, but the verbal feedback from the teachers indicated that this program did have some impact. From Terre Haute North a student was able to use the instrumentation for his science fair project to construct a pill dispensing system. The following year this student enrolled at Rose-Hulman as a mechanical engineer, but expressed a new-found interest in a double major with electrical engineering.

Before the program can be expanded further, some important improvements need to be made. First, the two day workshop needs to be expanded to a weeklong workshop. While the online meetings help, many of the teachers still feel insecure about using and experimenting with the technology. The workshop should also occur closer to the start of the school year, so that there isn't so much time to forget everything that is presented. Second, each lesson plan needs to have much more detail including the underlying physics. Separate lesson plans with additional content need to be provided for the teachers.

Ideas for assessment tools have been expressed, but still need to be developed. Scores from the AP Physics test can provide historical data and a measure of change. Quizzes and surveys to be done prior to and after doing an experiment can provide a better evaluation of individual lessons. Care must be taken to not overload the students. Enrollment statistics from the involved high schools could provide some measure of how many students are entering undergraduate electrical engineering programs.

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Using LEGO Mindstorms to Engage Students on Algorithm Design

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Students on *Basic Programming* courses often have difficulties with program design tasks. This problem mainly arises from their lack of program solving skills. To overcome this lack, students' need to practice. Manipulating real entities can be a useful and motivating strategy to engage students in such endeavor. In this context, several authors have used *LEGO Mindstorms* robots to help students on basic programming courses. In this paper, we present the results obtained from an experience conducted on a *Basic Programming* course using those robots to motivate students and to involve them in algorithm design.

Basic Programming; increase student motivation; LEGO Mindstorm

I. Introduction

Basic Programming is a first year mandatory course for the *Computer Engineering* degree at the University of the Basque Country (UPV/EHU). This course is the first contact many students have with programming, which is an essential and core topic of the degree. This course primarily centers on providing the students with the essential programming skills, giving a great importance to the analysis and algorithm construction phases using both pseudo-code and flow charts.

Despite being aware of how the *Basic Programming* course relates to *Computer Engineering*, students may feel disappointed as algorithm construction, and especially some of the proposed exercises, are far from what they expected from the course. Therefore, engaging students on algorithm design is a hard task as most first year students are not aware of its relevance, and are expecting to start coding as soon as possible. Moreover, some students already have some programming experience and it is still even more difficult to motivate them on design tasks. These facts might be some of the main reasons for first year students to drop out of the course.

LEGO Mindstorms are programmable robots aimed at fomenting reflection, analytical thinking and problem-solving skills in children. They are provided with a graphic environment that allows programming the robots to perform simple tasks by means of graphical elements similar to those of flow charts.

Our working hypothesis is that using this kind of robots in *Basic Programming* can lighten the learning curve for newcomers on programming and might also increase the motivation of the students. To evaluate this hypothesis, the authors have been using *LEGO Mindstorms* robots for two academic years in the *Basic Programming* course. After the positive comments received from students and the perception of the teachers the first year, a more detailed experiment has been developed on the second year. The results of that experience are presented throughout this paper.

The paper is organized as follows: first, some preliminary experiments on using *LEGO Mindstorms* for programming courses and how they might improve learning are described. More details of the *LEGO Mindstorms* are procured in Section III. The conducted experiment is depicted in Section IV. The results and discussion of this experiment are presented in Section V. Finally, the conclusions and future work are portrayed.

II. LEGO Mindstorms for Programming Courses

To master *Basic Programming*, students need both declarative and procedural knowledge. The first one is related to the syntax and semantics of programming languages and the second is related to problem solving and program design skills [1]. The main problem students have is related to the second kind of required knowledge; their problem begins at the first phase, when "*Students have to understand and apply abstract programming concepts to create algorithms to solve concrete problems*" [2].

A main solution for this learning/teaching process is to help students to obtain a good problem solving basis [2] to which end practicing is essential [3].

Considering these statements, several efforts have been carried out using *LEGO Mindstorms* robots as a means to increase students' motivation, interaction and retention [4], [5]. These experiences indicate that students acquire basic concepts in an easier way using robots [6].

It is worth mentioning that some authors have done studies in which the robots were used for all the practical sessions of the course and the obtained result was that students' using the robots had even worse results than those obtained by the

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control group [7]. However, the authors consider that this was mainly because the students on the experimental group could not bring the material home; therefore, they could not think over and reflect that much on the exercises. According to [5], iconic environments appear to be better for the initial learning stage but later that advantage is lost. Therefore, we have not introduced the robots for all the course practical sessions but for the first two, which were especially devoted to algorithm design.

III. LEGO MINDSTORMS ROBOTS

LEGO Mindstorms are programmable robots aimed at developing analytical thinking and problem solving skills through gamification, i.e., the use of games in non-game context to engage students in learning.

LEGO Mindstorms kits contain both the hardware and the software that can be used to create and program robots. The main element is the NXT brick, which allows controlling the set of modular sensors and motors installed.

Fig. 1 shows one of the robots used for the experiment. It was constructed using three servo motors and three sensors: ultrasonic, color, and touch sensors. It also shows some elements that were used on the exercises of the experiment. In particular, in the illustrated exercise the robot had to move towards the barrier and hit the blue ball.

Students used the NXT-G graphical environment, provided with the *LEGO Mindstorms* kit, aimed at programming the robots to perform simple tasks by means of graphical blocks (see Fig. 2). The graphical blocks can be attached together to construct programs. The NXT-G environment includes support, among others, for control statements, simple procedures and variables. Fig. 2a shows the representation of a conditional block, whereas Fig. 2b presents an iterative one. Parameters for each structure can also be defined. For example, we can state that a certain action is carried out when a certain time has elapsed (Fig. 2c) or when a sensor detects certain situation, e.g., a distance to an object is smaller than a particular value or certain sound is detected (see Fig. 2c).

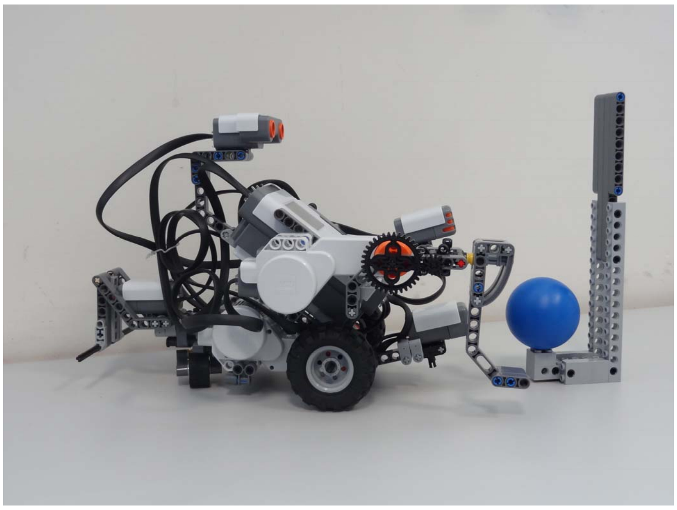

Fig. 1. LEGO robot used for the experience

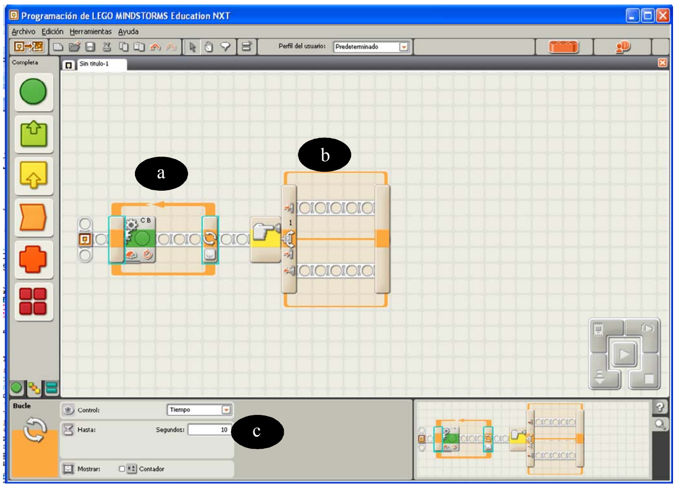

Fig. 2. LEGO robots graphical environment

IV. EVALUATION EXPERIMENT

As mentioned above, this work relies on the hypothesis that the use of the LEGO robots may lighten the learning curve for newcomers in programming and may also increase the motivation of the students. The experiment here described has been conducted to prove the working hypothesis. Following deeper details on the experiment are provided.

A. Objectives

The general aim of this work is to improve the teaching of *Basic Programming*. In this experiment, we have focused in the use of robots in the first phase of the course to engage students by increasing their motivation and to improve their skills in algorithm design construction. Therefore, the four specific objectives of the experience have been:

- **O-Motivation**: Study how the experience affects students' motivation.
- **O-Perception-S**: Study students' perception of the learning process using robots
- **O-Improvement**: Identify improvements derived from the use of the robots in students' algorithm design construction.
- **O-Perception-T**: Analyze the teachers' perception about how the use of the robots influence the students' learning process.

B. Used Tools/Techniques

The experience presented throughout this paper has been evaluated using both qualitative and quantitative methods. Quantitative methods allow statistical analysis to be applied to data results by limiting the set of answer categories for each question. On the other hand, qualitative methods give more freedom to users by using inquiry techniques, e.g., open questions, interviews, surveys, observation or logbooks. These techniques allow participants to give their personal opinions. Although qualitative results are more difficult to analyze, they are able to capture users' subjective perspectives. Therefore, a combination of qualitative and quantitative evaluation methods [8] has been used.

To evaluate the motivation, both surveys and interviews have been conducted. Knowledge improvement has been measured by two classic means: pre and post-tests, and experimental and control groups. The first involves the same subjects in pre- and post- tests, which are developed before and after the use of the tool; the second splits up the subject set into two groups, those who used the robots (*experimental group, G_Experimental*) and those who did not use it (*control group, G_Control*).

C. Procedure

The experiment followed the sequence of six steps illustrated in Fig. 3.

Step 1: To test students' prior knowledge, they were requested to answer a short questionnaire about their background on programming. Next, students were provided with the problem shown in Fig. 1 and requested to indicate how they would solve it. After that, answers of the exercise were analyzed to evaluate whether they were capable of identifying the correct step sequence, and had properly used the conditional and repetitive structures. This step was carried out the first day of the course with students on G_Control and G_Experimental groups.

TABLE I. PRETEST EXERCISE

You want to paint all the rooms of your flat. Take into account that you may need several coverings of paint to vanish all the spots. The paint has to dry before the next covering and the employed tools must be properly cleaned. Specify the steps needed to carry out the described task.

Step 2: Being the experiment oriented towards improving algorithm design skills, no emphasis was given to the robot construction. Therefore, students were provided with already constructed robots (such as that shown in Fig. 1). In this step, these robots and the software to be used were presented to the students.

Step 3: During two 90-minute laboratory sessions, the students were provided with the robots and the set of problems to be solved (see example in TABLE II.). They had to design the programs using the provided software and then load the program in the robot and execute it to test the program performance.

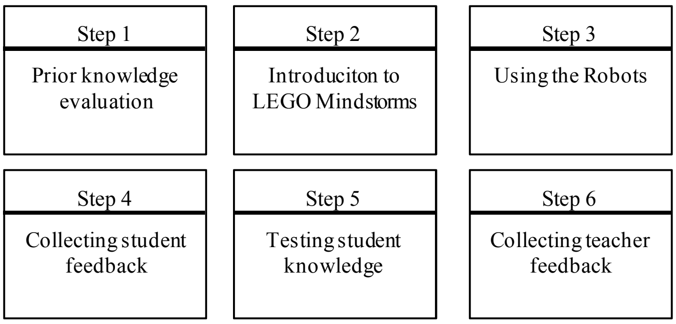

Fig. 3. Step sequence for the evaluation

TABLE II. PROBLEM EXAMPLE

Given the robot and the objects shown in Fig. 1, design the program that enables the robot to perform the following task: it must move forward until it is close enough to hit the ball. Then, the robot must check whether or not the ball is red. If the ball is red, the robot will raise the hand and hit the ball. Otherwise, it will move backwards and play a sound.

Step 4: Two instruments were used to collect the students' feedback: logbooks and surveys. Students were encouraged to fill in a logbook (Fig. 4) to describe both the problems they had and every impression or perception about the experience.

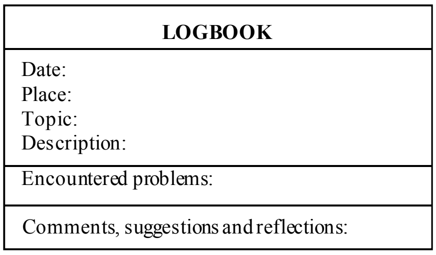

Fig. 4. User logbooks for recording comments, suggestions and reflections

In addition, a survey was used to evaluate the achievement degree of the objectives of this work, in particular the O-Motivation goal. TABLE III. shows an excerpt of the survey used for this work. The survey entailed 13 five-level format Likert items [9], two yes/no questions and an open-ended question. The yes/no questions were aimed at identifying if the students felt disappointed with the use of the robots whereas the open-ended question allowed us to gather more detailed information of their opinions [10].

TABLE III. EXCERPT OF THE SURVEY USED TO COLLECT FEEDBACK FROM G_EXPERIMENTAL STUDENTS

		1	2	3	4	5
1	Did you find it easy to use the software?					
	O-Motivation					
2	Using the robots has increased my motivation					
3	Using the robots has made the course more interesting					
4	Using the robots has helped me identifying the course usefulness					
5	Would you have preferred not to use LEGO robots?	**YES/NO**				
	O-perception					
6	Using the robots has helped me understanding conditional statements					
7	Using the robots has helped me understanding iterative statements					
8	Using the robots has helped me learning design concepts					
9	Additional comments or suggestions regarding the experience					

The Likert items were oriented to measure the motivation of the students (O-Motivation), along with their perception of how the use of the robots might have influenced the learning of basic programming concepts such as variables, conditional, or iterative statements (O-Perception-S). Considering that the usability and difficulty of the employed software might influence the students' motivation and perception, question 1 was included to measure this issue.

Information from the students on the control group (G_Control) regarding the feelings transmitted by the students on the Experimental group (G_Experimental) in relation with the experience was also collected. To this end we used a survey with two questions (see TABLE IV.).

TABLE IV. EXCERPT OF THE SURVEY USED TO COLLECT FEEDBACK FROM G_CONTROL STUDENTS

		Yes	No
1	Would you have preferred to used the robots?		
2	Have any comments from your classmates on G_Experimental motivate your answer to question 1? Which ones?		

Step 5: The course evaluation follows a continuous process where the students have to sit for three exams. The first one is composed of a set of questions that ask students to develop the program design for a certain number of problems. The results of this first exam have been used to evaluate the knowledge improvement of students.

Step 6: Teachers lecturing practical sessions fulfilled a logbook (see Fig. 4) to describe the discovered problems and their impressions and perception about the whole experiment

D. Participants

Students enrolled in the Basic Programming course are usually very heterogeneous; ranging from students with no prior knowledge on programming to those repeating the course. Besides, some students have attended programming courses outside the university, which mainly focus on syntax learning and give no emphasis to problem solving. Therefore, those students are highly confident in their programming knowledge, but lack algorithm design skills.

Students were randomly divided into two groups: the experimental group, which used the Robots (G_Experimental), and the control group (G_Control), those who did not used them. Therefore, using the robots was not elective for students.

G_Experimental had 14 students taking the course for the first time and 8 were retaking the course. On G_Control 9 were taking the course for the first time and 13 were repeating. This shows the heterogeneity of the groups, which has also been confirmed with the analysis of the pretest exercise.

V. RESULTS AND DISCUSSION

The results obtained in the experiment are presented throughout this section.

As mentioned above, the usability of the employed software can influence the students' performance and perception. To this end, question 1 (*"Did you find it easy to use the software?"*) was included. In general, students' found the provided software easy to use; only 22.7% of students indicated that had some problems with it (see Fig. 5).

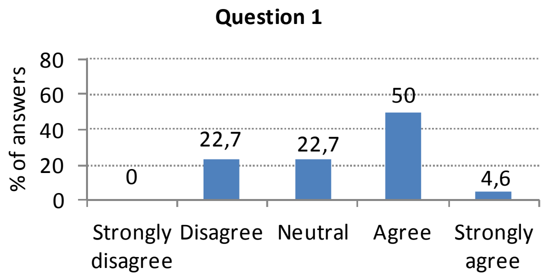

Fig. 5. Answers to survey question 1 –"Did you find it easy to use the software?"

Next, the results for each defined evaluation objective, i.e. O-Motivation, O-Perception-S, O-Improvement, and O-Perception-T, are described

A. Results regarding how the experience has influenced students motivation

From answers to question 2 *("Using the robots has increased my motivation")* and 3 (*"Using the robots has made the course more interesting"*) related to motivation and interest of students, we can derive that students were motivated and interested because of the use of the robots (see Fig. 6). 59.1% of students indicated that their motivation had highly increased due to the use of the robots; moreover none of the students answered that using them had not increased their motivation (Fig. 6 a). Similarly using the robots greatly increased 68.2% of students' interest in the course (Fig. 6 b).

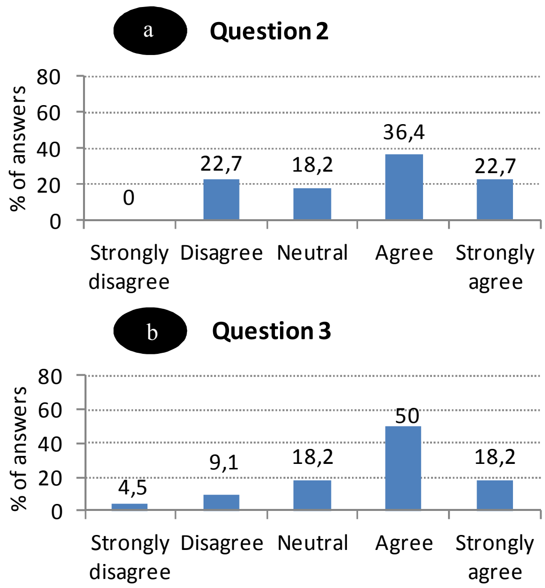

Fig. 6. Answers to survey question 2 "Using the robots has increased my motivation" and 3 "Using the robots has made the course more interesting"

Furthermore, students were asked if the robots had contributed to better identify the usefulness of the course in question 4. Regarding this question 91% of students agreed with this assertion (see Fig. 7 a)

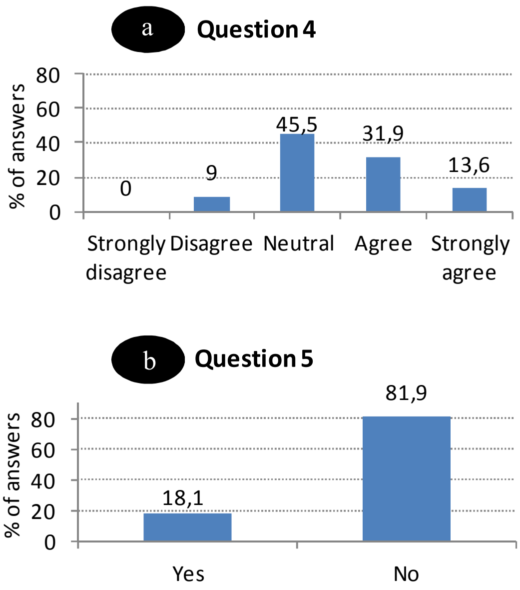

Fig. 7. Answers to survey question 4 "Using the robots has helped me identifying the course usefulness" and 5 "Would you have preferred not to use LEGO robots?"

For evaluating the O-Motivation objective we also took into account the answer to the survey of students on G-Control. 68% of students on this group would have liked to use robots. This value increases up to 100% for newcomers. The main motivation for these answers were the comments heard from students on G_Experimental indicating, for instance, that using the robots *"was entertaining, pleasant and had increased their interest in the course "*.

In accordance with this, only 18.1% of students (see Fig. 7 b) indicated that they would prefer not to use the robots (Question 5 on the survey, *"Would you have preferred not to use LEGO robots?"*). However it is worth noting that the students preferring not to use them were the ones retaking the course.

B. Students perceptions

Students' knowledge awareness is essential for the learning process. Therefore the survey included some questions for analyzing the students' perception of their learning process using robots.

Only 18% of the G_Experimental students stated that using the robots had not helped them much in learning design concepts (Question 8). None of them considered that the robots were useless (see Fig. 8).

More specifically, students' were asked whether they felt using the robots had helped them in understanding the concepts of conditional (question 6) and iterative (question 7) statements. Regarding conditional statements, 50.1% of the students thought that it had helped them, 22.7% did not have it very clear (Fig. 9 a) and 27.2% indicated that it did not help them. For iterative statements, 45.5% indicated it had helped them, 22.7% did not have it very clear and it did not help 31.8% of students (Fig. 9 b).

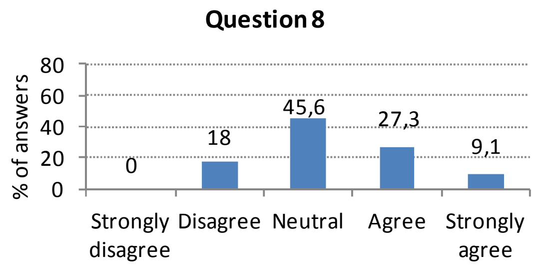

Fig. 8. Answer to survey question 8 "Using the robots has helped me learning design concepts"

In the open-ended question (Question 9, *"Additional comments or suggestions regarding the experience"*), students provided positive feedback associated to their perception. They pointed out that *"my classmates not using robots, progress more slowly than those using them"* and *"is a useful means to introduce newcomers programming concepts"*.

C. Learning improvements

A statistical analysis has been conducted to determine the impact of the use of robots in the students' learning process.

A between-subjects study [11] has been carried out, comparing the marks obtained by students using robots (G_Experimental) with the marks of those not using them (G_Control). For this analysis both posttest and final marks have been considered.

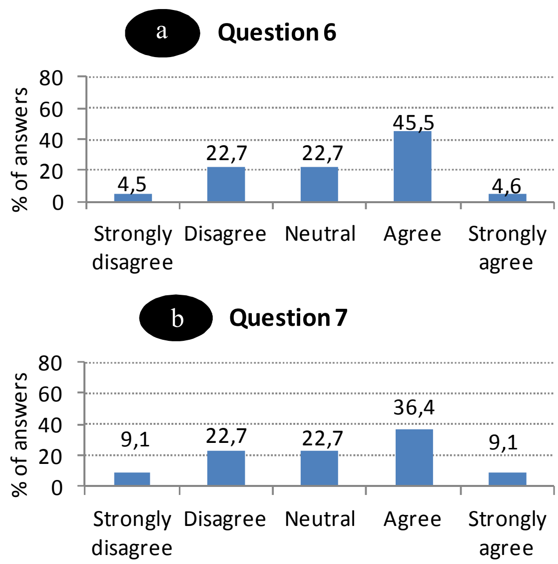

Fig. 9. Answers to survey question 6 "*Using the robots has helped me understanding conditional staments*" and 7"*Using the robots has helped me understanding iterative statements*"

The average marks have been compared and the Wilcoxon test has been applied to check the significance of the average differences.

The obtained results have not shown any statistical significance between the groups; although teachers expected that the robots would improve the students' marks.

D. Teachers' perceptions

Teachers participating in the experiment have detected an increase on students' motivation and improvement of classroom atmosphere. G_Experimental students were more active and participative in the practical sessions with the robots; this continued for the rest of the term.

Teachers observed that G_Experimental students were able to properly use conditional and iterative statements much earlier and easily than G_Control group students. Therefore they expected more positive answers to questions related to objective O-Perception-S and better exam marks on G_Experimental.

VI. CONCLUSIONS

This paper has described the experiments carried out with LEGO Mindstorms robots on the 2012-2013 academic year on the *Basic Programming* course at the UPV/EHU. 44 students and 2 teachers have participated on this experience that has been focused on four objectives: O-Improvement, O-Motivation, O-Perception-S and O-Perception-T.

Concerning O-improvement, the results show that there have not been significant differences between the groups. The use of robots has not improved students' mark but has neither decreased them as in the experiment presented in [7].

Analyzing the survey results, G_Experimental students were highly motivated and interested using robots. G_Control students express that they also would have preferred to use the robots.

G_Experimental students perceived that using the robots helped them to learn programming design concepts. Similarly teachers also observed that G_Experimental students were more engaged with the design aspects. All this improved the classroom atmosphere.

The obtained results encourage us to continue the experience for the following academic years. However some difficulties inherent to the use of physical devices have been detected: factors related to the movement of the robots and rooms' light conditions. Aspects such as the different surface frictions (for example on the table or on the floor) or the battery load affected the movement of robots. In addition, the lightening of the room was not homogeneous so the parameters for discovering whether a ball was blue or red varied from one place to another in the room. Therefore, exercises must be designed considering these factors.

Due to the motivation increase produced by LEGO robots, our objective for the next academic year is to continue using them in the *Basic Programming* course. However, the approach must be enhanced to appropriately tackle the O-Improvement objective. Therefore, a deeper analysis of the number of laboratory sessions to use robots in must be conducted. Also, given that the students of the course are very heterogeneous (e.g. newcomers or repeating students), they should be classified using a more exhaustive pretest in order to adapt the proposed exercises to specific student characteristics to improve their performance.

Acknowledgments

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Educating Innovators of Future Internet of Things

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***Abstract*—The concept of "Internet-of-Things" will undoubtedly emerge as the technology of the future. Educating specialists ready to bring the concept to the reality remains challenging in the scope of traditional university courses. The main challenge is how to enable students to think outside the boundaries of the particular discipline and therefore to enable the innovative thinking. This article describes an experiment with teaching Internet-of-Things as a common red thread across three courses which ran in parallel during fall semester 2012 at Luleå University of Technology in Sweden. We discuss the teaching methodology, the technology blocks which laid the ground for our teaching philosophy as well as the experiences and lessons learned.**

I. INTRODUCTION

While the term "Internet of things" (IoT) was coined for quite a while now, a systematic education of specialists in this area has not yet taken off. Traditionally, courses in Computer Science programs at universities offer a standard set of disciplines focusing on specific aspects of the IoT technology. The courses vary from different flavors of hardware-near "Wireless Sensor Networks" classes to higher-level "Web-Design and Service Oriented Architectures" and similar. The demonstration of a place of the particular discipline in the holistic view of the IoT universe is often rather vague and in many cases is limited to one or two theoretical classes discussing problematics of adjacent subjects. This is in no way a surprising situation. Prior to all, the IoT concept only now starts to grow out of its embryonic, academic research phase. It is today it begins to be filled in with specific implementations.

One message is important to convey to students already now - the future of IoT technologies is about: a.) Innovations; b.) Cross-disciplinary knowledge; and c.) Multi-face programming. These principles formed the ground for an educational experiment conducted at Luleå University of Technology in the fall semester of 2012. During the experiment, further in the text referred to as *triple-run*, three courses of the Computer Science program were aligned in their theoretical and practical parts to convey a holistic view of an IoT ecosystem. The classes were taught in parallel.

The theoretical content of the three courses allowed creating a scenario covering the entire technology chain of the Internet of Things: gathering and communicating sensory data; scalable and distributed processing of big data; value-added, human relevant network services. In the practical part students in the three classes (60 in total) acted as startup companies in the respective technology domain. These startups were assigned a task to deliver a common holistic system given time, performance and budget constrains. This task required students in a particular course to constantly communicate to other students outside the courses boundaries. In particular, through these activities students were trained on skills for industrial level development and integration of complex IT systems and innovative thinking by exploring problems, methods and solution spaces of each other.

On the technical side the triple-run experiment was conducted using Amazon Web Services [1] as a common computing platform. This choice allowed us to draw interesting conclusions about students work load, the degree of their actual involvement in the learning process as well as the cost of the triple-run. A pedagogy-oriented and close-to-reality real-time simulation environment was used in Wireless sensor networks course included in the triple-run experiment to substantially facilitate experimentation with large quantities of communicating sensors. This simulation environment is our main technical contribution supporting teaching of principles and advances of "communicating things".

The article is organised as follows. Section II elaborates the theoretical background and the related work. The syllabi of the courses under the experiment are summarised in Section III. The scenario behind the triple-run trial is described in Section IV. Section V presents the technology blocks used in the experiment. We present our reflections and outline future developments in Section VI before concluding the article in Section VII.

II. THEORETICAL FOUNDATION OF THE TRIPLE-RUN EXPERIMENT AND RELATED WORK

It would not be a big discovery to make that one of the largest motivating factors for today's Computer Science students is their excitement about the success of young innovators behind such IT giants as Facebook, Google, Skype and similar. The key to success is on the one hand evident: It is the innovative thinking, entrepreneurship and team-work. On the other hand, it is less evident how to foster such skills in the framework of the traditional education system.

The importance of empowering students with tools and opportunities to exploit the knowledge and to stimulate self-learning is reflected in many sources on modern methodologies in higher education. For example, [1], [2] asserts that by giving students tools, guidance and freedom as part of contextual understanding the educators encourage both innovation and the spirit of entrepreneurship. Commonly a range of student-centered education methods where learning is supported by projects, problems of discovery nature and just in-time teaching is referred to as *inductive education* [3]. The goal of

[1] Amazon AWS website, [Online]. Available: http://aws.amazon.com.

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TABLE I. SUMMARY OF COURSES' SYLLABI *before* THE TRIPLE-RUN EXPERIMENT

	Courses		
	D7015E	D7001D	D0036D
Credits	7.5 ECTS		
Level	Graduate. First year of MSc.		Undergraduate. Second year.
Goal	The student should know fundamentals of modern short range radio transmission technologies on all layers of the communication stack and the specifics of WSN network architecture like data-centric communications, in-network processing, etc. The student should be able to understand research articles in selected areas of the course and be able to present their analysis for a wider audience. The student should develop skills of modeling an advanced networking functionality as well as developing it in one of the main-stream operating systems for WSN.	The student should understand the fundamentals distributed networked applications, e.g. in-depth understanding of threads and associated performance problems, fundamentals of fault detection in distributed application, etc. The student should be able to understand research articles in selected areas of the course and be able to present their analysis for a wider audience. The student should master the skills of programming of parallel events with threads, timers, counters and communication security in Java programming language.	The student should understand fundamentals of network programming including relevant aspects of TCP/IP stack, main communication paradigms, basics of threads, sockets and remote method invocation. The students should develop skills of programming a simple to medium complex network functionality, e.g. a threaded TCP server and a simple networking computer game with in-advance prepared skeleton of the functionality.
Structure	In-class lectures, student seminars and practical work.		Lectures and practical work.
Examination	Continuous examination. Final score is computed as a weighted average of the score in three examination moments: Labs, Seminar and Mini-project.	Traditional closed book final written exam.	

inductive education is to develop essential social and teamwork skills [4] by tackling real-world and open-end problems [5] which is is highly appreciated by students [6].

In our triple-run experiment we combined the inductive collaborative learning approach with the product-based learning. One of the important goals set to students were understanding project management and production processes. This approach applied previously in computer science education [7] showed positive results and is highly valued by industry.

Finally, we followed concepts of *adaptive expertise* or *deep learning* [8], [9] enabling students to motivate their solutions both from the technology and economical perspectives.

A. *Related work*

Clearly, we are not alone looking at the problematic of educating innovators of the future Internet of Things. A very recent work (as of February 2013) from the Open University in the UK [10] build their education approach using similar motivation. The work also includes the references to other world-leading schools in the US and Europe being active in the development of the IoT directed education lines. While sharing common objectives and parts of the methodologies our experiment described in this article is, however, different in several important ways:

1) We are not developing a single overview course, instead we make students from three focused courses to interact and collaborate with each other in the scope of a common IoT vision.
2) We target students with diverse backgrounds aligning the courses on the second year bachelor and the last year master levels. This step allows students on lower education stages to get insight to the diversity of problems considered at higher stages.
3) We do not use play environments, our students work with real software and hardware platforms which they later on meet on the job market.

The key points listed above make our experiment a unique contribution to the methodology of education in the area of the Internet of Things.

III. COURSES UNDER EXPERIMENT

The courses selected for the triple-run experiment were: Wireless sensor networks, further referred to by its catalogue code D7015E for brevity reasons; Network programming and distributed applications, further referred to as D7001D; and Network programming, further referred as D0036D. In the Swedish education system an academic year is divided in quarters (teaching periods). The duration of each quarter is 2 months. A regular course span over one quarter. The triple-run experiment was conducted in the first quarter of 2012 starting from the last week of August and ending with the exam week on the last week of October. Table I summarises relevant aspects of the courses' syllabi as of before the experiment. While the theoretical part and the goals of the syllabi remained unchanged, the practical part and the emphasis of the courses was shifted to IoT enabling technologies.

By the time of the experiment the D7015E course was given at two occasions in 2008 and 2010. The previous results of the course evaluation for both occasions were positive. On a methodology side the students highly evaluated the continuous form of examination, highlighting that this examination form assisted them in pacing their learning process properly and overly contributed to better learning. On a criticism side the students continuously highlighted difficulties with time-consuming programming and debugging of the code on real wireless sensor devices in foreign for them development environment. During the triple-run experiment we decided to adopt the continuous examination form in all three courses.

The common to both D7001D and D0036D courses problems were shortcomings associated with lab infrastructures required to perform the practical parts. Although both courses are based on Java programming language, proper access rights to low-layers network configuration facilities were needed. In many cases students resorted to experimenting with very

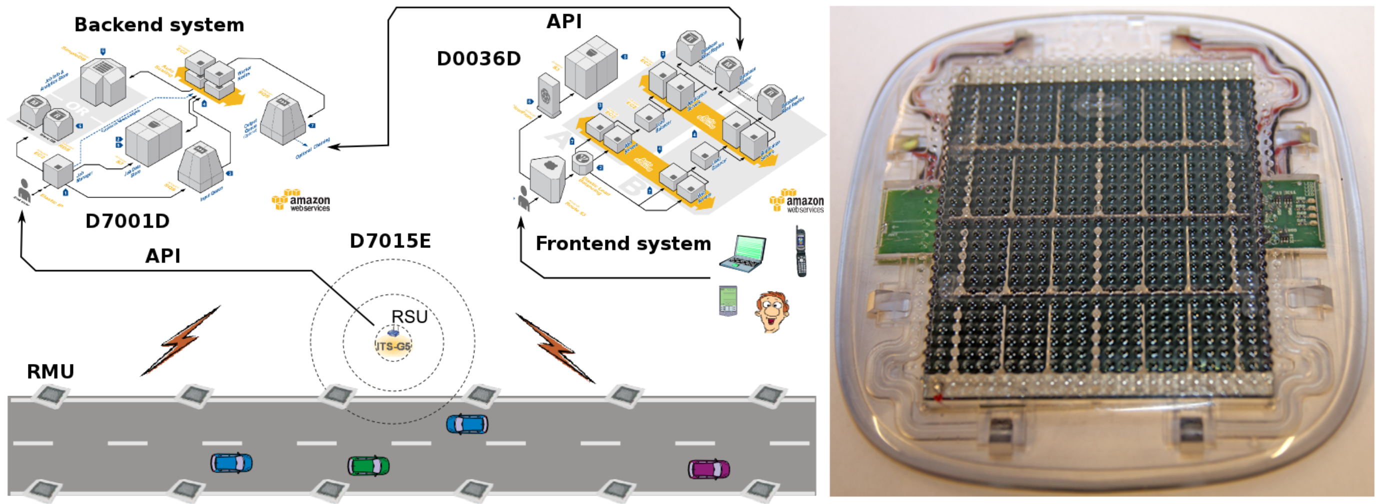

Fig. 1. A graphical representation of the scenario for the triple-run experiment.

simple network topologies basically consistent of their own computers (where they had the appropriate rights) and few hosts in the university network. In general, we the course instructors experienced major differences in developing non-trivial practical scenarios linking to the theoretical content of the course. The typical course-book-like code examples constantly raised students' critique as missing sufficient connection to real-life applications. The major change in the syllabi of the D0036D and D7001D courses was introducing the "Cloud" and the "Internet of Things" topics as the main themes both into their theoretical and practical parts. Looking ahead, by performing the practical part of the courses in the Amazon Web Services environment lifted up students' satisfaction and their experience of programming networking functionality dramatically.

IV. The *triple-run* structure

The theoretical content of three courses described above allowed creating a scenario covering the whole technology chain of the Internet of Things: gathering and communicating sensory data; scalable and distributed processing of Big Data; value-added, human relevant network services.

A. Common IoT scenario script

The offered to the students common IoT scenario is rooted in the ongoing at LTU research project iRoad[2]. In short the project aims at enabling a non-intrusive and anonymous detection of vehicles using on road sensor networks [11]. The core of the iRoad technology is a specially designed *Road Marking Unit*, which is shown in the right part of Figure 1. It consists of a wireless sensor unit built on 16-bits Renessas microcontroller and put in a specially designed robust polymer casing resistant to overriding by heavy vehicles. The RMU is equipped with a magnetometer sensor and a ZigBee-compatible low power radio transceiver. Technologically, the RMUs are thermally glued onto the road surface. After that they detect vehicles by sampling the readings of the magnetometer. The samples are then transmitted via a gateway serving several such RMUs to a powerful computing backend system for advanced signal processing and execution of application-specific functions. While in the scope of the project we performed installations with several tens nodes[3], within the triple-run experiments we let students to work with virtually unlimited number of such sensors generating realistic traffic.

The overall concept behind the triple-run application scenario is shown in Figure 1. The students in the three courses were treated as start-up companies getting a contract to develop a part of the global IoT system. In particular, the start-up of the D7015E course was responsible for organisation of communications from RMUs to the gateway and from the gateway to the back-end system. The D7001D start-up was responsible for the design and development of a scalable cloud-based architecture for real-time processing and storage of the incoming data as well for serving the requests coming from a front-end system. Finally, the D0036D start-up was responsible for the implementation of a scalable web-based front-end system visualising the results of the computations. It is essential to note that on all stages of the project the students were faced with the real data traffic as it would come from real physical devices, see Section V for more information.

B. Implementation

The work flow of the triple-run experiment is illustrated in Figure 2. The classical style lectures gave students the theoretical skeleton of the courses' content. The first three introductory lectures were common to all three courses. Besides the introduction of the triple-run concept the common lectures gave a crash course on machine-to-machine communications, the Internet-of-Things ecosystem and the basics of the cloud computing using Amazon Web Services. After the introductory lectures all three courses followed their own lanes in the lecture part. All lectures in the three courses, however, were

[2]iRoad project. [Online] Available: http://www.iroad.se

[3]iRoad project's demonstrator [Online] Available: http://www.youtube.com/watch?v=GYyWkYfsJhk

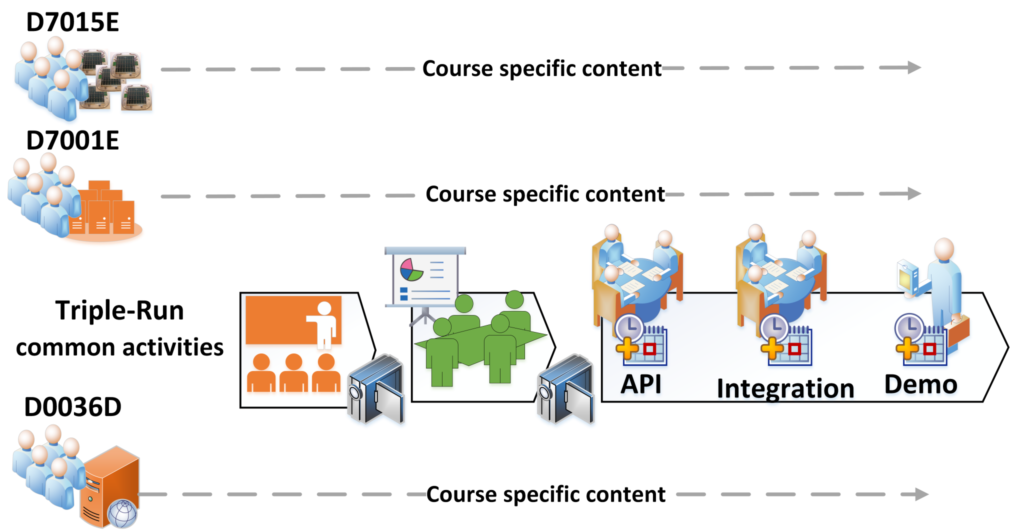

Fig. 2. Workflow of the triple-run experiment. At the course start two common lectures were given to all three courses. The lectures included course structure and introduction, presentation of the common scenario, general overview of IoT and involved technologies as well as hands-on tutorials for AWS programming. Further, common seminar presentations and concertation meeting, and demonstration of final solution were carried out commonly.

recorded using the Adobe Connect[4] facility and the recordings were available in a common to all three courses space of e-learning system Fronter[5]. This step allowed interested students of the particular course an option of following selected parts of another course.

The seminar series of the MSc-level courses D7001D and D7015E were made open to students of all three classes. The students could either attend the events physically as an optional course moment or watch the recorded presentations off-line. The themes offered for student seminars in the particular course aimed at presenting different design choices on selected functionalities, which later on should be developed by students in the practical part. For students from other courses attending the seminars, the aim was to introduce them to the world of the adjacent course. Not completely unexpected we were happy to observe that 20 to 30% of students from the adjacent courses attended the seminar series of each another motivating it by pure curiosity.

The practical part was structured similarly in all three courses and consists of three stages. At the first stage a hands-on exercises with Amazon AWS environment were intended to familiarise students key aspects of practical cloud computing. At the second stage a set of course-specific lab assignments emphasised the core practical issues of the particular subject. Finally, at the third stage the knowledge and skills from the previous two phases were applied to execute a corresponding part of the common to the three courses project. All practical stages were carefully synchronised across the three courses so that student groups would avoid unnecessary delays due to dependencies on the results from other student groups.

In order to orchestrate and pace collaboration and the joint progress two concertation meetings for students from all three courses were planed: a.) For agreeing on the common API between the subsystems and b.) For integrating the developed parts into a holistic IoT system. In practice students from different courses clustered in groups, which met together outside the scheduled meeting hours in order to synchronously develop the final demonstrator.

Finally, the culmination of the triple-run experiment was a *general assembly* where all students were gathered in a large auditorium for demonstration and presentation their solutions. We organized this gathering as poster-session where student pitched they solutions to other participants. This event was made open to a wider public both for publicity reasons as well as to give students a feeling of a technology fair.

V. Technology used in triple-run courses

In this section two technology blocks laying the ground for the triple-run experiment are described. In the sensor network course a pedagogy-oriented simulation environment named Symphony [12] was used to give students skills of developing a real sensor network software while reducing the frustration of debugging the code on real hardware.

The practical tasks in all three courses were conducted inside the Amazon Web Services IaaS environment. While students in the D7015E course used Amazon AWS only as a virtual computer to run the Symphony simulator, the students of other two courses experimented with more or less the entire spectrum of the AWS functionality. For the triple-run experiment we received an educational grant from Amazon covering all needs in computing infrastructure for all students in the three courses. In the next section we report the cost details of our approach.

A. Symphony - a Pedagogy Oriented WSN Simulation Framework

Simulation framework Symphony [12] is rooted in the authors' own experience while teaching the D7015E course

[4]Adobe Conect. [Online] Available: http://www.adobe.com/products/adobeconnect.html

[5]Fronter LMS. [Online] Available: http://com.fronter.info/

as well as when developing and testing a real-life medium-scale distributed WSN application in the domain of intelligent transportation systems. On the teaching front we were confronted with a dual challenge. On the one hand students really appreciated to work with real WSN software and hardware. On the other hand, however, we observed that students were literally suffering from painful debugging of their (rather simple) distributed network functionality and got frustrated from time consuming reprogramming of devices. Even though at the end most of the students get used to the development environment, we the course instructors understood that this in many cases is done by the cost of devoting less time to conceptual understanding of the problems related to the design, analysis and deployment of resource constrained wireless sensor networks.

An architecture of Symphony is illustrated in Figure 3. It consists of three operating and programming scopes: an operating system (OS) scope, a hardware (HW) scope, and an orchestration and communication scope. The OS scope provides necessary tools and a set of rules for building existing operating systems for sensor devices (e.g. Contiki, TinyOS, FreeRTOS) to a virtual image. To the best of our knowledge Symphony is the only environment where students may seamlessly work with different operating systems in a single experiment avoiding a hustle of installing them on the devices. The HW scope of Symphony contains a set of models accurately emulating time behaviour of hardware components. From the teaching perspective this scope gives a possibility to demonstrate the effect of resource constraint hardware elements on the performance of higher layers' communication protocols, which otherwise is at least challenging if not impossible to demonstrate on real devices. Network simulator *ns-3*[6] offers the orchestration and communication scope of Symphony. The choice of a popular network simulator as a provider of communication models allows considering non-trivial network topologies and communication scenarios. Moreover *ns-3* provides a possibility to run simulations in real-time and establish network connection with any computer connected to the Internet. We utilised this capability of Symphony extensively by letting the students to direct the simulated sensory traffic to the back-end system developed by students from the D7001D class.

Finally, since the framework is executed on a PC a favourite integrated development environment supporting main stream programming languages could be used. This makes experimenting with WSN functionality in Symphony more methodological and less time consuming. Although Symphony could be installed on any physical computer, during the course of the triple-run experiment we ran Symphony in the cloud. The rationale behind executing the simulator in the Amazon AWS is twofold. Firstly, we gave students from the D7015E course a taste of working in the IaaS cloud environment, which was appreciated. Secondly, this choice simplified our assistance to possible technical problems since we as the instructors had full access to the virtual machines of the students. In order to shorten the starting up time we prepared a Virtual Machine Image with all necessary software and development environment pre-installed.

[6]Ns-3 simulator, [Online] Available: http://www.nsnam.org/.

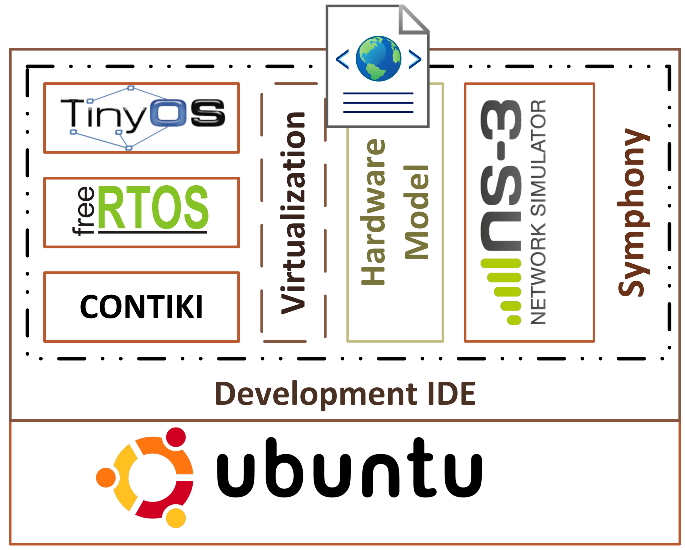

Fig. 3. Symphony framework set up.

B. Amazon AWS as the base computing infrastructure in the triple-run experiment

The choice of the cloud infrastructure in general and Amazon AWS in particular is rather straightforward. Prior to all we intended to give students skills of working with the cutting-edge platform for production of commercial ICT solutions. Secondly, the flexibility, the diversity and the availability of the Amazon AWS infrastructure go far beyond similar parameters of the university's own. Thirdly, as the courses in question assume programming of rather low level network functionality an IaaS cloud modality, where one gets an access to raw computing resources is virtually the only choice.

While teaching network programming related courses using an IaaS cloud infrastructure infrastructure provides many methodological benefits a substantial amount of time were spent on making the cloud environment ready for education purposes. Amazon AWS being a tool for professional developers needed to be adapted for the triple-run experiments in the following ways. Firstly, we introduced naming conventions for tagging different functional elements, such as authorisation keys, EC2 instances and others. In order to keep the resource usage under control we developed a "cloud-crawler" script, which cleaned up the unused and orphaned resources at scheduled time periods. Although we did not place any restrictions on the usage of a specific operating system we prepared an Ubuntu-based Virtual Machine Image with all necessary network configurations and pre-configured an integrated development environment. The image was available to students before the course began.

VI. Reflections, Lessons Learned and Future Developments

"The concept with combining three courses is a great one!", "I loved an idea of working on the same project between three course", "To work with real tools and systems, which are currently used in the industry was great!". "It was the first time I've got an impression of working in a company with real project, interesting topics, and nice atmosphere in the class[7].". These are examples of the overall impression about the triple-run courses, which we got as the result of courses' evaluations by students. Our general impression from the triple-run experiment is overly positive and we definitely will work further towards improving and polishing the concept. In this section we present selected observations we made during the course of the experiment.

The main critique from many students was about *their feeling* of the work load being un-proportional to the course credits[8]. We analyzed the usage pattern of virtual machines (EC2 instances) available from the Amazon management console as a reference of the actual time an average student spent on programming. The de-facto maximum load in the practical part is approximately 100 hours per student. This number also met our expectations before the course start. We advocate that this *feeling* comes mainly because of the diversity of techniques the students were *offered* to use and the nature of *open end problems* in the practical part. This observation, however, does not increase the student satisfaction index by itself. Our on-going work on the next edition of the *triple-run* is directed towards improving this situation.

A. *Enabling innovative thinking in CS students*

Innovation, as the catalyst to economical growth, is enabled through combining existing products, processes, services and technologies into a unique (novel) constellation, which is more effective for solving a particular problem. Our credo for enabling the innovative thinking in students includes exposing them to technologies outside the boundaries of the particular subject and giving them free hands to solve open end problems.

In particular, for the D7015E sensor networks course we built a line of reasoning for counter-weighing the processing of real data in resource constraint sensor devices (in-network processing) to processing of real-time data in the high-end back-end systems.

The implementation of our "free-hands-on-open-end-problem" concept is best visible in Figure 4 showing the usage pattern of virtual machine resources (EC-2 instances) of different types. At the course start the main concepts were explained using the least powerful *Micro* instance shown by the green solid line in the chart. Closer to the courses' midterm the students could try the entire palette of cloud functional elements (the dotted red line). Naturally, closer to the end of the course the students converged to an optimal configuration (the dashed blue line), which suits just their needs for implementing their particular design.

B. *Issues connected to using Amazon AWS in programming courses*

Although cloud computing is a mature technology, using it for education purposes in programming-related courses is not trivial. The biggest challenge we encountered is unavailability of an easy to use student and resource management facility.

[7] An interview with one of the triple-run student, [Online]. Available: http://www.ltu.se/ltu/media/news/Utbildningsnyheter/Unikt-projekt-lar-studenter-jobba-i-molnet-1.99264?l=en

[8] According to regulations of Swedish Ministry of Higher Education a course worth 7.5 ECTS credits should generate work load amounting to 200 hours.

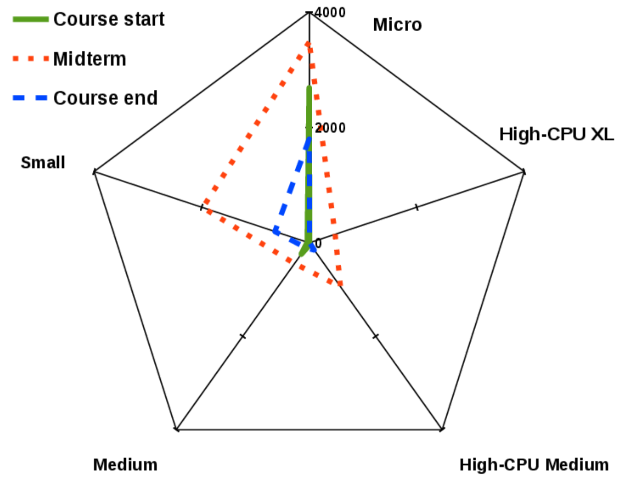

Fig. 4. The de facto work load distribution in terms of hours of usage and types of used EC2 instances.

As a matter of fact the web-based management console of Amazon AWS does not meet the demands of a large group of students with diverse programming skills. For example, when starting an instance of a virtual machine manually, one needs to select an machine image, a security group, and a key pair used for login. With more than 60 students creating own instances under the same AWS account the size of drop-down menus offering functional element quickly became too large making even simple manipulations with the environment long and sometimes frustrating. Although as the course progressed the students started using scripts to manage their resources and the above mentioned issue became less critical, we conjecture that education oriented management tools are a desirable feature in cloud infrastructures.

C. *Economy of the triple-run experiment*

The resulting accounting showed a cost of $200 per student for the duration of the trial. In fact this is a first occasion when we can see the real cost of giving a computer science course per student. This information is normally hidden when using University infrastructure. The question whether this cost is appropriate should be considered while weighting the flexibility and possibilities, which the cloud-based infrastructure provides. Figure 5 shows a distribution of costs per different functional elements of Amazon AWS. The resource allocation amongst different Amazon AWS elements was unequally distributed as depicted in the figure. Most monetary resources were consumed by students using the DynoDB data storage component. In fact this element was not critical for the triple-run practical part and was optional to use. It, however, contributed to almost 70 % of all costs. This is due to a very unclear charging model making it difficult to calculate in-front costs when using this resource. Without this component the cost per student would reduce to a much more reasonable $60.

VII. Conclusions

We presented a teaching experiment named "triple-run". The content and the time line of three courses covering the

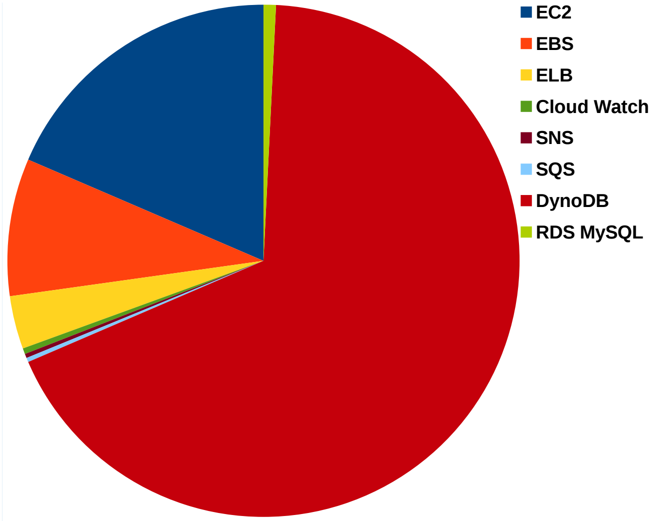

Fig. 5. Distribution of consumed resources per different functional elements in terms of cost.

entire technology chain of Internet of Things were aligned to present a holistic picture to students and enable innovative thinking. The first experiences are definitely positive and we intend to develop and improve the triple-run philosophy further. Main challenges, which remain to address are connected to the logistics of using cloud infrastructure for education purposes.

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Writing Groups in Computer Science Research Labs

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***Abstract*—Researchers must excel at writing to effectively engage the scientific community. Clear and engaging writing advances new knowledge and increases the impact of a researcher's work.**

As developing researchers, it is essential that graduate students learn to write clearly and effectively so that their work is accessible to their peers and colleagues. An essential part of graduate school education should include the teaching of formal writing skills. In most graduate programs, students learn formal writing skills from two sources, their advisors or a writing class. We identify a third source: the graduate student peer group. In this paper, we describe how we leveraged the existing collaborative research dynamic among students in a graduate research lab and created a writing group, similar in spirit to the concept of a reading group.

We describe the inspiration, implementation, and impact of a writing group in a real-world research lab. We show how the writing group started organically after a PhD student took a graduate writing class in the Computer Science Department and thereafter initiated the writing group in his research lab. We also describe how a writing group can be implemented in other research labs to improve the writing of graduate students worldwide.

I. Introduction

Ask any established researcher and she will tell you just how important writing skills are for being a successful researcher and scientist. It is through our writing that we achieve one of our main goals: To spread our ideas to our colleagues and to the general public. Some of the main vectors for the spread of ideas are through written research papers, journal articles, book chapters, email communications, posters, and magazine and newspaper articles, all of which, we hope, are read by our peers.

Graduate students are the next wave of researchers and scientists, and it is our job as educators and advisors to instruct graduate students on all aspects of the research endeavor. We do an excellent job of teaching our students to carry out scientifically sound research, but are we doing an equally excellent job in the related areas of graduate study? In particular, are we teaching our graduate students how to write and communicate their ideas effectively? Do we illuminate all of the components of the writing process and give students the tools for excellent writing?

Excellent writing skills are vital for graduate student success. Great writing can increase the chances that a student's paper is accepted for publication, increase the impact of the student's work, and hopefully increase the number of citations of the student's work. However, more importantly, writing skills provide students with a base of knowledge that will benefit them regardless of their career trajectory—writing skills are equally valued in academia, in industry, in government, and in entrepreneurial ventures.

Traditionally, graduate students learn formal writing skills from interactions with their advisors, either in the form of red-ink editing corrections on a student's manuscript or one-on-one mentoring. A second way that graduate students learn formal writing skills is by participating in an academic writing class focused on the rhetorical demands of science writing [1].

But there is a third source where graduate students can learn formal writing skills—their peer group. In addition to developing the skills of research design and data interpretation, the graduate student peer group provides the ideal social dynamic for the discussion of writing. Building on the culture of group analysis and discussion that already exists in the graduate student research lab, we created and introduce here the concept of a *research lab writing group,* inspired by the idea of the reading group, a common activity in many science research labs.

In the research lab writing group, graduate students not only learn the techniques of formal writing from their peers, they also learn the writing and research norms of their specific research field. Students also gain insights into how other students in their lab approach the writing process.

In this paper, we present the concept of a research lab writing group and describe the high-level goals that such a group should achieve. We also describe the structure of the writing group and the roles and behaviors of the group leader, the authors, and the audience. Our discussion is meant to inspire other graduate students and their advisors to start their own writing groups, thus improving graduate student writing skills in graduate research labs all around the world.

II. Idea Germination

The writing group concept came about after a PhD student completed a graduate-level academic writing course for scientists offered by the Computer Science Department at the University of California, Santa Barbara [1]. After attending the class and soaking up all the writing skills that were offered [2], the student wished to share this knowledge with his fellow graduate students in his research lab.

The student modeled the writing group concept after a common practice in his lab: the reading group. For those who are not familiar, a reading group is a common activity among research labs. The purpose of a reading group is to stay on top of newly published research in a specific field. In most formats, one student is selected to present a research paper to the rest of the group. Most reading group formats meet weekly from 30 minutes to an hour. The student presenting the paper begins by leading the group through an overview of the paper. The

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presenter then moderates a discussion of various aspects of the paper, including the positive contributions of the research, the appropriateness of the topic for the venue, experimental design, weaknesses in any aspect of the work, and future research work related to the paper.

The aspects of a *reading group* that we wish to capture in the *writing group* are the weekly meeting format, the group discussion, and the rotation of student presenters.

We have been running our writing group for 20 weeks in a real-world computer security research lab with 14 PhD students and five interns. Participation is completely voluntary and peer-motivated. Importantly, while the faculty advisors of the research lab encourage the idea, they do not attend the writing group—the creation of the group, the attendance, and the interactive discourse are 100% student driven.

The writing group initially lasted for nine weeks, one week short of the standard 10-week quarterly course. The group went on hiatus after the first 9 weeks, not because of a lack of interest from the students, but because the leader left for a summer internship. Interestingly, as a direct result of writing this paper, the students in the research lab were motived to reestablish the writing group. The second phase of the writing group has been continuing successfully for 11 weeks and is still going strong.

III. Goals

When developing the design of the writing group, we had multiple goals in mind.

To improve the writing of the research lab. It may seem obvious, but our goal, first and foremost, is to enhance the writing of the graduate students in the research lab. We want to foster a culture of writing excellence and support each other through the difficulties of the writing process. We also want to build the confidence of the students and help nonnative English speakers develop advanced English writing skills.

To maximize participation. We want to maximize the number of graduate students who attend the writing group. This increased participation is important for two reasons. First, the more people who attend the meetings, the more impact we can have on their writing. Second, because the writing group is a collaborative meeting, the group as a whole benefits from having the perspective from the most number of students.

To maximize interaction among the participants. We see interaction during the meeting as being different from simply showing up. It is one of our explicit objectives to encourage each lab member to share her ideas and opinions. In addition to looking at writing, we also hope that participants feel increased confidence in their ability to analyze and discuss a research text.

To develop core writing skills as well as a successful and useful approach to the analysis and discussion of texts. Our purpose is to impart the concepts and vocabulary taught in a formal academic writing class, including rhetorical positioning, audience, purpose, development of the problem space, data commentary, clarity, tone, register, coherence, transitions, readability, and so on [3], [4]. We also want to focus on the important sub-genres of a science text like abstracts, introductions, data commentaries and results, literature review, and conclusions.

To be focused on current writing tasks. We want our writing group to focus on current writing tasks so that we can have a direct impact on the quality of the texts produced by lab members. This focus increases the relevance for group members because we look at real texts instead of contrived writing samples. By doing real work, we see increased attendance in the writing group as students are offered the opportunity to read and review current work by their peers.

To spread knowledge among the group about the ways to structure and write about research issues that are idiosyncratic to our area of Computer Science research. We want to make sure that all lab members are aware of the norms and subtleties of science discourse in our specific subfield. These subtleties apply not only to issues such as paper structure, but also to research design and research focus.

IV. Group Structure

We now turn our attention to a description of the specific mechanics of our writing group sessions. We describe the roles involved along with the format of the writing group.

A. Roles

For a writing group to operate successfully and achieve all of the goals we set out in Section III, the roles of each of the participants in the writing group should be well defined. Here, we define the roles in the writing group as we have experienced them, and in Section V we describe the suggested actions and behaviors of each of the roles.

1) Leader: The leader of the writing group is ideally a student who cares deeply about both the writing process and improving the writing of her peers. The leader should have a solid grounding in formal writing skills because it is the leader's job to teach scientific writing concepts. In our writing group, the leader had completed a class in academic writing in our Computer Science Department taught by a linguist on the Computer Science faculty. The leader is in charge of founding and starting the writing group, and preparing the lesson for each meeting.

2) Author: The author is a member of the writing group who is either selected or who volunteers to share her writing with the rest of the group. This role rotates for each meeting. Each author must get ready for the writing group beforehand by preparing her writing sample to share with the group.

3) Audience: The audience is anyone who attends the writing group meeting, excluding that session's author. Nothing is required of these students before the meeting except for an open mind, a passion to improve their writing skills, and the willingness to offer helpful feedback to peer authors. If a faculty member chooses to attend a meeting, she assumes the role of an audience member.

B. Format

We ran our writing group meetings weekly for a total of 20 weeks. To increase attendance, we made the time requirement manageable for the students—30 minutes. And we kept to this time limit strictly, respecting students' busy schedules.

We worked hard to find a time that was convenient for everyone and that did not conflict with regularly-scheduled recurring meetings. Because most graduate students do not have consistent working schedules—some come in to the lab early while others come in much later—we chose a meeting time of 5 PM, as this did not conflict with any other meetings, and the time was late enough in the day that all students in the lab who wanted to attend could be present.

The 30 minutes of the writing group are broken down into two different sections. The first section, lasting ten minutes, is dedicated to teaching and discussing a specific writing concept selected by the leader, such as tone, audience, abstracts, and so on. The leader—the student who had taken the writing class—introduces the writing concept for the first few minutes, and then leads a group discussion about the specific concept.

The second phase of the writing group, lasting 20 minutes, is a group editing session of the author's writing. The author projects her writing onto a screen so that the entire audience can read the text. An important point here is that the author must prepare the text in a format that is easy to edit and change. Specifically, this means either OpenOffice or Google Docs, rather than a LaTeX file that needs to be compiled. The ability of the author to edit text quickly during the group editing session is critical so that all group members can see and evaluate in real-time the changes the author is making to the piece of writing.

Figure 1 shows a real-world group editing session. The author, situated in the upper left, is facing the audience and is ready to make changes to his text. The author's text is projected onto a screen so that the author and the audience can easily read the text at the same time.

Finally, at the end of a writing group session, the leader announces next week's topic, and the group chooses the author for the next week's session.

V. Behavior

Now that we have discussed the roles in the writing group and the format of the writing group, we turn our attention to the behaviors and actions necessary for the writing group to achieve its goals. These observations come from our hands-on experiences with our writing group and clarify the responsibilities of the leader, the author, and the audience.

A. Assembling the Writing Group

Before considering any other part of the writing group, the leader must first get the writing group started. To start the writing group and get maximal attendance from the leader's research peers, it is important for the leader to get buy-in about the writing group idea from some of the students before proposing the creation of a writing group to the entire research lab.

In our case, the leader used a persuasion technique that originated in the business community called pre-wiring [5]. Before announcing the idea for the writing group to the entire lab, the leader personally met with the four students who had been with the research lab the longest to explain the concept and the specifics of the writing group. The goal here was to address any concerns from these students about the writing group and to get them excited about the idea. Then, when the idea was proposed to the entire lab, these four students chimed in that they thought the writing group was a great idea. We believe that using pre-wiring increased attendance and buy-in from the entire group.

B. Ten-minute Teaching Session

The leader begins the writing group by leading a ten minute lecture and discussion about a writing concept announced at the previous meeting.

After the leader lectures and explains the concept, there is an open discussion among the audience facilitated by the leader, focused on the concept. The conversation is meant to address any questions about the concept, to get each member of the audience thinking about how to apply the concept in their own writing, and also to identify areas where the lab's sub-field may apply the concept differently from the general scientific community.

C. Twenty-minute Group Editing Session

The group editing is supervised by the leader. The leader guides the group editing session to focus on the specific topic of the week. For instance, when the leader introduces the concept of the Introduction and how to structure an Introduction in a research paper, the author should be willing to share and discuss the Introduction of her research paper, and the audience should limit its analysis and feedback to the Introduction as well. While it is very useful to focus on the particular "concept of the week," it is equally important that the leader also allow other topics to bubble up organically from the audience.

The leader follows a format for the group editing session. First, the leader asks the author to read her text aloud to the audience. Having authors read their own work out loud is important. First, it is vital, especially for nonnative English speakers, for authors to get a feel for how the writing sounds [6]. The group picks up on sentences and phrasings that do not sound right. Also, places where the author stumbles while reading are possible red flags for revisions and improvements.

After the author reads the text out loud to the group, the leader asks the group for comments and suggestions about how to improve the writing. However, before asking for comments, the leader must make several things clear. First, the author is in complete control of the text and any changes suggested by an audience member are ultimately up to the author's discretion. At the same time, the leader should encourage the author to experiment with changes.

Another important thing that the leader should mention to the group is how nervous an author can feel when their writing is criticized. Therefore, the leader should ask that the group be respectful of the author's feelings when critiquing the text. At the same time, the leader should remind the author that the group is there to help, and that the author should not take comments about the writing personally.

Fig. 1. Group editing session. Note how the author is situated in front of the group and that the author's text is presented on a screen for the entire group to easily read.

The group discussion is so valuable because it offers the writer the unique chance to receive insightful feedback from real readers. The responsibility of the audience, then, is to give helpful suggestions that advance the writer's story, the clarity, the organization, and the readability of the text. We are particularly fond of using Weissberg's approach to keeping audience comments "as specific as possible" [7].

Ideally, the leader lets the group and nature of the discussion develop in a natural manner. Of course, the leader should not hesitate to give her own opinion about the writing and what should be done. The leader must be aware, however, that because of her leadership role, others in the group may perceive the leader's opinion as carrying more weight. It is a subtle but very important aspect of the group dynamic that the leader should tread lightly with her own comments and feedback, and instead engage the group to focus on a specific area by asking leading questions about specific aspects of the text.

During the discussion, the leader should ensure that no one is dominating the conversation (including herself) and that everyone is participating. This can mean directly asking quiet members their opinions about the current topic or directing frequent contributors to let other students have a chance to speak.

We advocate a thorough and detailed approach to group editing. We talk about word choice, idioms, sentence restructuring, sentence combination, adding sentences, deleting sentences, adding connections, reducing repetition, and many other topics. We also play around with different variations and keep working at finding the right phrasing and sentence structure until the author and group are happy. We should also note that the author is not a passive participant in this process. It is the responsibility of the author to take an active role in reworking the text by interacting with each group member who offers feedback.

D. Choosing the Next Author

An important component for the continuing success of the writing group is to have a different author present her work for the group editing session every meeting. The leader should ask, at the end of the current meeting, for volunteer authors for the next week. Some coercion may be necessary to identify a volunteer. It is vital that the leader get a student to verbally commit in front of all her peers to be the author for the next week [8]. This verbal commitment creates a social contract between the author and her peer group, increasing the likelihood that the student will take the responsibility seriously and be prepared to discuss her writing at the next meeting.

VI. Leader Feedback

In this section, we discuss the leader's perspective on what can be improved with the writing group and what is going well.

A. Cons

The biggest drawback of the writing group approach as we implemented it was reliance on a single leader. Once the student had left the lab, no other student stepped up to take over the leadership role. We believe that in the future, reliance on a single leader can be mitigated by the leader actively recruiting assistant leaders to take over when necessary. The leader can ask the assistants to lead a writing group every few weeks, thus cultivating a group of students who feel confident and capable of leading the writing group in the original leader's absence. The reliance on one leader was probably the biggest drawback of the current approach, and when we started up the writing group again the leader made a conscious effort to build a group of capable leaders. Because of these capable leaders, this latest incarnation of the writing group has survived the absence of the original leader.

Everyone is busy (yes, even graduate students), so it is difficult to convince students to attend the writing group. Attendance would frequently dip close to a conference submission deadline, because the students are busy writing papers to meet the deadline. This problem is further compounded because all the students in the lab share the same deadlines. Hence, these deadlines can drop the attendance of the writing group significantly.

Unfortunately, as the leader is a peer of the students, she cannot force them to attend if they are busy. The best way to mitigate the effects of deadlines on the students' attendance is to demonstrate to them, before the deadline, that they will benefit greatly through a group editing of their work. The leader should choose authors to present their work for group edit even when they have a deadline. The rationale here, which must be explained to the authors, is that the authors will get the most out of a group editing session when their text is relevant and about to be submitted. Unfortunately, this approach is not fool-proof, as often before a deadline students are still running experiments rather than writing. Thus, they do not see the benefit of "wasting" a half hour to polish their writing when they still have experiments to run to complete the paper.

Another problem of the writing group is that the learning of the concepts and vocabulary necessary to be able to talk about student texts develops slowly. A shared vocabulary allows students to use statements like "I think that the tone of that paragraph is not appropriate for the given venue," rather than saying "That sentence sounds wrong." A better idea might be to spend more time, perhaps even the entire first meeting, going over the most fundamental writing terms and concepts. The risk here is that the students may lose interest in the writing group because they do not get to participate immediately in the interactive group editing session.

Finally, the role of leader is a huge responsibility. It requires out-of-group time to get things organized, and it asks for focused concentration and real-time teaching and leadership. These responsibilities of the leader are critical for the success of a writing group. At the same time, we want to point out that because the leader is teaching and guiding the group dynamics, she actually receives less benefit from the sessions that the rest of the group members.

B. Pros

Once everyone was on the same level of understanding concerning basic academic writing principles, the group editing sessions increased in efficiency, and we were able to cover more text. This shared level of writing vocabulary had ancillary benefits as well. We observed that the students who participated in the writing group used these concepts when working with each other on other papers. The benefit came not just from students collaborating on the same paper, but also when one student asked another to review or edit her individual paper.

While it is difficult for an author to bare her unfinished work to the world and subject it to the critique of other students, getting the students used to this kind of criticism and feedback was immensely beneficial. Once the students understood not to take the feedback personally, this tolerance and open-mindedness carried over to receiving feedback from others outside the group, including advisors and anonymous reviewers. Developing an open mind and a willingness to listen to feedback without becoming defensive, is an important skill not just in writing but in many other aspects of the career of a scientist.

A benefit for the authors when participating in the writing group editing session is that they learn to think through and justify their writing choices. Often, this process happens before the actual writing group takes place, as the author scrutinizes her work more carefully when she knows that it will be reviewed in the writing group.

During the group editing exercise, the group proposes changes to the author and the author decides to implement the changes or not. The author is encouraged to discuss with the group why she is making the change or why she is not making the change. Teaching authors to look at their own writing and justify the choices they make is an important writing skill, because good writing is all about choices, and a writer who is able to defend those choices, or has at least thought about the choices, will be more deliberate and clear with her writing.

Another huge benefit of the writing group is the transfer of knowledge from the "older" students to the "younger" students. Here, we are not referring to the age of the students, but rather to the length of time they have been in their graduate program. Older students have, on average, read more papers, written more papers, and have an understanding of how their specific field works. This means that the older students have a lot to teach the younger students.

Note that this transfer of knowledge is not limited to writing. Often, we see a lot of benefit from the writing group when older students explain to younger students the idioms and particulars of our field. There are also explanations and discussions about the different writing styles of our advisors. One specific example is our discussion about how one professor prefers to put the Related Work section at the end of a paper, rather than after the Introduction, which is more typical. We feel that this transfer of knowledge among students is critical to the development of the younger graduate students. It helps prevent them from making the same mistakes that the older students made in the early stages of their writing development. Another benefit is that the younger students pay attention to the points the older students make when they read new papers.

While our specific writing group meetings involve only the peers in our lab, a benefit of the writing group is the possibility to have an advisor or even a writing professor attend the meetings and participate in the writing group. The format of the writing group does not need to change to accommodate the newcomer. The beginning ten minute session might be replaced with a lecture from the experienced advisor about any topic related to writing. One caveat to address is that the leader should remind the new attendee, before the meeting and in private, to please consider their words carefully when critiquing the students' work, especially when the new attendee has role power over the student. It is essential for the openness and frank discussion that no student feel ashamed to make a comment because their boss or teacher is in attendance.

Finally, a writing group has a lot of benefit for students who are nonnative speakers of English. As long as there are a few native English speakers in the audience who have an ear for appropriate English usage and idioms, the nonnative speakers can benefit greatly. This transfer of knowledge is similar to the transfer of knowledge from older students to younger students. The native speakers can help the nonnative speakers with the subtleties of English. Specific areas of attention are word choice and phrases or sentences that, while grammatically correct, are not the common or correct way to express a thought.

VII. Student Feedback—In Their Own Words

We asked the students who have participated in the writing group the following three questions: (1) What specifically about the writing group did you find valuable? (2) What would you change about the writing group? (3) Are there any other information or inspiring quotes you'd like to share about writing or the writing group? We selected some of the student comments to share here to provide insight into their experiences with the writing group.

One first-year PhD student wrote that the most valuable part of the writing group was gaining insight into the writing process:

> You see how everybody (even the good writers) are struggling to write even a single paragraph: If you are a bad writer and your writing skills-related self-confidence is near zero (i.e., me), it's a *huge* help to boost your confidence! Writing is hard. Period. It's good to know.
>
> I believe everybody should develop his own writing process: When you don't have one, it's really useful to see how the good writers are actually producing a good paragraph of text! In fact, you are usually able to just "read" a good paragraph, but you don't know what the process is behind it (the really important part).

A third-year PhD student appreciated seeing other students' viewpoints and how they criticized a text:

> I liked to see how others criticize a piece of writing. It certainly widened my view. Particularly, knowing why someone prefers a piece of text to be written in a certain way helps considerably.
>
> I like to hear the unedited version of why others like a style of writing. I prefer their comments to be more about why they personally like it, and not the cliché formatting bugs. This way I can recognize what most people like and why they like it, and not only a standard way of writing (which, by definition, is one of many ways you can write a good text). The personal feedback enables me to change my style more freely, without religiously sticking to unbendable formats.

Another first-year PhD student commented on specific topics that we covered, particularly about the organization of a paper:

> The discussion we had about the paper's organization was really valuable as well. For example, understanding that there is no fixed-rule about where to put the Related Work section is a good thing to know. More in general: Bad writers (me) need to understand which rules are "fixed" and, more importantly, which are *not*!

For improvements to the writing group, one second-year student wanted more focused meetings:

> [An improvement could be] small themed meetings. Like we pick a specific topic (how to connect paragraphs for example) and we speak about it and work on some sample texts. Specifically if we do it on our own papers it will help a lot and improve our writing.

VIII. Concluding Remarks

The goal of the scientist is to share and spread her ideas. An exceptional scientist will write her thoughts clearly and express her ideas elegantly, creating a persuasive story that is readable and interesting to her audience. We believe that developing a culture of excellence in writing should be a fundamental aspect of graduate school education. To achieve this lofty goal, we require new ways of teaching writing skills to train the next generation of scientists who will make breakthroughs we can only dream of.

A research lab writing group, as discussed in this paper, is a novel approach to helping graduate students develop the tools necessary to refine their formal writing skills. In fact, if you have a single student who has completed an advanced writing course who is motivated to form a writing group, an entire research lab can participate in what realistically amounts to a mini-writing class.

We hope you steal our ideas and adapt them to your own research lab. Together we can improve the writing of graduate school scientists in labs all over the world.

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Teaching Web Engineering using a Project Component

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***Abstract*—Web applications are an intricate part of the world today. Everything from banking to checking our Facebook status may now be done through the use of web applications. Todays students need to balance numerous concerns in order to create a web application that is robust, on time and on budget.**

At the Department of Software Engineering at the Rochester Institute of Technology, we created a course called *Web Engineering*. As part of this course, we developed an innovative project component which focused on students following software engineering principles such as elicitation, requirements generation, testing and deployment.

I. Introduction

Web applications represent a confluence of diverse technologies and numerous challenges. Some of which include networked environments, persistent storage, concurrency and usability. Web engineering is defined as the systematic, disciplined and quantifiable approach to development, operation and maintenance of web-based systems and applications [11] [7] [9]. While similar to software engineering, the concept of web engineering differs in several key areas [3]. The planning of continual growth and change has a higher significance in web applications [2].

Last year, the Software Engineering Department at the Rochester Institute of Technology (RIT) added a course entitled Web Engineering to their curriculum which is typically comprised of upper level 3rd through 5th year students. A signficant component to this course was a cross course collaborative effort with a focus on security. The cooperation is beneficial because it allows students to gain experience working with a an adjacent software team. Students will often collaborate in teams in industry, but are often unprepared to do so [6]. Additionally, focusing on security is valuable as web applications expose powerful technologies and assets to the Internet. Application security is an area which students and even workers in industry are typically deficient in [12] [4].

This project component is also distinct in the way it mimics a real world project as closely as possible. Students are not handed a firm list of requirements. They are expected to elicit, negotiate and comprehend changing requirements. This is an area that is extremely important for students have proficiency, but far too often lack [1] [10]. The project also utilized contemporary web technologies that allowed students to create a final product which they were actually interested in using and sharing with friends. This helped to foster student enthusiasm in the project.

In the following experience report, we describe the project as well as future improvements to be implemented in subsequent course offerings. Our goal is to allow other instructors to learn from our experiences and to be able to enact a similar project in their own web engineering courses at their own institutions.

II. Method

A significant aspect of our Web Engineering course was a project component. The main premise of the project was for each group to create a web application using both custom built and already existing components through web service and Application Programming Interface (API) calls while adhering to proper security standards for several vulnerability categories. Some of which included authentication, message encryption, authorization and session management.

The instructor took on two distinct roles for the project: teacher and customer. The way the customer reacts to student questions significantly differs depending on what role the instructor is currently playing. While representing the role of teacher, the instructor may give project advice and answer technical questions wherever possible. As the customer, they attempted to mimic a client in the real world and students were encouraged to clarify requirements with them. So students may understand which role the instructor is playing, students are encouraged to ask whenever they are unsure and begin their inquisitions with As the customer or As the teacher.

The goal of the project is to create a personalized web portal that would be customized for each user. The user initially logs in with their Facebook account. Once the user logged into the application, they are exposed to several pieces of personal, customizable information. One of the most significant is a section on the main page which is very similar to the wall in the traditional Facebook application. For this section, students were asked to again tie into the Facebook API to retrieve the necessary data. They were required to modify the appearance of these items and utilize aspects of usability covered in the course. Various other Facebook APIs such as photo albums, chatting with friends and status updates were used in similar ways. We selected these requirements not only because the Facebook API was readily available, but because we felt that incorporating Facebook here would help to encourage student interest in the project.

Several other aspects of the project required the students to write custom software to interact with extra data services or feeds. Students were asked to incorporate a stock viewing web page into their project. The user would initially enter in a stock that they mythically purchased along with the purchase price and number of shares. This information would

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be stored in a student created relational database. For all of these simulated purchased stocks, information would be retrieved from a third party web service and the page would be expected to display the current stock price, the day's high and low price, along with the amount of money the investment has thus far made or lost for the buyer. A chart is also displayed for the stock which is retrieved using an external feed of the groups choice. Other aspects of the application include a weather based component and a chat feature based upon HTML5. The reason for this chat component is to both familiarize the students with HTML5 and to acquaint them with how to properly place and utilize such an interactive element. In order to acclimate students to development environments like they would encounter in industry, several virtual machines were provided to each team. These were intended to act as development, staging and production environments.

During the ten week quarter, each team was expected to produce several deliverables. The first few weeks of the project aspect of the course focused on building up a base for understanding web engineering along with team formation. Teams of 4-6 students were created since this is often the size of groups in industry and has been found to be conducive to student learning in previous projects [5] [8]. Several roles exist on each team. These included team, development and testing coordinator. Since the course was comprised of upper level students, they were given the opportunity to self-appoint these roles. Students have indicated their satisfaction with this freedom. However, if the class was primarily made up of more novice students, the instructor may want to appoint team roles.

In the third week of the quarter, the students were asked to complete a requirements document and in the subsequent week, a design document. The expectation was laid out to each team that these were to be constantly evolving documents. The grading on these initial deliverables was not aimed at ensuring that the students had a completely accurate document on their first attempt. The main goal was for the students to have followed the proper guidelines for producing these deliverables and that an adequate effort was at least given to create them as accurately as possible. During the second half of each class session, teams were given the opportunity to meet with the instructor to ask requirement and general project questions. In these interactions, the students were also able to negotiate expectations with the customer. They were encouraged to show prototypes, screenshots and anything else they desired to the customer. The goal was not to limit customer interaction, or punish inquisitions as long as they were reasonable. The aim was to encourage customer interaction and elicitation.

The first software release was due in the sixth week of the quarter. Teams were asked to deliver a fully functional version of their application, but with only the functionality agreed upon with the customer for the first release. Less emphasis was placed upon appearance than functionality. Aspects such as mobile compatibility and cross browser support were not evaluated. Teams are also asked to provide updated requirements and design documentation, along with thorough test plans with the implemented tests. Some of which include unit and acceptance tests.

The Software Engineering Department at RIT places a large emphasis on public speaking, presentation and overall communication skills for their students. For the first release, each group was asked to give a 20 minute presentation about some of the major aspects and technologies used in their project. Other areas discussed were team roles and dynamics, a short demonstration of their application and their plan for the second release.

Immediately after the initial release, each group is asked to work on a team self-reflection document. Components of this paper include identifying areas of the project that went well, along with portions of the project which can be improved and how. Students are encouraged to deeply think and elaborate on these areas of went well and what can be improved.

Ensuring an adequate level of security is an important aspect of web based applications [4]. A week after the first release, each group is asked to release their application to a group in a concurrent software security course. The security course, entitled Engineering Secure Software, is a class designed to train students on the principles and practices incorporating security into the entire software development lifecycle. One of the class projects was the development of a web application fuzz testing tool (fuzzer), that automates the discovery of inputs and potential vulnerabilities in websites. Students would develop a set of scripts that would crawl a local website, discover the inputs, and then attempt to exploit those inputs using commonly-used attacks. Each fuzzer team was given a different web engineering product to fuzz, and was asked to report their fuzzing results to the web engineering team.

The second and final release occurs during the last week of the term and is conducted in a very similar fashion to the first release. The major difference is that the appearance and functionality are now both thoroughly evaluated. Additionally, applications are expected to be mobile device friendly. On the final day of class, each group again conducts a post mortem and investigates what went well and why along with what may be improved upon.

A goal of the project is to supply the groups with enough guidelines to provide them a solid direction, but allow them enough freedom in order to be creative. Additionally, the teams were encouraged to work with the customer to formulate extra features for the project which would be beneficial for the customer. This aspect was helpful in stimulating the students ingenuity for the project, working on their elicitation skills and in helping to add variability to each team's final product.

Future instructors are encouraged to deviate at moderate levels as they desire with the requirements for this project. These aberrations will not only keep the projects fresh and allow for freedom from both the instructor and the students, but will allow the instructor to explore and evaluate possible alternative paths for the project so it may be enhanced in future iterations.

III. Outcome

Before the beginning of the term, students expressed their excitement over the course and specifically for the project. They were interested in the real-world aspect of the project and how it interacted with contemporary technologies, tools and practices. Additionally, they were attracted to the freedom that the project structure would afford their teams.

At the conclusion of the course, an anonymous process was used to gather student feedback and was only made visible to the instructor after final grades had been submitted. Generally, the student feedback regarding both the course and project was positive. We feel that some of the reasons for dislike need to be addressed in upcoming course iterations. Other issues are ones which the students may not necessarily enjoy, but are essential for a proper student learning.

The students indicated that they felt the most beneficial learning aspect of the course was the project. Based upon this feedback, we believe that we are on the correct path with the project and feel it only needs tweaking in several areas. Student feedback also indicated several areas which they felt were beneficial. One of the most prevalent was the use of APIs and web services from groups such as Facebook and Google. They enjoyed using current and well known technologies for both their allure and practicality. Students also appreciated beginning the project with a reasonable list of requirements and not having to begin the elicitation phase from scratch. Other areas of positive feedback included the availability of the customer and the ability to self-appoint teams. The following are representative samples of written feedback we have received:

> I really like this project because it is giving us [software engineering students] experience with technologies that companies are truly looking for that without this class there was no formal way to learn. It was really interesting because it covered multiple aspects of web development from using certain frameworks, dealing with social aggregation, hosting our own chat service, and also learning about API's etc. Also it allowed us to see how rapid web development can be and how fast paced the field is

> After taking Web Engineering, I can confidently say: Why isn't there more of this class in our curriculum? As students living a web world, fast requirement shifts and one-click deployment are the norms for modern software vendors. Companies are now, more than ever before, looking for students with skills like JavaScript, Web Application Frameworks, and third party web API's. So far, this is the only class that has managed to capture the buzz that's ultimately here to stay.

IV. Conclusion

This paper presents some early findings regarding a project based component in a web engineering course. The primary areas of the project were discussed. These included the technical details, major deliverables and how the team was expected to interact with the customer. A main goal of this activity is to emulate a real world project situation as closely as possible. The role of the instructor acting as the customer was also conveyed. An interesting aspect of this project was the cross course collaboration which occurred with an adjacent security course. We will evolve and improve this collaboration in future course offerings.

While the course and project component generally went well, several areas can be improved upon. These include altering project requirements to aid in security testing and spending more time acclimating students with various technical concepts of web engineering. Future research will be done to discover how different technologies can be incorporated into the project in order make it both more appealing to the students, but more educational as well. This information will be gathered from instructor observations, official student feedback forms, and informal conversations with the students. We hope that our work in creating and refining a project based component can help others build a more educational and enjoyable web engineering Course for their students.

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Incorporating Service-Oriented Programming Techniques into Undergraduate CS and SE Curricula

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***Abstract*—Service-Oriented Programming (SOP) has emerged as a new programming paradigm that allows the wrapping of existing software as web services, thus permitting the development of new software applications by using existing web services as building blocks. SOP has attracted great attention from industry as it dramatically increases software reuse. Despite the growing demand for an SOP-trained workforce, SOP has not been adequately covered in coursework for undergraduate students in Computer Science (CS) and Software Engineering (SE). This project addresses this curricular shortcoming via the design and creation of SOP materials for undergraduate CS and SE. The concept of *course modules*—self-contained units of instruction that can be incorporated into several existing courses—is used to make these materials accessible at multiple educational institutions. This paper describes an exemplification and visualization framework that supports the teaching of SOP, along with three course modules that can be folded into typical courses currently offered to CS or SE undergraduates.**

Keywords—service-oriented programming; service-oriented architecture; web services; computer science; software engineering

I. Introduction

With the increasing popularity of Service-Oriented Computing (SOC) and Cloud Computing, more and more businesses have started offering various services on the Web [1], [2], [3], [4]. Of the three major types of services, i.e., Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS), SaaS has attracted a fairly large and rapidly increasing number of service providers. With SaaS, the Web is transformed into a programming platform with a large number of software services, which in turn serve as building blocks for constructing new software applications. This dramatic change has thus enabled a new programming paradigm, Service-Oriented Programming (SOP) [5], [6], which is centered on software reuse. SOP's importance is illustrated by a WinterGreen Report [7] that concludes that the global service-oriented middleware market will grow to at least $8.2 billion by 2016.

Unfortunately, these developments in web services, service-oriented computing, cloud computing cloud computing and SOP have not been properly incorporated into undergraduate Computer Science (CS) and Software Engineering (SE) curricula. Courses currently offered are typically aimed at graduate or senior undergraduate students, and focus on research thrusts and open issues in these areas. Few attempts have been made to teach SOP holistically at the undergraduate level, i.e., to teach students how to program using the large number of software services on the Web using SOP. Lim, Hosack and Vogt [8] is the one major exception: they use a web service-oriented approach for teaching SOP as part of freshman computing. Our project draws upon their experiences but makes significant extensions, for example, we provide a more comprehensive coverage of key SOP concepts and technologies; a structured, vertical incorporation of SOP across the undergraduate curriculum; and identification and usage of effective pedagogical methodologies to deliver SOP knowledge to undergraduate students.

Our approach employs two pedagogical methods for effective and timely incorporation of SOP into CS/SE undergraduate curricula. First, an SOP platform is being developed to exemplify and visualize SOP concepts and technologies. Our approach is motivated by *teaching by example*, an effective pedagogy, especially when introducing new technologies to students. Students will learn SOP via the proposed platform that showcases techniques for developing, outsourcing, and composing web services. Second, the curricular materials are being developed in the form of *course modules*, which are well-defined, self-contained units of instruction that can be incorporated into one specific course, either as-is or with minor modification, within several courses currently offered in diverse computing disciplines such as CS or SE. Course modules are becoming common in computing pedagogy, and have been used in introductory programming, computer graphics and security. This modular approach also allows for vertical integration of SOP into the undergraduate curriculum.

The reminder of this paper is organized as follows. Section II presents an example where SOP is used to develop a complex application, and Section III describes our SOP framework that supports the development of SOP applications. In Section IV, we present an overview of three course modules that can be used for teaching SOP and how these modules can be incorporated into existing CS/SE courses. Section V

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summarizes the current status of our project.

II. An Example SOP Application

Suppose we want to develop a web-based hotel query application that allows users to view information about hotels, given a specific location. This is a fairly common web scenario that most people are accustomed to. More specifically, the application may take an address as input from users and then return a list of hotels nearby, perhaps with other related information such as local weather, and driving directions to each selected hotel from another specified address

Obviously, to build such an application from scratch, i.e., without outsourcing any functionality to existing service providers, would take considerable effort and would also require direct access to resources such as database content (hotel, weather and routing information) and efficient query mechanisms for processing and presenting the needed information. However, under the SOP paradigm, we first decompose this application into three components: (1) a *hotel query* component that takes an address as input and returns a list of hotels nearby and related information such as names, addresses, contact phones; (2) a *weather query* component that takes an address as input and returns the local weather information such as temperature and wind; (3) a *route query* component that takes two addresses as input and returns the driving directions between them. To build this application, we then investigate existing web services that can be used to create each of these required components; examples of such web services include the Expedia APIs, the Weather Underground API, and Google Directions APIs. We can finally develop the application using these APIs and connecting them together appropriately.

III. The SOP Framework

The backend of our SOP framework contains a *web service pool* and an *SOP application pool*. The services and the applications are registered in the *registry* that will handle the service queries from students. Students may specify and submit their queries via the *query interface*. They can also publish their own developed services in the registry via the subscription interface, and log the development steps using the logging manager. The *visualization interface* provides a mechanism to visualize the process of SOP application development.

The service pool contains web services that can be outsourced for constructing new applications. For the purpose of exemplification, the services vary in their types, e.g., the two typical interfacing approaches, SOAP (Simple Object Access Protocol) and REST (Representational State Transfer); functionality, e.g., movie service or weather service; and domain, e.g., travel or medical. From these sample services, students can explore the external features such as Web Service Definition Language (WSDL) and Universal Description Discovery and Integration (UDDI) descriptions, and internal features such as implementation code and configuration files, of these services. Beside these "in-house" services, the service pool includes services from third-party providers, e.g., Facebook APIs and Twitter APIs, to enhance service diversity that improves overall learning. The application pool contains those applications built from the services in the service pool.

Our framework uses the two major development platforms for developing web services and SOP applications: J2EE and .NET. In J2EE, web services and applications are implemented using Java on a widely used Integrated Development Environments (IDEs) such as Eclipse and NetBean. In .NET, web services and applications are developed using C# on a current version of Microsoft's Visual Studio.

The framework provides a convenient and flexible interface that can be used by students to search for their desired services and applications. The search criteria can include the service types, development platforms, functionality, and domains. Students can get access to the implementation codes and configuration files of all of the in-house services and applications, as well as WSDL descriptions or documentation of all services in the service pool.

The visualization interface helps to demonstrate how applications may be created by putting together existing services. The interface also shows students how different component services collaborate with one another. In this regard, the visualization interface provides a holistic view that helps students gain a deeper understanding of SOP development, including the generation of message exchanges and invocation orders.

The subscription interface allows students to register their own services and applications to the registry for future use. This helps students enhance their understanding of the fundamental SOP architecture consisting of service providers, service consumer, and service registry. Meanwhile, by allowing them to query and reuse their own services/applications to develop new applications, the subscription interface further strengthens student understanding of software reuse.

IV. SOP Course Modules

A course module is a collection of curricular materials that typically addresses one specific course learning outcome. It removes barriers by providing adoptable materials, summarizes required background expertise, and makes it easier to gain institutional acceptance [9]. Each course module is independent and a faculty member can individually select a course module to experiment with and adopt it to his or her own courses. Table I shows the components of our course modules.

To teach SOP and incorporate the developed course modules into CS/SE curricula, we designed three course modules to be offered at three levels–introductory, mid-level and senior–in both CS and SE. These course modules are discussed next.

A. Course Module 1—Introductory Level

This module targets CS2, the second course in the problem solving sequence typically required for first year students in several computing majors such as Computer Science, Software Engineering, Computer Engineering, and Computational Math. The major components of this course module include lecture slides, sample questions, demos, and labs. The lecture slides provide a brief overview of service-oriented architecture, key Web service standards, including WSDL and UDDI, and the fundamental principles of SOP. Topics span the motivation and historical overview of SOP, typical SOP applications, a comparison of SOP with other problem solving methodologies, and an introduction to the state-of-the-art SOP technologies.

TABLE I. COMPONENTS OF A COURSE MODULE

Component	Brief Description
Overview	Description of module, prerequisite knowledge, and module learning outcomes
Rationale	Motivation for the module
Recommended use	Recommendations for typical usage
Slides	Module content for lectures or independent learning activities
Sample questions	For use in low-stake quizzes
Labs/assignments	For hands-on experiences in solution design, implementation, and verification
FAQ	Answers to students frequently asked questions
Readings	Introductory or supplementary materials referenced in the module
Links	Pointers to online and other materials used in the module
Module evaluation	Assessment tools to measure learning and module effectiveness

In our first offering of this module, we covered these slides between one and two weeks. The sample questions focus on basic SOP concepts and technologies, for example, *"Describe the three roles in a service oriented architecture," "Explain the difference between SOAP and REST,"* and *"Explain the structure of a WSDL document."* The demo showcases the development of a Web service using NetBeans, and of an application that uses several services from the platform's service pool. The labs provide step-by-step instructions for developing web services and SOP applications.

B. Course Module 2—Mid-level

This module targets a mid-level course such as a Programming Language Concepts course, which typically examines various high-level programming languages and different programming paradigms such as imperative, functional, and logic. This module presents SOP as a programming paradigm for reuse, with the lecture slides covering topics including service-oriented architecture, service discovery, service description, service invocation, and service composition. In the first offering of this module, we spent around two weeks on the lectures. Students develop a program library for reuse and clearly identify the contract between the library and its clients; wrap the library as a Web service using that contract; register the service to the platform's poo; perform a UDDI query to the service pool to select the desired services; and use the selected services to construct a client application using Business Process Execution Language (BPEL) or XML Process Definition Language (XPDL).

C. Course Module 3—Senior Level

This module targets a senior level SE course, e.g., Software Engineering of Enterprise Systems, which focuses on the architecture, design, and implementation of enterprise-critical software systems. Topics include service-oriented architecture, cloud infrastructure, service-based workflow systems, adaptive service composition, and Web service security. The course module also includes several elective topics such as efficient service discovery, change management, privacy protection, and Web service transaction management. Two to three weeks of the course schedule is allocated to this module. A team-based, term project provides students with the opportunity to develop an application reflecting a real-world scenario. Students investigate cutting-edge research efforts on the topics covered during lecture, choose appropriate approaches, and integrate them into their projects.

V. CURRENT STATUS

We have developed several sample web services in various domains, including travel, entertainment, and finance, and SOP applications using both Java and C#; we have implemented an initial version of the query, subscription, and visualization interfaces. We have also developed the first versions of the three course modules and have offered two of these modules in spring term in 2013: course module 1, both at Howard University, and SUNY at Oswego, and course module 2 at Rochester Institute of Technology (RIT). We have scheduled workshops on SOP at RIT and at FIE 2013. Once the developed curricular materials and the SOP framework are ready, we plan to post them on our project website.

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Generic integration of remote laboratories in learning and content management systems through federation protocols

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***Abstract*—Educational remote laboratories are a software and hardware tool that allows students to remotely access real equipment located in universities as if they were in a hands-on-lab session. Their integration in Content and Learning Management Systems (CMSs or LMSs) has been an active research topic for years, supporting mainly ad hoc solutions. A notable exception has been the use of federation protocols –commonly used for sharing laboratories from one university to other–, for actually sharing laboratories from a remote laboratory system to a C/LMS. This approach opened new doors in the simplification of the process, since it did not require the remote laboratories to make any type of change. The focus of this contribution is to provide a solution to decrease the number of functionalities required for creating an integration by providing a software component that reuses them. As shown in the contribution, this component has been implemented and two remote laboratory management systems (which provide access to multiple remote laboratories) are already supported, and a third one is under development. In the C/LMS side, all the LMSs supporting IMS LTI are supported, and HTTP APIs are provided for being supported by other systems. Indeed, the contribution describes its support in the Joomla CMS and in the Moodle 1.9 and dotLRN LMSs which do not support IMS LTI. The solution, called gateway4labs, is an open source initiative which targets to be used in production.**

I. INTRODUCTION

An Educational Remote Laboratory is a software and hardware solution that enables students to access real equipment located in their institution, as if they were in a hands-on-lab session. There are many kinds of remote laboratories, including fields such as Physics, Electronics, Robotics or Chemistry. Once these laboratories are available through the Internet, it becomes possible to share them with other universities. Given that both traditional and remote laboratories pass long time unused (nights, weekends, weeks which no practical lessons…), if *University A* shares two laboratories with *University B* and vice versa, then both have 4 labs with similar maintenance costs. For this reason, remote laboratories federations have been explored and been used in production for years.

Integrations of remote laboratories on Content Management Systems (CMSs) or Learning Management Systems (LMSs) –in the rest of the document, C/LMS– have been addressed in the literature. The focus is to integrate remote laboratories (which are educational resources after all) into LMSs (which is where the students and teachers meet and where students find other educational resources). While this integration has always been a relevant topic in the area of remote laboratories, most solutions in the literature have been ad-hoc: this remote laboratory developed in *University A* is integrated in the LMS used in University A and will not work with other C/LMSs. Not supporting this integration forces remote laboratory systems to duplicate certain structures (e.g., authorization) commonly already available in the C/LMS. Additionally, the user experience would be improved if the remote laboratories were treated as yet another educational resource in the LMS.

Last year, the usage of remote laboratories federations for the integration of remote laboratories in C/LMSs was proposed and evaluated [1]. In that contribution, a particular remote laboratory management system (WebLab-Deusto) was integrated in one LMS (Moodle) and one CMS (Joomla) to validate that federation protocols enable this integration in a simple approach. While the approach of using federation for this integration was novel, and it was noticeable that it did not require changes on the remote laboratory management system, it still required much of the logic to be implemented as plugins in the different C/LMSs.

The focus of this contribution is to present a novel and open

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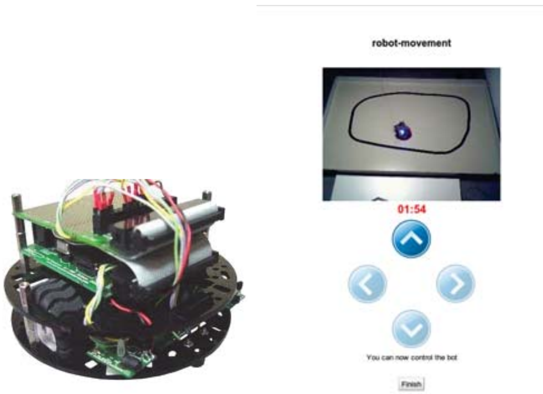

Fig. 1. Robot laboratory [2]. At the left, the mobile robot itself. At the right, the user interface once the program has been submitted.

source software component, called gateway4labs, that makes it possible to support different LMSs through the use of IMS LTI, as well as other systems (such as LMSs not supporting LTI, or CMSs) with lighter plug-ins than it was in that contribution. This component also supports a set of plug-ins for integrating new remote laboratory management systems, so it is extensible in both sides. It has been evaluated testing it in Moodle LMS (through IMS LTI), the .LRN LMS (without IMS LTI) and the Joomla CMS.

The paper is structured as follows: Section II introduces the concepts of remote laboratory, remote laboratory management system and remote laboratory federation. Then, Section III shows what integrations of remote laboratories in C/LMSs are available in the literature. Section IV explains the proposed solution and the analyzed use cases. Finally, Section VI describes the conclusions and the future work.

II. Remote Laboratories Federations

This section introduces the concepts of Remote laboratories, Remote Laboratory Management Systems and remote laboratory federations.

A. Remote Laboratories

A remote laboratory is a software and hardware tool that allows students to remotely access real equipment located in the university. Users access this equipment as if they were in a traditional hands-on-lab session, but through the Internet. To show a clear example, Figure 1 shows a mobile low cost robot laboratory described in [2]. Students learn to program a Microchip PIC microcontroller, and they write the code at home, compile it with the proper tools, and then submit the binary file to a real robot through the Internet. Then, students can see how the robot performs with their program through the Internet (e.g., if it follows the black line according to the submitted program, etc.) in a real environment.

In this line, there are many examples and classifications in the literature [3], [4]. Indeed, remote laboratories were born nearly two decades ago [5], [6], [7], and since then they have been adopted in multiple fields: chemistry [8], [9], physics [10], [11], electronics [12], [13], robotics [14], [15] and even nuclear reactor [16].

B. Remote Laboratory Management Systems

Every remote laboratory manages at least a subset of the following features: authentication, authorization, scheduling users to ensure exclusive accesses -typically through a queue or calendar-based booking-, user tracking and administration tools. These features are common to most remote laboratories, and are actually independent of the particular remote laboratory settings. For example, an authentication and queuing system is valid both for an electronics laboratory and for a chemistry laboratory.

For this reason, Remote Laboratory Management Systems (RLMSs) arose. These systems (e.g., MIT iLabs[1], WebLab-Deusto[2] or Labshare Sahara[3]) provide development toolkits for developing new remote laboratories, as well as management tools and common services (authentication, authorization, scheduling mechanisms). The main idea is that by adding a new feature to one of them (e.g., supporting LDAP, or LMSs), all the laboratories which are developed on top of them will support this feature automatically.

C. Federating Remote Laboratories

One of the features that RLMSs started supporting was federating their remote laboratories. For example, if two universities (*University A* and *University B*) install a particular RLMS, they support federation protocols so *University A* shares a laboratory with students of *University B* without knowing these students. The key here is that the provider university does not need to register particular students, but rather groups or simply universities. It is the consumer system who defines that a set of local users can access a particular laboratory of the provider system.

Therefore, the relationship between two federated entities is the following:

- The consumer system manages the authentication and authorization of its students.
- The provider system manages the scheduling and the access to the laboratories, storing what the users did.
- The consumer system will later ask for results to the provider system.
- In every moment, the provider system does not need to know anything related to the particular students.

D. Relevance

Remote Laboratories have been considered as part of the *Five Major Shifts in 100 years of Engineering Education* in the Special Centennial Issue of the Proceedings of the IEEE [17], in respect to the influence of Information Communications and Computational Technologies.

In particular, the interest on federation of remote laboratories is growing. The Labshare project survey [18], made on all 34 Australian universities offering undergraduate engineering programs, reflects that the interviewed executives were more

[1] http://ilab.mit.edu/
[2] http://www.weblab.deusto.es
[3] http://labshare-sahara.sf.net

interested in getting involved for the pedagogic merits of the remote laboratories, and were more inclined on initially being laboratory consumers than providers. Indeed, the European Union Commission is investing 60 million euros in research actions, projects and network of excellences in Technology-Enhanced Learning (TEL), under the objective ICT-2011.8.1 of the call FP7-ICT-2011-8. One of the target outcomes is precisely *"Supporting European wide federation and use of remote laboratories and virtual experimentations for learning and teaching purposes"*[4]. Indeed, the IP project Go-Lab[5], funded by this call with 10 million euros, aims to support a wide federation of remote and virtual laboratories. Parallel and related efforts have been placed on systems that index remote laboratories located at different institutions such as lab2go [19] or even grant access to laboratories as LiLa [20], [21], [22].

III. Existing Integration of Remote Laboratories in Learning / Content Management Systems

The relevance of this field is that, as detailed in [23], there are several services duplicated between remote laboratories and learning management systems. The administration and user experience would increase if they were merged. Both systems usually support user authentication, authorization, group management, administrative tools, user tracking, and even scheduling. Some integration approaches suggest to delegate all these services to the LMS, but some of these services will still be at least shared, such as scheduling (especially when federation systems arise) or user tracking (since some interactions with the remote laboratory might occur outside the scope of the web browser).

There are two types of solutions in the literature for using Remote laboratories in C/LMSs: ad-hoc solutions or based on federation protocols.

A. Ad-hoc Solutions

In order to integrate remote laboratories and LMSs, [3] discusses the usage of SCORM and [21] implements an architecture around it. This technology is designed to be supported by different LMSs and indeed multiple LMSs have implemented different versions. However, since it is a client-side technology and therefore it cannot contain any server code, it does not support a secure way to exchange credentials, ensure reservations or return results to the LMS.

Other approach is to develop an ad-hoc plug-in to include a particular remote laboratory on a LMS, applying the required changes in the remote laboratory [24]. This approach is common in the literature, and sometimes it is implemented by just copying or exchanging the users among both systems. Within the field of integrating remote laboratories on electronic tools appears the integration of remote laboratories on CMSs. In [25], the remote laboratory relies on Joomla to perform all the administrative tasks. This approach is interesting since it does not duplicates all the tasks refered in [23]. However, it is an example of an ad-hoc integration which does not support the integration of other remote laboratories neither the integration on other CMSs.

[4]http://cordis.europa.eu/fp7/ict/telearn-digicult/telearn-objectives_en.html
[5]http://www.go-lab-project.eu/

B. Federated Solutions

In [1], it was proposed other approach to integrate remote laboratories in C/LMSs, relying on the existing federation protocols already existing in certain RLMSs. The advantage of this approach is that indeed, federation protocols have the same targets as the integration protocols of remote laboratories in C/LMSs, where the consumer system is the C/LMS. Indeed, if in the description of federations presented in Section II-C, the term *consumer system* was replaced by *C/LMS*, the following description would be presented, which applies very well to the definition of integration of remote laboratories in C/LMSs:

- The C/LMS manages the authentication and authorization of its students.
- The provider system manages the scheduling and the access to the laboratories, storing what the users did.
- The C/LMS will later ask for results to the provider system.
- In every moment, the provider system does not need to know anything related to the particular students.

So as to demonstrate this, [1] presented two use cases, both using the WebLab-Deusto RLMS and using plug-ins which consumed the federation protocol for two C/LMSs: Joomla and Moodle. In both cases, the development was dependent on the federation protocol of WebLab-Deusto, and two C/LMS plug-ins which required some administration tasks (for managing the authentication and authorization) were required. The use of federation for integrating different tools has also been addressed in the literature [26].

IV. Discussion

As it was already presented in [1], it is possible to use federation protocols to integrate remote laboratories in C/LMSs. However, the solution presented in that contribution was only suitable for those particular systems (WebLab-Deusto, Joomla, Moodle). However, RLMSs need to support multiple C/LMSs, since they are installed in multiple universities which may use different C/LMSs.

If 3 C/LMSs were aimed, and 2 RLMSs were attempted to be supported, then 6 integrations (and testing) would be required. This does not only increases the time required to support other systems, but also decreases the chances of doing such implementations until it is well known that somebody is going to require them.

Another problem is that these C/LMSs plug-ins shared certain logic. Concepts such as *course A and course B have permission on laboratory L* needed to be implemented in all of them. The implementation and maintenance of the federation protocols of the RLMSs was also required, and it is not a trivial task.

However, let us assume that there was a new component in the middle, between RLMSs and C/LMSs. C/LMSs would build plug-ins aiming this middle component, instead of focusing on a particular RLMS. This component might have a plug-in system, and RLMSs would do the work of developing plug-ins for it, instead of focusing on particular C/LMSs.

The result would be that only 3 C/LMS plug-ins would be required for supporting all the RLMSs that had developed plug-ins. In the same way, 2 RLMS plug-ins would be required for supporting all the C/LMSs. Using this approach, if a RLMS is deployed in a location where a fourth C/LMS was used, it would be easy that they developed the support for that C/LMS. The interesting point is that once they do it, all the supported RLMS (present and future) benefit from this. In the same way, if a RLMS aimed to be supported using this system, it would suddenly be available for all the C/LMSs supported by this component.

Furthermore, once the component supports other existing protocols, RLMSs can be used by them automatically. For example, several LMSs support IMS Basic LTI, which is a standard for interoperability among Learning Tools. Once the component supported Basic LTI, RLMSs could be used by those LMSs supporting Basic LTI without any plug-in or change in the LMS, as it is evaluated in the next section. This approach also opens new opportunities. The GLUE! architecture [27] supports that certail tools (where gateway4labs could be a tool) are consumed by other systems, such as Mediawiki or LAMS. While not tested, it is theorically possible to connect both architectures in a seamless way to benefit each other and extend their tools to be connected.

The target of this contribution is precisely to propose and demonstrate that it is possible to develop such a canonical component, and this improves the current state of integrations of remote laboratories in C/LMSs.

V. Evaluation

So as to evaluate, such component has been implemented and released under an Open Source license, and it has been called gateway4labs[6]. A number of plug-ins to support C/LMSs and RLMSs have been implemented. This section describes this component and how this addresses the contribution of this statement and analyzes it.

A. Overall design

The architecture of gateway4labsis described in Figure 2. In the middle, there is a component called *LabManager*. Then, there are two parts:

- The C/LMS side or *consumer side*, where the different C/LMSs implement one of the supported protocols. The LabManager is not aware of the particular type of C/LMS which consumes it.
- The RLMS side, or *provider side*, where the different RLMSs are managed. The LabManager has a single plug-in for each RLMS, and the RLMSs remain unchanged, since their federation protocols are used.

The LabManager has a registry per each C/LMS, and it is aware of what courses are in each of them. The LabManager administrator configures what laboratories are available in each RLMS, and what C/LMSs have permissions on which laboratories. Then, when an administrator of the C/LMS system enters in the LabManager, he can select which courses will get permissions to each laboratory available for that C/LMS.

[6] http://github.com/gateway4labs

Finally, students enrolled in those courses are automatically enabled to use those laboratories.

The LabManager is Open Source so it can be deployed in each institution, but also the RLMS side can install it to enable access to those universities interested in consuming their laboratories.

B. Consumer side

In the C/LMS side there are two supported approaches: IMS LTI or plug-ins in the C/LMSs by using a RESTful HTTP interface.

The *LabManager* implements IMS LTI (Learning Tools Interoperability, a standard developed by IMS), so any C/LMS implementing it can consume the *LabManager* and therefore, all the laboratories supported by those supported RLMSs. At the time of this writing, this includes Moodle since its 2.2 release, as well as Blackboard, Sakai, WebCT among others. This way, all these LMSs will automatically support all the supported RLMSs directly, without implementing any type of plug-in.

However, not all the C/LMSs support IMS LTI. Ilias, dotLRN, older versions of Moodle still used in production, and most CMSs do not support it. For this reason, gateway4labsalso provides a simple bidirectional HTTP interface that can be consumed by other systems.

The following is a sample request which the C/LMS must perform to the *LabManager*, stating that there is a valid user called “john” (which neither the *LabManager* or the RLMS know), authenticated in the C/LMS, who is requesting the laboratory identified as “robot” for that particular C/LMS. This student is enrolled in a set of courses as student.

```
POST /gateway4labs/labmanager/requests/ HTTP/1.0
Authorization: Basic dW5lZDpwYXNzd29yZA==

{
   "user-id"    : "john",
   "full-name"  : "John Doe",
   "is-admin"   : true,
   "user-agent" : "Mozilla/5.0 (X11; Ubuntu; ...",
   "origin-ip"  : "192.168.1.1",
   "referer"    : "http://.../",
   "courses"    : {
        "01"    : "s",
        "02"    : "s",
        "03"    : "t", // "t" = teacher, "s" = student
        "04"    : "s",
   },
   "request-payload" : "{
        'action'     : 'reserve',
        'laboratory' : 'robot',
   }"
}
```

The *LabManager* relies on the C/LMS for guaranteeing this information. With it, it can check the permissions of those courses to see whether the user can use the “robot” laboratory or not, and this laboratory has previously been mapped by the *LabManager* administrator to a particular RLMS. These courses have previously been added by the C/LMS administrator in the LabManager, using other HTTP interface, but this time provided by the C/LMS through a plug-in.

It is important to remark that this protocol is between the C/LMS server and the *LabManager*. This way, the information

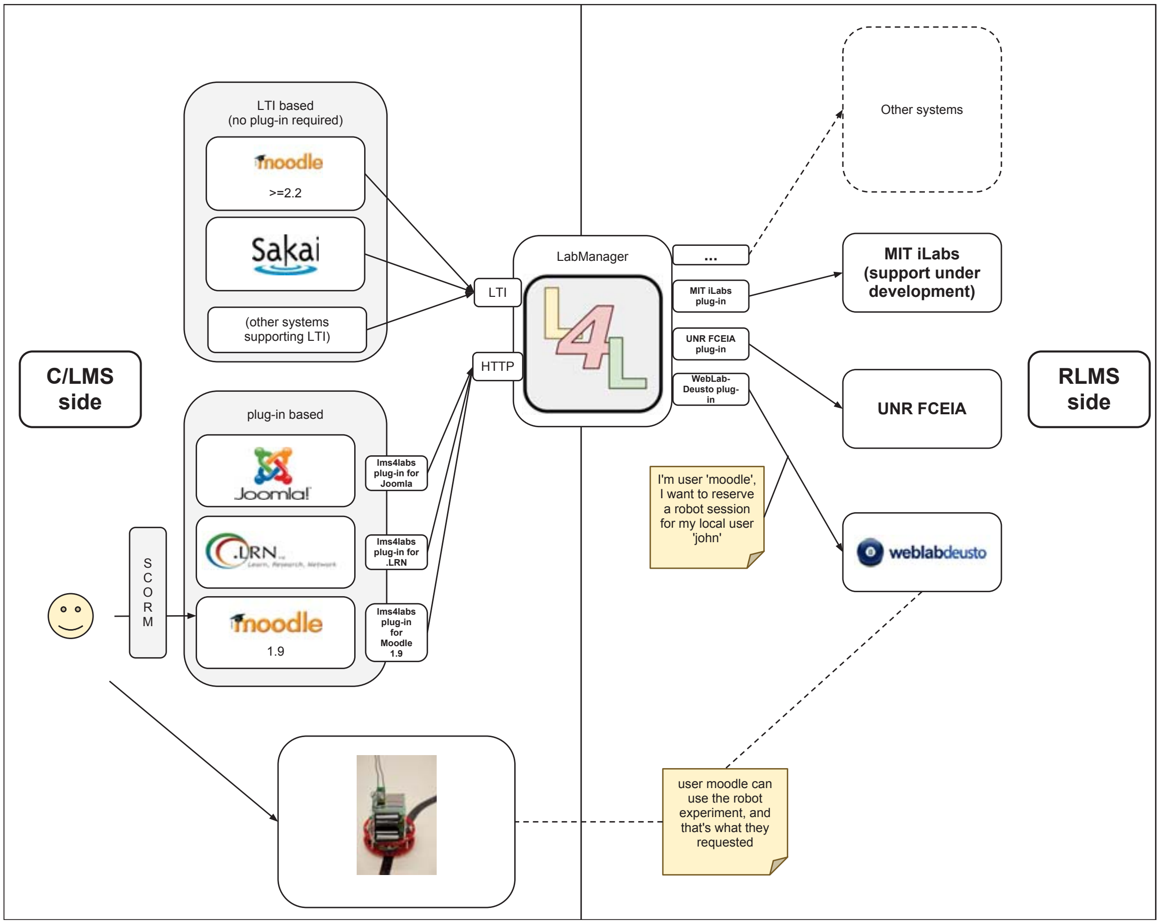

Fig. 2. Architecture of gateway4labs

is securely submitted, but it is required to modify the C/LMS (usually through a plug-in) to do this.

To make the development of this task easier in the case of LMSs, it is optionally possible to rely on SCORM. SCORM is a standard well supported in LMSs which enables instructors to upload contents in a generic format. This format does not support server side code and therefore any solution only relying on it will be insecure. However, the LMS plug-in could implement a simple HTTP API defined by gateway4labs, which enables SCORM objects to be shared among different LMSs supporting gateway4labs. This way, the SCORM objects call this HTTP API, which is implemented by the particular LMS plug-in and calls the HTTP interface explained above at the *LabManager*. This way, the LMS plug-in remains small, since even the contents are developed by the instructors. Unfortunately, for CMSs or systems not supporting SCORM, the user interface must be implemented from scratch.

The IMS LTI approach has been tested with Moodle 2.3, without requiring any development at LMS level (no plug-in was required). The HTTP interface approach has been tested with two LMSs (Moodle 1.9 and dotLRN, both using the SCORM approach mentioned above), and with one CMS (Joomla, without using SCORM).

C. Provider side

The provider side refers to the part of the *LabManager* which supports the different RLMSs. At the time of this writing, a simple interface has been defined, and two implementations have been developed on top of it. The interface basically defines operations such as: *what laboratories do you provide?* and *perform a reservation to a user called "John" to the "Robot laboratory"*, relying on the RLMS federation protocol. The RLMS trusts the *LabManager* and does not need to know "John". The RLMS generates a URL which is passed to the user through the *LabManager*, and therefore the user will finally go to the RLMS with the scheduled session.

At the time of this writing, this interface is always requesting an access *now*, so it fits very well with queueing systems, where students are granted URLs which make students wait in the queue until they use it. However, it has not yet been defined its counterpart for calendar-based booking.

The two plug-ins developed for supporting RLMSs are WebLab-Deusto and FCEIA-UNR. WebLab-Deusto [28] is a pure RLMS on top of which multiple remote laboratories have been developed, mainly in the University of Deusto (Spain) but also in other universities. FCEIA-UNR [29] is a remote laboratory developed in the Universidad Nacional de Rosario (UNR, Argentine).

Support for MIT iLabs is still under development at the

TABLE I. SUPPORTED C/LMSS AND LINES OF CODE. ADMINISTRATION PAGES LINES OF CODE INCLUDED.

C/LMS	Type	Approach	Lines of code
Moodle 2.3 (and others)	LMS	IMS LTI	0
Moodle 1.9	LMS	HTTP + SCORM	504
dotLRN	LMS	HTTP + SCORM	708
Joomla	CMS	HTTP	676

TABLE II. SUPPORTED RLMSS AND LINES OF CODE.

RLMS	Lines of code
WebLab-Deusto	890
FCEIA-UNR	141

time of this writing.

D. Results analysis

This subsection analyzes the approach presented, mainly from the point of view of the complexity and flexibility of the system.

First, let us analyze what is required to support a new C/LMS. In the case of those supporting IMS LTI, nothing is required. As seen on Table I, supporting Moodle 2.3 costs zero lines of code, since no plug-in is required. In the case of those systems where a plug-in is required, the system does not need to deal with authorization (which courses can access which laboratories is implemented in the *LabManager*), neither with the particular laboratories (the plug-ins for the RLMSs are implemented in the *LabManager*), but only implementing the HTTP interface. Additionally, it is possible to support the HTTP interface for supporting SCORM objects and therefore the same SCORM objects can be shared among different LMSs. As seen on Table I, implementing this requires really few lines of code (and take into account that code for administration pages is included).

Second, let us analyze what is required to support a new RLMS. A plug-in must be developed in Python in the *LabManager*, and it will be automatically used by all the C/LMSs. This plug-in depends on the complexity of the RLMS interface. Table II shows that it still requires few lines of code in the case of WebLab-Deusto and FCEIA-UNR.

These results show that a small amount of code is actually required for both C/LMS and RLMS support. This is so since the *LabManager* already implements some of the key shared features, such as user interfaces and selecting which RLMSs are available for each particular course (see Figure 3).

Third, it is remarkable that using this design, every component is implemented only once. The FCEIA-UNR plug-in is developed using Python in the *LabManager* and it is automatically available for all the C/LMS, present and future, regardless they are implemented on PHP (Joomla, Moodle), TCL (dotLRN), Java (Sakai, which supports IMS LTI) or any other technology. No re-implementation is required. This should encourage RLMS developers to develop and provide their own plug-ins to support a wide range of C/LMS systems.

Fourth, as explained in [30], in the RLMS side, depending on its complexity, it is possible to achieve more complex chains. For example, WebLab-Deusto supports transitive federation (University A sharing a laboratory to University B automatically enables University B to re-share it with University C). Applied to this case, this means that being the *LabManager* in University C still enables students to access laboratories of University A.

Finally, from the point of view of efficiency, it might seem that so many layers add an notable latency. However, while the reservation process might add this latency due to the different networks that could be involved (user $\rightarrow$ C/LMS $\rightarrow$ *LabManager* $\rightarrow$ RLMS), the interaction with the final RLMS is direct, so the added latency once using the laboratory is zero.

VI. CONCLUSIONS AND FUTURE WORK

This contribution is based on the assumption that it is possible to integrate remote laboratories in C/LMSs using federation protocols [1]. On top of this assumption, it shows how it is possible to use this approach collecting several common features (e.g., authorization or federation protocols clients) into a single software component. This way, instead of multiplying the supported C/LMSs by the RLMSs for calculating the number of integrations (e.g., supporting 4 C/LMSs in 3 RLMSs would require 12 ad hoc integrations), the number of integrations are notably decreased (e.g., supporting 4 C/LMSs in 3 RLMS would only require 4 integrations with the middle component plus 3 RLMS plug-ins, which not only sums only 7, but each integration is much smaller). Additionally, this encourages different RLMS developers to work together in the support of C/LMSs that will be automatically supported for them.

So as to demonstrate it, this middle component has been implemented, as well as support for certain RLMSs (WebLab-Deusto, FCEIA-UNR) and C/LMSs (using both IMS LTI –which includes Moodle since 2.2 and Sakai among others–; as well as through plug-ins in Joomla, Moodle 1.9 and dotLRN). The number of lines of code have been presented to verify that once the middle component (called *LabManager*) is implemented, all these integrations become small, therefore reusing a lot of code (the whole *LabManager*). This implementation is open source and available for being tested[7].

Regarding future work, ongoing efforts on polishing the system target to use it in production in different universities with students. There are other efforts to support other approaches in the consumer side, to not only support C/LMSs but also Personal Learning Environments (PLEs) such as Graasp[31], as well as other architectures that connect different tools, such as GLUE! [27]. Additionally, one of the drawbacks of the current provider API is that it only supports requests for accessing the remote laboratory at the time of the request, instead of also supporting a calendar-based booking scheme. With its support, more RLMSs will be supported. Finally, the system does not support usage retrieval at this stage.

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[7] http://github.com/gateway4labs

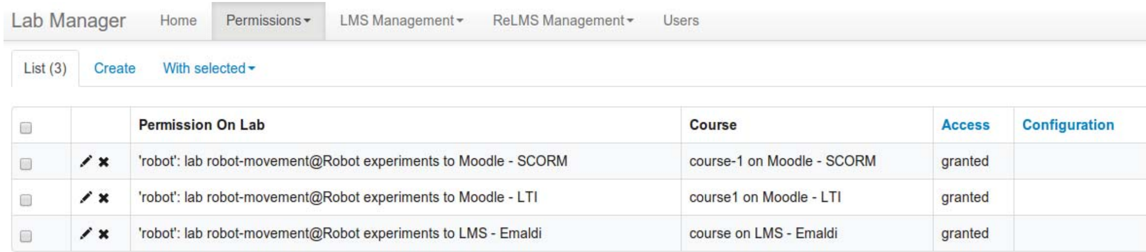

Fig. 3. Example screen of the Lab Manager

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Embedded and Real-time Systems Classes in Traditional and Distance Education Format

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***Abstract*—Embedded Systems design courses are important components in software, computer, and electrical engineering programs and curricula. We describe topics for inclusion in these courses and associated hands-on experiences as required portions of the courses including example development systems based upon two popular microcontrollers. We also describe the challenges of offering these courses in distance format and provide examples of how the hands-on component may be included for distance students.**

Keywords—embedded systems; distance education

I. Introduction

A significant number of computer and software engineers practice in the area of embedded and real-time systems design. Embedded Systems (ES) are found in virtually every application domain such as transportation, defense, communications and industrial control and are also ubiquitous in consumer products such as appliances and televisions. The application settings usually require that the embedded system must adhere to real-time constraints. Therefore, a mainstream topic within modern computer and software engineering curricula is embedded systems design and implementation. Such courses can be very effective when combined with practical laboratory exercises that involve hardware interfacing and the development of systems-on-chip comprised of a processor core, memory, peripherals, and real-time firmware. Using this approach, the student learns the necessary skills of software and hardware design that will provide the foundation for future embedded system design.

Many educators agree that an effective means for administering classes in these areas is to combine a lecture portion with hands-on projects [7][8][9][10]. Consistent with this viewpoint, traditional embedded system courses have separate lecture and laboratory sessions. Students learn embedded system theory and concepts in the lecture session, and then apply this knowledge to practical applications in the laboratory session.

However, there is an increasing number of distance education students who need to participate remotely through various forms of synchronous and asynchronous distance learning. Coupled with the desired content of an embedded systems class is the need for supporting distance education students. The number of students requiring distance education formatted courses continues to increase as more and more students are moving from traditional on-campus class attendance to remotely administered courses [11]. While many methods exist for delivering the lecture session to distance education students, a significant challenge is the delivery of the laboratory sections remotely.

This paper addresses the challenge of offering an embedded systems class containing content consistent with modern processors and design methods in both a traditional and distance education format. Distance education classes that are comprised of laboratory content require carefully crafted experiments and hands-on experiences in order to be successfully administered to distance students. However, there are significant challenges to providing a meaningful laboratory experience to students at a distance. In this paper we describe these challenges and propose some approaches to delivering such a course.

In particular, we describe embedded and real-time systems classes that are based upon the ARM® and Arduino® processor architectures with associated laboratory/project sections that are designed to be accessible by both traditional and distance students. We address the challenge of offering the class in a distance format while also incorporating a required laboratory. A description of experiments and projects is included and is accompanied by an evaluation of different types of equipment, software, and simulators available to support the laboratory section. One of the discussed approaches utilizes a HDL (Hardware Description Language) softcore version of an ARM® processor and HDL descriptions for the interfacing portions of the project. Using these resources, laboratory experiments and course projects can be conducted remotely by distance students.

II. Embedded Systems Background

Embedded systems are generally defined to be any system composed of input/output devices, at least one processor, and dedicated memory that are integrated subsystems within a larger overall system. These systems often have real-time or near real-time constraints in that the production of an output response must occur within some specified time frame after the occurrence of a corresponding input event. For this reason, most embedded systems contain dedicated timers or other means for meeting application-specific deadlines. Other commonly included support circuitry includes data converters for transformation of analog to digital signals and

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vice versa. Many embedded systems involve significant amounts of signal processing capability and the designer must determine which portions of the signal conditioning and processing should be ported into dedicated hardware or implemented in software. The microcontroller unit contains the CPU and is responsible for running the application-specific software as well as providing internal embedded system control.

In modern embedded systems, the CPU is present in the form of a single integrated chip (IC) that is typically comprised of other cores such as timers, on-chip memory, data converters, and hardware accelerators. Many products that have anticipated large volume sales in the marketplace contain custom microcontroller chips that are designed for the specific application and are referred to as a 'System on Chip' (SoC). The design flow for a SoC generally involves the selection of a set of third party vendor cores such as a CPU, memory, I/O interfaces, and hardware accelerators with little custom circuitry. These cores are interconnected within the custom microcontroller through the use of custom or industry standard busses. The use of standardized busses is more common and includes busses such as AMBA, I2C, and others. Bus controller and interface cores are available from third party vendors for inclusion in custom SoC microcontroller designs.

In terms of supporting software, the microcontroller within an ES is most usually intended for a specific function and it is thus uncommon to find commonly known general-purpose operating systems (OS) such as Microsoft Windows in use. Some ES do utilize an OS specifically designed for the ES design space such as open source software variants of Linux or commercial real-time operating system, while other more simple ES rely on simple monitors or even a main controlling program that contains system housekeeping within the dedicated application [5]. Because a typical ES must have the capability to reboot at the time of power-up, the controlling software is typically present in on-board non-volatile memory such as Flash and is referred to as 'firmware'. Those ES that utilize an OS have different requirements as compared to an OS for a general purpose computing system such as a laptop and generally do not need the capability to support a large variety of I/O devices and virtual memory support. Furthermore, most ES utilizing an OS do require a real-time component, thus such OS often support timing relating features.

Many ES are implemented as portable devices such as a cell phone or hearing aids and thus require careful consideration of power usage. Additionally, performance is an important consideration due to processing time constraints. These two design constraints present a tradeoff since power savings is generally inversely proportional to performance. In order to meet ES requirements, the systems level design process involves the determination of a hardware/software co-design partitioning followed by determining how the individual hardware and software components will be implemented. Hardware implementation is accomplished through a selection of third party hard- or soft-cores and the choice of technologies for any custom hardware devices. If it is determined that some hardware components will be directly designed, a further choice is made regarding the use of commercial off-the-shelf (COTS) programmable logic devices versus a standard cell or custom implementation. Similar tradeoffs are made with regard to software implementation with those most crucial portions of the software implemented in low-level assembler language and those less crucial portions implemented in higher-level languages such as *C*. It is often the case that high-level language paradigms such as object-oriented programming are avoided due to the overhead required by the compiler to support features such as operator overloading being to costly in terms of performance.

III. ES Course Core Topics

Embedded system classes are taught at both the undergraduate and graduate levels. Given the description of an ES architecture as provided in the previous section, it is clear that several core academic topics may be present in a typical ES design class. Particular program curricula at a given institution often include some of these topics in prerequisite courses. In this case, the corresponding topic may not be present in the actual ES course syllabus.

1) Digital Logic Design and Implementation
2) Computer Architecture
3) Operating Systems
4) Software Design and Implementation
5) Systems Design and Implementation

Each of the core topics comprises an extensive amount of material and they are typically present in most curricula as one or more stand-alone courses. The IEEE and ACM jointly developed a model undergraduate curriculum for the embedded systems component of a model curriculum as shown in Table I.

TABLE I. ES Class Knowledge Units from 2004 IEEE/ACM Model Curriculum [9]

Topics/Knowledge Units	Importance	Time Allocated
History and Overview	CORE	1
Embedded Microcontrollers	CORE	6
Embedded Programs	CORE	3
Real-Time Operating Systems	CORE	3
Low-Power Computing	CORE	2
Reliable System Design	CORE	2
Design Methodologies	CORE	3
Tool Support	ELECTIVE	variable
Embedded Multiprocessors	ELECTIVE	variable
Networked Embedded Systems	ELECTIVE	variable
Interfacing and Mixed-Signal Systems	ELECTIVE	variable

Uthariaraj and Babu suggested that (a graduate course) in ES should have the following components in [12]:

*"**Introduction**: Embedded computing, characteristics of embedded computing applications, embedded-system design challenges, constraint-driven design, IP-based design, hardware, software codesign*
***Development environment**: Execution environment, memory organization, system space, code space, data space, unpopulated memory space, I/O space, system start-up,*

interrupt response cycle, function calls and stack frames, runtime environment, object placement
Embedded computing platform: *CPU bus, memory devices, I/O devices, component interfacing, designing with microprocessors, development and debugging, design examples, design patterns, data-flow graphs, assembly and linking, basic compilation techniques, analysis and optimization*
Distributed embedded-system design: *Interprocess communication, signals, signals in UML, shared-memory communication, accelerated design, design for video accelerators, networks for embedded systems, network-based design, Internet-enabled systems*
Design techniques: *Design methodologies and tools, design flows, designing hardware and software components, requirement analysis and specification, system analysis and architecture design, system integration, structural and behavioral description, case studies"*

An ES course when offered at the upper-level of an undergraduate curriculum will likely need to include a survey of the most important subtopics within the listed core topics as it is unlikely that a typical undergraduate student will have completed standalone courses for each. The core topic 'Systems Design and Implementation' is likely to be the one where students have the least amount of prerequisite knowledge and will likely represent the area comprising the majority of the ES course content. From this point of view, we describe those subtopics that are most important within each category.

A. Digital Logic Design and Implementation

To support the design of the one or more SoC present in an ES, an intermediate understanding of digital logic design and implementation is needed. Most digital systems designed with FPGA or standard cell technology targets are based upon specification of the desired functionality in the form of a hardware description language (HDL) such as VHDL or Verilog. This HDL description is then used as input to automated logic synthesis tools that result in configuration bitstreams for FPGAs or a 'tape-out' file used by standard cell ASIC manufacturers. Other uses of the HDL specification are to perform pre- and post-synthesis timing analyses and for verification of correct functionality. To perform these tasks, students need familiarity with the use of HDLs and the accompanying electronic design automation (EDA) software tools such as logic synthesis, timing analyzers, simulators, and verification. Additionally, due to the large variety of FPGA architectures, students need some familiarity with the different types of available FPGAs and their strengths and weaknesses.

Another important aspect of this subset of knowledge areas is familiarity with commonly used standards and protocols for digital systems such as the I/O and internal bus standards to be used. It may be the case that familiarity with these standards is not included in a prerequisite digital design course, thus this subject matter is included in the ES course. Another topic that may not be covered to a sufficient degree in a prerequisite digital design course is the interfacing of the ICs that comprise the ES. Knowledge of digital circuit I/O signaling standards and how to select the most appropriate I/O standard is needed.

When ES classes are implemented with an FPGA development board as the principle equipment for the hands-on component, it is important to include a processor core in the system. Some FPGA development boards have dedicated processor chips as on-board assets, but these can be prohibitively expensive. Another alternative is to use a synthesizable processor core such as the NIOS II processor available from the Altera Corporation. This processor is available in softcore format and can be used as an ES microcontroller. The advantage of this approach is that manual wiring and circuit construction skills are not required by students.

B. Computer Architecture

Because the ES contains one or more dedicated CPUs, students must have sufficient knowledge of architectural varieties so that appropriate CPUs can be selected. Furthermore, since it is common that the ES firmware will be implemented at a low-level to exploit performance, knowledge of internal CPU architecture is required to effectively generate the software. Students may have been exposed to CPU architecture in previous courses; however, it is likely that they need more emphasis on how to exploit a particular architecture to achieve gains in performance or to minimize power dissipation.

C. Operating Systems

Because many ES are designed with multiple concurrent tasks and must adhere to real-time deadlines, the inclusion of pertinent OS topics is an important component of an ES class. If an OS class is not a prerequisite course, selected topics must be included in the lecture portion of the course to enable students to utilize an RTOS properly. Such topics include memory protection, critical sections, and RTOS mechanisms for their enforcement such as mutual exclusion and semaphores.

D. Software Design and Implementation

Depending on ES course prerequisites students often have varying degrees of software development experience. The approach taken by some of the authors includes a review of assembler programming concurrently with a study of microcontroller architecture concepts. This provides context for assembler language programming as hands-on experiments involving arithmetic and logic instructions can be included while studying concepts such as fixed-point usage and ALU structure. During the study of memory system architecture and I/O device interfacing, hands-on exercises can also include material that enables students to gain familiarity with various addressing modes in the assembler instruction set and provides a convenient place in the curriculum to review the concepts of pointers in *C*.

Most students are familiar with application development and are accustomed to generating software with a distinct halting state. They are also aware of deterministic finite automata as state machines or counters encountered in a basic digital logic course. Because many ES controller programs have no halting state, the structure of the controlling program as a non-halting state machine is included in the course curriculum. This provides a review of basic *C* control structures and is a good way to begin introduction of Operating System (OS) services. Initially I/O interaction can be implemented in software through the use of polling and delay loops and then follow-on projects can replace delay loops with use of on-board HW programmable timers and polling loops can be replaced with interrupt-driven input.

E. Systems Design Concepts

Concepts from companion courses such as signals and systems, mixed-signal design, and computer arithmetic are important foundations for the ES course. These concepts are briefly reviewed in the ES course as reminder to students who have taken these courses and to provide necessary background for those who have not. Because many ES do not support floating-point HW units, a review of Q notation for fixed-point representations and fixed-point algorithms are included in the ES course. System level concepts include the choice of fixed-point word size and tradeoffs in using fixed- versus floating point.

Many ES contain sensors and output devices that are analog in nature and thus contain data converters for both A/D and D/A conversions. Detailed design of data converters is beyond the scope of a typical ES course; however, system-level concepts regarding data conversion is an important component. The specification of converter resolution and dynamic range are included using logarithmic units (dB) and the resulting effect on system performance are included. This knowledge enables the ES designer to specify and select appropriate data converters for a specific application.

While many students have taken courses in circuit-level design, they are often not aware of various IC signaling standards for IC I/O pins and may not have experience in IC interfacing. Topics that include calculation of pull-up and pull-down resistance values and source and sinking current calculations are provided.

IV. PREVIOUS AND RELATED WORK

Because ES design is a creative activity where multiple unique solutions are possible, we recommend that ES courses contain requisite laboratory sections. A good overview of typical embedded systems laboratory projects is described by and summarized in Figs. 1 and 2.

The laboratory exercises may be implemented as a series of independent experiences that provide experience within each identified topic, or as a cumulative set of exercises culminating in a course design project for an example ES. Regardless of the approach taken, the inclusion of the laboratory portion of the course can present a challenge for distance students. We survey several of these laboratory sections including those used by the authors.

There have been previous attempts to develop laboratory assignments for distance education students. Distance laboratories can be classified as the following two types [4]: (1) Virtual, which use GUI's to simulate physical systems, and (2) Remote, which allow control of real physical systems in a remote location. Examples of virtual laboratories include using simulators for computer architecture and organization courses [3] [13] [18], while examples of remote laboratories include real-time embedded systems for remote controlled robots [2] [14] [15].

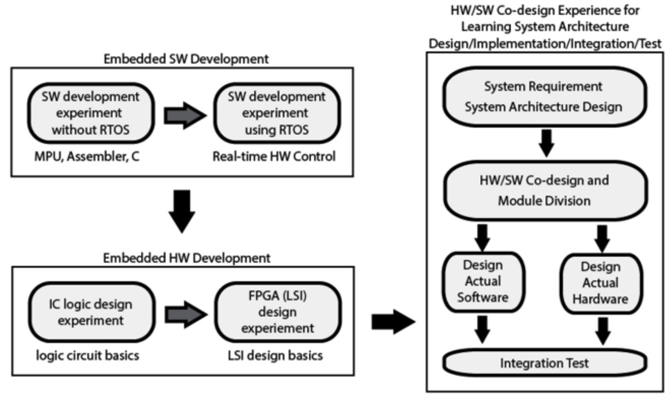

Fig. 1. Embedded System SW and HW Exercise Relationships

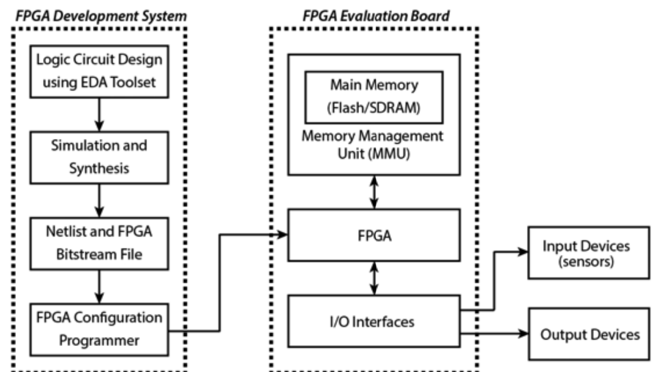

Fig. 2. FPGA-based ES Development System

Some researchers have experimented with virtual laboratories for embedded systems teaching purposes [17] [19] [20] [21]. Virtual laboratories are relatively easy to establish at low cost, but can only model a limited degree of realism [14]. Remote laboratories offer a more realistic laboratory experience; however, this approach often requires expensive equipment and networking resources [6]. Therefore, a common way to address this issue has been to have distance education students combine simulations with using a low-cost, stand-along kit to construct and test their design at their home site [4] [16]. Brejcha et al also developed an online undergraduate embedded systems laboratory course using a remote, virtual laboratory but their results have yet to be reported [1].

The authors' institutions deliver distance courses via the Internet in a number of ways including providing streaming video recordings of course lectures. Distance students can communicate with course instructors through a variety of means including email, phone calls, and web-hosted conferencing services. Examinations are provided to pre-designated proctors for each distance student, or are provided as web-based forms with authentication. This model of course delivery is very similar to that used in some of the recently instituted 'massively open online courses' (MOOCs) offerings.

A. Laboratory Requirements

The at-a-distance laboratory needs for an embedded systems course depend on the concepts to be taught. One model for such a laboratory at different levels is shown in Table II for non-electrical engineers. In this course, the projects and experiments were developed using the Arduino® microcontroller.

TABLE II. ARDUINO®-BASED LAB CONCEPTS AND EQUIPMENT

Level	Concepts	Equipment	Cost
1	• Basic Embedded Systems • Real-time Control • Device Interfacing • High-level Language Programming	• Arduino® board, Sensors, Actuators, wire • Arduino® SW (open src)	• $95 • Free
2	• Adv. Dev. Interfacing • Sampling Theory • Signal Processing	• A/D, D/A, OpAmp • O-scope on chip • Multimeter • Soldering equip.	• $25 • $50 • $40 • $40
3	• ASIC/VLSI • HDL (Verilog)	• EDA Design Tools	• Free
4	• FPGA • SoC	• EDA Design Tools • FPGA board	• Free • $200

- **Level 1**: Arduino® uses a modified *C* language subset with additional language constructs useful for constructing embedded systems such as interrupt control functionality.
- **Level 2**: A/D and D/A converters , op-amps and timers. amd more sophisticated device inputs and control. We assume students own some basic tools such as pliers, screwdrivers, magnifying glass, etc. otherwise these will need to be purchased. $40 for good multimeter and $50 for an oscilloscope on a chip.
- **Level 3**: HDL based design for standards-based peripherals. Utilize an open source simulator or EDA tools on university servers.
- **Level 4**: HDL based design for custom peripherals with implementation on an FPGA evaluation board. Utilize the EDA tools on the FPGA board.

Another ES course that we have offered to 4th-year and new graduate electrical and computer engineering students is shown in Table III. This course is based upon the ARM® processor core and uses the Keil MDK software development system. In contrast to the Arduino® course, the students are assumed to have prerequisite experience in basic digital logic and undergraduate signals and systems. However, the level of programming experience by students in this course is less and many students are unfamiliar with the theory of operating systems and software engineering methodology. For this reason, more emphasis is placed upon low-level programming concepts and less upon digital design.

- **Level 1**: The STM32C board contains memory, I/O interfaces, and external I/O device ports. Additionally it contains user switches, a joystick, and a small graphics output display. Because this class contains students with previous experience in digital circuit design, all ES peripherals are modeled using the buttons/joystick as input sensors and the graphical display as an output. This alleviates distance students from obtaining basic hardware components and performing construction activities remotely. The companion Keil MDK-ARM® software provides support for direct generation of assembler, *C*, or mixed C/assembler programming.

TABLE III. ARM®-BASED LAB CONCEPTS AND EQUIPMENT

Level	Concepts	Equipment	Cost
1	• Computer architecture • ES architecture • CPU architecture • Assembler programming • *C* language programming	• Keil STM32C board • MDK-ARM Lite SW	• $350 • Free
2	• Polling vs. interrupts • Device drivers • Basic OS concepts • Timing and RTOS • Multi-tasking	• MDK-ARM® (RTL)	• $200
3	• Memory interfaces • Parallel bus standard • Serial bus standard	• Standards documents	• Free
4	• A/D and D/A • Memory technology • IC interfacing/signalling	• none	• Free

- **Level 2**: Supported through laboratory exercises that utilize polling and software timing loops, followed by replacing these constructs with interrupt driven input events and the use of on-board programmable timers. OS systems concepts are described in class with emphasis on multi-tasking, deadlock avoidance and prevention through MUTEX blocks and semaphores, and the enforcement of timing deadlines for multiple tasks. Experiments using the Keil RTL RTOS Kernal functions are accomplished in the hands-on portion of the class.
- **Level 3**: This portion of the course begins with memory interfaces and memory decoding design and is followed by extending these concepts to memory mapped I/O interface circuitry. Because the students in this class have previous digital design and Verilog HDL experience, the laboratory portion of the course is implemented by requiring students to implement interface logic in Verilog and to simulate their designs using on-campus tools. It is also possible for students to utilize open source or evaluation versions of HDL simulators on their personal computing devices. HDL testbenches are provided as well as modules that simulate the processor and peripherals and students must design the interfaces. This portion of the course also focuses upon various bus standards and similar approaches to laboratory experiments can be accomplished.
- **Level 4**: This portion of the course consists of a collection of topics that are comprised of a survey of data converter architectures, converter requirements/specifications, internal memory

architecture, and IC interfacing topics. Students are not expected to design data converters but they do gain experience in selection of appropriate converters with respect to performance, dynamic range, resolution, and distortion. A survey of both volatile and non-volatile memory cells at the transistor level is presented so that students may choose the most appropriate types of memory devices to use in ES designs. Finally, students are exposed to concepts involving the calculation of source and sink currents and I/O signaling standards for chip set ICs including how to calculate pull-up and pull-down resistor values and basic topics involving slew rate calculations.

V. Project Examples

In the Arduino® course, students design, build and test a real-time system. Projects that have been completed in the blended graduate course using a "Level 1" laboratory include:

- Traffic light control system
- Anti-lock braking system
- Elevator control system
- Train control system (using model train parts)

Students have written their own operating system (e.g. for one of the embedded platforms), used an open source real-time solution, or simply used non-interrupt driven approaches to achieve simultaneity (e.g. a simple cyclic executive).

Student pilot study involved level-2 laboratory equipment and built a USB interface for Guitar Hero drum-sets that allowed users to play the drums through a Personal Computer or Laptop. The project included the development of the hardware interface design prototype then fabrication on printed circuit board via third party service (cost was less than $20 for fabrication). Software programming included the *C#*, Python, and Arduino® *C* languages.

In the ARM® version of the ES course, the hands-on experiences are provided as a series of experiments or mini-projects. Table IV summarizes one set of experiments for the ARM® version of the course.

VI. Assessment

Multiple choice, fill-in-the-blank, matching and related exams are a widely accepted mechanism to assess learning along the Bloom's knowledge (recall), comprehension (understanding of meaning), application and analysis levels of learning. For example, the professional licensure exam for electrical, computer, and software engineers in the United States uses multiple-choice exams to assess minimal competence and we can model course assessment exams after these instruments. Massively open online courses (MOOCs) also use online assessment to assess student learning. Therefore, we intend to use frequent multiple choice, fill-in the blank, matching, and short answer exams for learning assessment. Where applicable, students will also be required to submit project artifacts such as circuit diagrams, FPGA netlists, Verilog or VHDL files, and *C* and assembler language program source code and block diagrams for manual grading by instructors or instructional assistants.

The hands-on aspect of electronics courses presents certain challenges in assessment of learning from a distance, particularly in demonstration of some level of competence in the construction of demonstration circuits and systems. While for many of the student produced designs hardware description languages can satisfy proof of concept, it may be desirable for students to deliver as-built projects via post or parcel services to the instructor for assessment. As a minimum, distance students are required to email their design files (both HDL and software language) to course instructors who then synthesize, recompile, and implement the distance projects for evaluation.

Shortly after the midterm examinations, students prepare proposals outlining the course project in the form of a brief written document and a presentation slide deck. On-campus students deliver brief presentations of their proposals in class and distance students email their presentations and narrative notes to the distance instructor. In the future, we intend to experiment with remote delivery of project proposals using inexpensive web-cams and Internet communications software such as Skype. This portion of the course provides for assessment of educational objectives involving communication and presentation skills. While the majority of students choose the suggested course project, the proposal activity allows for the possibility for students to propose custom embedded systems projects that are better-suited for their particular interests and provides a mechanism for approval of such projects by the course instructor.

Finally, course evaluation surveys will be administered at the end of the course and these will include questions for students to self-assess learning.

VII. Conclusion

It is possible to build effective laboratories at a distance for embedded systems courses – the blended graduate course and pilot undergrad course as well as the successes of other researchers demonstrate this potential. Distance students face challenges in that live instructor help with respect to circuit debugging is lacking and some degree of maturity in trouble-shooting is required. The availability of low-cost evaluation boards and evaluation versions of software development systems enable students to create their own personal laboratory and project environments. If on-campus licensed software is used, students must have the capability to use their personal computing devices as remote terminals and must login remotely through ssh services or through the establishment of a VPN connection. An alternative to actual circuit construction is the use of HDL simulators; however, students need prerequisite experience in digital logic design based upon RTL HDL descriptions and familiarity with EDA tools and methods is desirable.

It is anticipated that more synthesizable processor cores will become available for student use in the future. One such core that is currently available is the NIOS II core from the Altera corporation. Discussions with personnel at ARM® indicate that a version of the ARM® Cortex-M0 processor core will soon be available for educational use. As these cores become available, ES courses will have more flexibility in choice of equipment for the hands-on portion of the course. To support distance education, it will become more important for students to have familiarity with the use of HDLs for digital design so that softcore processors and FPGAs can be used to support interfacing experiments remotely.

TABLE IV. ARM®-BASED COURSE EXPERIMENTS/MINI-PROJECTS

Topic	Level
Equipment Familiarity: Software Development Environment	0
Assembler: Arithmetic & Logic Instructions	1
Assembler: Memory Access & Addressing Modes	1
Assembler: I/O Access	1, 2
Assembler: Non-OS Output Device Access	1, 2
Verilog: Memory Decoder Design	3, 4
Verilog: Interface Design for Standard Bus	3, 4
C: Non-OS ES with SW Delay Loop and SW Polled Input	1, 2
C: Non-OS ES with HW Timers for Delay and SW Polled Input	1, 2, 3
C: Non-OS ES with HW Timers for Delay and Interrupt-driven Input	1, 2, 3
C: RTOS-based three Task ES with I/O	1, 2, 3, 4

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Student Engagement in Geographically Distributed Classrooms through Localized Solutions

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***Abstract*—Engaging students across geographically distributed teaching and learning activities can be a challenge in contemporary higher institutions. Often, technical constraints, e.g., hardware and software availability, network connectivity and support availability, affect the quality of teaching and learning activities in remote sites. Student participation in the remote sites decreases if the quality of activities is appalling. This paper reports the approaches taken by the faculty and support staff to overcome the challenges in student engagement in a joint graduate research level course on Information Systems geographically distributed in multiple sites in Hong Kong and China. A combination of Web LiveCast and local Voice over IP (VoIP) messaging tools have been deployed on existing thin client hardware to deliver the "quick and dirty" solution. The solution was proved to be effective in improving student engagement, in terms of improved quality in teaching and learning activities, minimal interruption to the students and teachers by preserving the "natural" way of conducting teaching and learning activities, in the remote site without additional resources input on existing solutions.**

Keywords— geographically distributed course, disruptive innovation, localized solution, student engagement, resource utilization.

I. INTRODUCTION

Technical and pedagogical issues on distance learning have been widely discussed in early e-learning literature [1]. During the time when collaborative learning technologies, e.g., Learning Management Systems (LMS) incorporating communication and social media functions, were not widely available to the general users, learners' participation in the distance learning courses were primarily individual and asynchronous in nature. This is exemplified in the evaluation of distance learning models in the past century. Passer and Granger [2] summarize the trend of distance learning models by media and communication. In the matter of the delivery media, the trend of content delivery has been switched from paper content (or physical materials) towards electronic media (e.g., radio broadcast, television broadcast and Internet delivery). In respect of communication mode, the trend tends to shift from asynchronous (e.g., pre-recorded content) to synchronous (e.g., live broadcast from the instructor) and from unilateral delivery (e.g., viewing instructor's teaching) to bilateral interaction (e.g., discussion through text and video conferencing).

The teaching and learning process always involve transferring ambiguous and complex information in a high-speed manner in which quick feedback is desired. Face to face (F2F) settings are always considered to be ideal in education but are always limited in the process of distance learning. "Rich" media, defined as the media that can (1) handle multiple information simultaneously; (2) facilitate rapid feedback; (3) establish a personal focus and (4) utilize natural language, are always the best option to facilitate distance learning [3].According to these criteria, it seems that live broadcasting instructors' teaching with real-time interaction among students would be an ideal option for conducting distance learning. Resources and technical constraints, however, often hinder the implementation of this ideal solution.

One direction to explore the solutions that overcome the constraints is to look at contemporary disruptive innovations [4] that are low cost and low resources demanding, which are potentially useful in distance learning. Building a localized solution with low cost disruptive technologies would be more effective, efficient and, most importantly, practical than introducing a "good quality" solution. One key area of promising disruptive innovation is Peer to Peer (P2P) technology as it eliminates the high cost in conducting traditional interactive sessions through video conferencing with relatively acceptable performance. In developing countries, alternatives to the "good quality" solutions are more realistic to educational institutions because of heavy resources and technology constraints.

The purpose of this paper is to discuss how low cost disruptive technologies can be used to facilitate student learning across geographically distributed campuses of a joint research programme. Resources in these campuses vary significantly in which the "good quality" solution cannot be replicated in other campuses. We chronicle our efforts in designing and implementing a locally built low-cost solution utilizing disruptive technologies to bring real-time engaging student experiences across different campuses in a synchronized manner. Lessons learnt are presented.

II. LITERATURE REVIEW

This section presents two theoretical frameworks on media richness and disruptive innovations respectively. Research on computer-supported distance learning always assert that rich media, e.g., synchronous F2F learning, yield the highest level

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of participation and result in the lowest level of conflicts and misunderstandings among learners and instructors [5]. Richness of media, however, is a subjective perception which is heavily influenced by users' perception on usefulness, ease of use as well as prior usage experience [6]. This implies that IT solutions commonly used in the daily life of learners can positively lead to better learning experience as they are considered as relatively "richer" media than a completely new solution. Notably, integrating disruptive innovations [4, 7] with learning technologies provides a completely user-friendly model on distance learning consuming little resources with acceptable quality.

A. Media Richness and Learning Experience

Media Richness Theory [3, 8] explains the relationship between communication media and the effectiveness of communication. While the purpose of communication is to reduce uncertainty and equivocality, the choice of communication media (electronic or non-electronic) should always achieve this purpose in an effective manner. Although the definition of "rich" media is subjective with respect to different individuals, generally a "rich" medium should possess the following four characteristics: (1) support the provision of fast feedback (e.g., synchronous/ concurrent or asynchronous/ sequential); (2) transmission of multiple non-verbal cues (e.g., emotional tone, attitude or formality); (3) delivery of multiple communication languages (e.g., graphics, tables and text); and (4) provision of personalized messages based on the receiver and the context in which the communication takes place [9].

Concepts of media richness have been integrated into e-learning systems and have positively influenced learners' experience. Rich media has already been included in the design of early desktop videoconferencing system for cooperative tele-learning almost two decades ago [10]. Longitudinal studies show that students at the remote side having access to the rich media for collaborative activities (i.e., cooperative conversation, debate, analysis, interpretation, and information sharing) tend to outperform in the higher level thinking activities than the control groups [10]. Feasibility of wide adoption of this distance collaborative tele-learning model, however, was limited at that time because the network resources (i.e., dedicated ISDN line) and hardware were extremely expensive.

Later research on media richness further confirms that individual and social behavioral factors play an important role in influencing individual's perception on the richness of media. Contemporary work on behavior analysis in electronic collaborative environment shows that users' prior experience with a new collaborative medium and peer effect with communication partners affect individual's perception on media's richness [9]. The effect of good rich media (e.g., virtual world) in knowledge exchange can be comparable to F2F meeting [11].

Even the benefits brought by rich media in delivering more engaging and effective learning to students in geographically distributed learning environments are acknowledged, attempts to implement technical solutions for delivery have been challenging due to technical and financial constraints. Next section presents the framework on disruptive innovations in which practical solutions would be built upon low cost and local resources.

B. Disruptive Innovation in Education

The key concept of disruptive innovation is the displacement of established products (services) by initially basic (simple) products (services) that are rapidly improving to meet general users' needs [7]. From a general users' viewpoint, functionalities that once considered expensive or resource demanding, in terms of financial cost or skilled manpower, will gradually be available in an affordable manner. Classic examples of disruptive innovations in IT include: digital camera (vs. film camera); personal computers (vs. mini computers); cloud computing (vs. mass storage media) and email (vs. fax).

While providing rich media in distance education through traditional educational technologies (e.g., video conferencing with ISDN line [10]) is not always possible, disruptive technology shows a promising direction to support distance learners with engaging and personalized learning environment that seamlessly bridge the local and remote sites in an affordable manner [4]. Personalized applications were once difficult to implement but are critical in e-learning systems as they build up users' habitual and long-term usage [12]. With mobile devices and a variety of disruptive applications, e.g., instant messaging, providing personalized rich media to learner is now possible in a low-cost and user-friendly manner.

User's satisfaction towards the distance learning solution by disruptive technologies, however, should be managed carefully. User's confirmation (i.e., whether the expectations on the solution are met) and satisfaction towards a new IT solution are critical in determining user's future use, and often influential to peers' willingness to use the solution [13, 14]. Once learners encounter disengaging experience when using the new solutions (e.g., unreliable connection or poor multimedia quality), it is likely that they will resist and discontinue in the future.

Next section presents some example of learning technologies used in geographically distributed courses incorporating rich media in different eras.

III. RELATED WORKS

E-Learning solutions for distance learning have been developed progressively with extensive support of rich media and disruptive technologies. This enables the learners to have better learning experience through engagement via active participation. This section examines two selected e-learning solutions that include rich media and social elements for distance learning.

The first case, known as Classroom 2000, was reported in 1999 [15]. Classroom 2000 was an innovative prototype aiming to bring a "living educational environment" to distance students through courseware production. The whole system attempted to make the production of lecture capture easy by simplifying the stages in production, and to provide a sustained way of rich media educational content production. Real-time student-teacher interaction was enabled through a specially developed tool simulating the whiteboard in a physical classroom. The author acknowledged that cost (financial and skilled manpower) and equipment were the major constraints at that moment, but asserted that it was the promising direction for future development.

Until mid-2000's, cost and equipment still remain bottlenecks for synchronous learning [16]. In late 2000's there was a bloom in synchronous learning. Shanghai Jiaotong University in China reported a self-developed integrated mobile learning solution for distance learning in rural branch campuses [17]. The purpose of the development is to provide distance students with live learning experience, i.e., real time interacting with the instructor and students in the main campus hosting the course. The solution includes an in-house developed live web broadcast system specially designed for mobile devices. A localized solution was designed to utilize CDMA network, which was popular among the learners at the time, to deliver rich media lecture. Interaction from students to teacher, however, could only rely on simple text messages.

General trends concluding from the above cases showing the development of distance learning technologies shows that the focus switches from the system development to solution delivery through existing software packages, and from a fixed computing device to mobility at the remote sides. Llamas-Nistal et al. also share similar views, asserting that the solutions have already been integrated in learning management systems [18]. We, therefore, attempt to follow these trends to deliver our solutions with rich media synchronous support by integrating existing low cost solutions. Next section presents the case background, followed by the directions on solution development.

IV. CASE BACKGROUND

At City University of Hong Kong (CityU HK), the history of live education conducted in geographically distributed classrooms can be traced back to the late 1990s. This section presents two cases at CityU that adopts different solutions to facilitate synchronous teaching and learning in geographically distributed classrooms.

A. Remote Classroom: Specialized Venue and Equipment for Overseas Lectures

Early attempts were made to broadcast live lectures hosted from a United States institution to Hong Kong in synchronous mode. As a pilot scheme, this project involved significant resources input, from sophisticated hardware and venue to a team of specialized technical support personnel. A dedicated control room in the university computing services center was set up to facilitate the events with special video-conferencing hardware, e.g., PictureTel video-conferencing products, ceiling microphones, video cameras, CRT projectors, switch signals and a delicate line linking Hong Kong to US classrooms. Apart from the expensive fixed assets, operational cost was high as a team of support staff would be necessary to hold an event. As specialized training was needed to operate the hardware equipment, the whole process could not be carried out smoothly without extensive technical support. The pilot scheme was eventually discontinued due to finance and manpower constraints. High financial cost hindered the institutionalization of the pilot project. Apart from the need for intensive technical support, transparency to the instructors and students, therefore, became an equally important issue negatively affecting user experience as the "natural" way of teaching and learning could not be preserved.

B. Host: Broadcast and Capture for Weekly Research Seminars

The Department of Information Systems (IS) has been hosting weekly research seminars for many years. The research seminars are formally included as a university course for the research postgraduate students in IS. Using video-conferencing tools, the research seminar was broadcast to Suzhou campus (near Shanghai, China) with a dedicated ISDN line. Similar to the previous case, video-conferencing tools have been installed in Hong Kong and Suzhou. Advancement in technology makes it less resources consuming to conduct the seminars but a staff is still needed to operate the video-conferencing system at both sites. Until January 2013, this approach has been implemented in association with the BlackBoard Learning Management System with the following workflow:

- A teaching assistant in Hong Kong collected the presentation materials from the speaker before the seminar and uploaded the materials (e.g., PowerPoint files) to BlackBoard.
- Students from the Suzhou campus downloaded the presentation materials from BlackBoard.
- The technical staff in Hong Kong would establish a dedicated ISDN connection with Suzhou. Often, long distance call was needed to communicate with the teaching assistant in Suzhou.
- The seminar began. Live broadcast was made to Suzhou. Recording would be provided after the seminar on BlackBoard for review.
- Interaction between speaker in Hong Kong and students at Suzhou was facilitated by video-conferencing.

With the expansion of new remote campuses in the mainland China, scalability becomes an issue because of the installation of the designated video-conferencing hardware with a support staff at individual site. This involves extra financial and human resources costs as the existing solution is replicated across multiple sites. The problem intensifies as these remote sites are under tight resources constraints. Often, there is no designated staff member to manage the computing resources at the remote classrooms.

To cope with the resources constraints, especially the constraints on hardware and manpower at the remote campuses, we attempt to design solutions that utilize existing resources available at CityU HK, and at the same time requiring minimal extra input at the remote sites. Localized applications are always the first priority to reduce the technical barriers for users, mainly students at the remote sites, to operate the systems smoothly without needing routine technical support.

The next section discusses the design of our solutions with existing CityU HK resources and promising Voice over IP (VoIP) application.

V. DESIGNING A LIVECAST SOLUTION

Although engagement of remote students are generally higher with extensive use of educational technologies [19], we witness that remote students are dissatisfied and eventually discontinue joining the research seminar course if the technology is unstable (e.g., poor video or audio quality, frequent network breakdown) or difficult to use. The e-learning team of CityU HK, therefore, aims to design a solution that is more reliable and scalable, with low-cost existing applications (e.g., disruptive technology) that are user-friendly at the remote sites, with rich media (e.g., real time audio, video and presentation video) support.

CityU HK has been adopting Echo360 Active Learning Platform institutionally throughout its campus in Hong Kong since 2008. Recent advancement in Echo360 extends its capability from a mere lecture-capture application for review to a platform supporting live broadcast which captures the audio and video of the speakers and materials synchronously, in a fully centralized and automated way. Different stakeholders are involved in the operation of Echo360 LiveCast event held across different campuses:

- CityU HK e-learning team: management and operation of Echo360 infrastructure institutionally
- CityU HK IS technical support team and teaching assistant: on-site technical support for IS research seminar
- Teaching assistants at remote sites: connection to IS seminar LiveCast with a computer and video projector

As the e-learning team in Hong Kong will handle all support centrally, there is no extra financial and manpower cost incurred to remote sites. Echo360 is included in the LiveCast solution in addition to the disruptive technologies. Table 1 shows the design with respect to the IS research seminar.

TABLE I. DESIGN OF SOLUTION USING DISRUPTIVE TECHNOLOGY AND ECHO360

Hardware/ Service	**"Old" solution**	**Proposed solution with disruptive technology**
Networking	Dedicated ISDN lines connecting different sites	The Internet, i.e., using WebCast
Video-conferencing service	PictureTel / PolyCom systems Switch Signal and Control room	Echo360 Lecture Capturing with LiveCast feature (licensed at CityU HK) VoIP applicaion, e.g., Skype/ QQ
Projectors	Two CRT projectors at each site	One video projector at each site
Video/ Audio input	Ceiling microphone and video camera	Web cam or a fixed camera with a wireless microphone
Post-event feedback	Text-only BBS	Discussion Board in BlackBoard

Workflow of our LiveCast solution is summarized below:

- The teaching assistant in Hong Kong informs the e-learning team at CityU HK to schedule the IS Seminar broadcast at the beginning of every semester. The broadcast will be launched automatically every time by the central Echo360 server.
- Before the start of each seminar, the teaching assistant in Hong Kong posts the hyperlink of the LiveCast on BlackBoard.
- Teaching assistants at the remote campuses connect to the LiveCast with a web browser and a standard notebook computer connected with a projector and the Internet.
- Teaching assistants connect to each site with VoIP tools (e.g., Skype or QQ) for questions and answers among speakers and all students at various campuses.

Next section presents the actual implementation of the solution at CityU HK and two remote sites.

VI. IMPLEMENTATION OF SOLUTION: LOCALIZATION WITH DYNAMICITY

To cope with IS Department's extension to two more remote sites (Shenzhen, approximately 40km from Hong Kong and Hefei, approximately 1100km from Hong Kong, see Fig. 1), the e-learning team at CityU HK conducted a series of testing with Echo360 LiveCast inside and outside the Hong Kong campus with the workflow described in the previous section from December 2012 to January 2013. The e-learning team could only use the existing technical and manpower resources to implement the solutions to a more diversified population of new users. The new solution, therefore, should address all technical and resources constraints. At the same time, the solution should provide a user-friendly environment and good user experience to the remote users, especially those users who had negative experience in the "old" sophisticated system with occasional breakdowns. Local testing and remote site testing sessions in Shenzhen have been conducted to optimize the performance of the solution before the first LiveCast event took place in late January 2013.

Fig. 1. *Distibution of CityU HK remote campuses*

A. Local Testing

The workflow of LiveCast establishment described in the previous section was tested in Hong Kong internally at CityU HK and externally with fixed and wireless network connection by a few local telecommunication operators. Results of the testing within the territory of Hong Kong were proved to be satisfactory in terms of synchronous learning experience provision, i.e., coherent audio and video without any interruption or significant delay. Minor technical issues, e.g., screen resolution and network latency, were addressed. Adjustments were made to optimize the system performance during the local testing process, e.g., adjusting the resolution of live seminar capture.

B. Remote Testing in Shenzhen

A visit to Shenzhen site by CityU HK e-learning team was conducted to: (1) identify the inadequacies of the existing video-conferencing solution; (2) figure out the technical limitations, especially on hardware and network connectivity, that restrict the adoption of LiveCast solution; and (3) stakeholders' needs and expectations of the new LiveCast solution. Figure 2 shows the existing ISDN solution for research seminars in Shenzhen.

Fig. 2. *Existing ISDN solution implemented at Shenzhen Campus. The right screen shows the live capture of the seminar in CityU HK using ISDN.*

Hardware in Shenzhen campus were comparable to Hong Kong's venue settings. On the other hand, software installed at the venue becomes a challenge to the e-learning team as local security software would occasionally prohibit the most updated contents (specifically, the most updated hyperlink to the LiveCast event) in Echo360 to be displayed in the browser.

With respect to video and audio quality, new Echo360 solution outperformed the existing solution. However, the interaction from Shenzhen to Hong Kong (e.g., letting participants in Shenzhen to ask questions to the speaker in Hong Kong) became a more complex issue. VoIP solutions (e.g., Skype) was not very stable and did not seem to be very comfortable to the participants.

Addressing the Shenzhen side's concerns, provisional amendments were made to the protocols. First, the e-learning team sets the starting time of the LiveCast 15 minutes earlier to allow sufficient time for the Shenzhen side to connect to the service. Second, a hyperlink directly links to the LiveCast event will be sent separately through BlackBoard to Shenzhen participants. This ensures that the remote side will always receive the most updated contents in case the contents are not displayed in the browser due to the local security software's effects.

The Shenzhen experience is extremely valuable to all stakeholders for the setup of the first IS research seminar using LiveCast event. As Suzhou campus will eventually be relocated to Hefei in the coming year, the e-learning team decided to focus on Hefei site on the first LiveCast.

C. The First LiveCast Event with new Solution: Hong Kong, Hefei and Shenzhen

With the experience in Shenzhen, one staff member from CityU HK e-learning team travelled to Hefei in late January 2013 to replicate the Shenzhen protocol in Hefei for preparation of the first LiveCast event, and to act as the on-site support during the first IS seminar LiveCast on 24 January. Resources are more constrained in Hefei. Table 2 shows the comparison of resources available in different campuses:

TABLE II. COMPARISON OF RESOURCES AVAILBLE IN DIFFERENT CAMPUSES

Hardware/ Service	**Hong Kong**	**Shenzhen**	**Hefei**
Fixed computer	1	1	No
Video projector	2	2	1
Wifi coverage	Yes	Yes	No
LAN coverage	Yes	Yes	Yes

Figure 3 shows the venue settings in Hefei, with only fixed network ports and one video projector available in the venue. As no fixed computer is available in the Hefei classroom, the teaching assistant generously brought her private notebook computer to connect and project the broadcast from Hong Kong on the screen to the whole class.

Fig. 3. *Conference room in Hefei where IS Seminar takes place*

User experience was reported to be unsatisfactory by the Hefei students in the previous IS seminars. Students expressed their dissatisfaction over the quality of broadcast, i.e., frequent breakdown and instable audio and video quality due to the adoption of phased out software, Macromedia Breeze, for IS Seminar in Hefei site. The poor quality was very disengaging to participants and some students eventually did not attend the Live Broadcast of IS Seminars. Quality of LiveCast, therefore, remains the key to engage the students in Hefei.

The Shenzhen protocol was replicated in Hefei for the first IS Seminar event with LiveCast. While the teaching assistant had no difficulties in connecting the personal notebook computer to the Echo360 LiveCast server and Skype connection across sites between Hong Kong, Hefei and Shenzhen's broadcast were not as coherent as expected. On-site support by local technicians was not readily available. Therefore, the on-site e-learning team staff from CityU HK took an active role to co-ordinate the parties at three different sites to work out the adjustment to the broadcast audio and video settings. Figure 4 shows the first LiveCast event took place in Hefei campus.

Fig. 4. *The first IS seminar LiveCast at Hefei. The presentation materials and the speaker from Hong Kong were synchronously available at the remote site.*

VII. User Feedback and Lessons Learnt

Users' immediate comments after the first LiveCast event were positive and encouraging in terms of significantly improved quality of contents and sense of real time engagement, i.e., the sense of being together as a group. The teaching assistant from Hefei emphasized that the audio and video quality of our LiveCast solution was "*far beyond the expectations*" and users at Hefei "*were totally satisfied with the quality*".

Issues arising from the VoIP application were mainly on the audio quality during interaction sessions between various campuses, and the operational issues with respect to its application. First, by nature of the LiveCast solution, a 5-second delay was observed between Hong Kong and other remote campuses. When communicating with VoIP applications across the campuses, echoing effect cannot be avoided especially when the same personal computer is used for both LiveCast and VoIP application. This seriously degrades the audio quality and is can be disturbing to the audience at all campuses. Second, Skype performance is not always reliable in China and is less favorable to the users than the domestic VoIP application.

These problems have been eventually addressed by adding existing hardware and adopting a localized VoIP application. A Hefei student offered to use his private notebook computer solely for VoIP application purpose minimizes the echoing effects. Instead of Skype, a local VoIP application known as QQ is adopted. This gives the local users a more familiar environment.

Resources constraint on hardware and support personnel at Hefei had previously led to the dissatisfied user experience, which in turn demotivated students from attending the seminar broadcast. They felt that downloading and watching the IS seminar archives after the seminar would be more comfortable. Faculty, however, are concerned that real-time group collaboration would be more engaging for active learning. Our solution would solve the previous technical problems by providing more engaging environments for research students to interact together as a group with diverse student populations geographically apart.

We, however, acknowledge that it is only at the preliminary stage of trial run and it is still a long way to institutionalize the whole model. The system log provides some preliminary evidence on the high utilization of our implementation. During this semester, average hit count of seminar archive is reported to be 27 per video archive. In the previous semester when the LiveCast technology was not available, the average hit count is only 2.5 per video archive. This figure confirms the new LiveCast technology is becoming popular among the users.

VIII. Discussion

With all these experiences in facilitating remote classroom, promoting the application in other courses will be the next step. As long as meeting physically is a challenge, the descripted tools and workflow may fine-tune to address the need. Nevertheless, such ad hoc solution needs to be carefully implemented as it lacks enterprise structure for institutionalization. After all, the current solution is adequate for course level applications instead of a completely online programme. The distinctions between such quick and dirty approach and an established protocol for university wide support must be emphasized. A system failure in one of the IS seminar Livecast sessions exposed the reliability issue in the absence of a contingency plan. This leads to the necessity of adjusting users' expectation when alternative solution does not exist.

Analysis on the exponential rise in the hit rate provides us with additional insights on developing technical and non-technical best practices for providing more engaging learning experience to learners in geographically distributed courses. In the technical domain, new solution adopting the "thin" client approach with emerging disruptive technologies is more preferred. Generally, this strategy requires less hardware and human resources. In our IS seminar case, all hardware at the remote sides are "standard" or "common" devices coming from the existing sources (e.g., devices readily available from and commonly used by the students or departments) without additional resources input. This is extremely important if there is a tight resources constraint at any of the remote sites beyond control of the host. "Standard" devices e.g., PC with Internet connection require minimal technical support as users (including students) are familiar with the operations. After the launch of our LiveCast solution, Teaching assistants at the remote campuses have successfully managed the subsequent IS seminar LiveCast events after the short briefing by CityU HK e-learning team staff. The technical support staff who managed IS Seminar at Hong Kong main campus no longer needs to take up an active role in the IS Seminar as the process is now automated. Technical support staff now only handles unexpected events instead of taking up the routine job in operating the ISDN video-conferencing system.

In the non-technical domain, providing good user experience is the key to sustain students' participation in geographically distributed classrooms. Synchronous rich media provide the ideal environment for knowledge exchange but system instability would negatively impact user experience. Hence, intention to continue participating in future event is decreased. Apart from choosing the right hardware and the right applications with carefully designed workflow under the local constraints, users' prior experience with the new solution (particularly on the disruptive technologies) and support availability (logistics and technical) can influence users' level of engagement. Adopting a popular disruptive technology among the user community is more preferred as it reduces the level of fear to technology. Likewise, ease to get support from related parties, although not always available at remote campuses with tight resources constraints, can further facilitate the formation of good user experience.

The new solution also attracts a number of new participants locally in Hong Kong. Further analysis on the hit rate gives us encouraging results on widening the participant population. A number of hit counts have been found from Hong Kong users outside CityU HK campus. While most of the students and faculty in IS Department at CityU HK attend the IS Seminar at the venue (face to face), some students and staff located at offices further away from the Department opt to view the LiveCast. We also discover that graduates from the IS Department continue to participate in the seminars through LiveCast. Before that, they could only have access to the post-seminar video archives.

IX. CONCLUSIONS

While higher institutions are expanding through satellite campuses in different territories, engaging students across different geographically distributed campuses with technology becomes a challenge. Ideally, all students at geographically distributed classrooms should feel being connected together. Synchronous rich media e.g., video-conferencing solutions provide solution but often cannot achieve the outcomes due to financial, hardware and human resources constraints. We aim to solve this problem by designing solutions that (1) utilize existing resources with minimal extra input; (2) integrate promising disruptive technologies to provide useful functionalities in an affordable way; (3) adopt locally popular applications to minimize the support needs. These principles have been applied in a Hong Kong – mainland China joint research level course with dynamic input from the Chinese users at the remote campuses. Results show that the remote students are now more engaged through improved satisfaction on content quality and ease for operation. Surprisingly, our solution brings in more local participants in the local Hong Kong campus.

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Enhanced Recommendations for e-Learning Authoring Tools based on a Proactive Context-aware Recommender

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***Abstract*—Authoring tools are powerful systems in the area of e-Learning that make easier for teachers to create new learning objects by reusing or editing existing educational resources coming from learning repositories or content providers. However, due to the overwhelming number of resources these tools can access, sometimes it is difficult for teachers to find the most suitable resources taking into account their needs in terms of content (e.g. topic) or pedagogical aspects (e.g. target level associated to their students). Recommender systems can take an important role trying to mitigate this problem. In this paper we propose a new model to generate proactive context-aware recommendations on resources during the creation process of a new learning object that a teacher carries out by using an authoring tool. The common use cases covered by the model for having recommendations in online authoring tools and details about the recommender model itself are presented.**

***Index Terms*—Authoring tools; Recommender systems; Learning objects; Proactivity; Context-awareness**

I. Introduction

In the area of e-Learning, authoring tools can help educators to repurpose digitized resources or create complex Learning Objects (LOs) using existing contents from third-party learning repositories. These tools usually present an overwhelming variety of resources, causing a problem related to identifying what are the best ones considering the personal needs of the teacher.

This issue is mitigated in other areas of Technology Enhanced Learning (TEL) by using recommender systems [1]. But in the authoring tool field the use of such kind of systems has not been exploited yet. Authoring tools usually do not take into account the teacher's background and current context while the LO creation process is carried out. The recommender should take into account the history of the user in the current process so as to recommend similar resources. For these reasons, the application of a context-aware recommender system [2] could improve the teacher experience because sometimes simple suggestions following a user-request pattern are not enough when teachers do not know exactly what type of resources are available or when it is possible to request them in the creation process.

In this scenario, a proactive recommender system can play an important role in the decision of which educational contents are more appropriate for a given situation. By analyzing context-awareness information related to the user's needs, like the topic of the LO (i.e. physics) or the target audience (i.e. students level for a school teacher), the system could suggest suitable resources without explicit user request being needed. Therefore, the user would discover the resources at the same time as the requirements appear during the creation process.

Bearing in mind the previous scenario, in this paper we present a new general model to improve previous work on proactive context-aware recommendations in e-Learning systems [3] to be applied in online e-Learning authoring tools. It covers several use cases related to common situations involved in the use of authoring tools to create new LOs based on existing educational resources.

II. Related Work

E-Learning authoring tools are computer based tools that allow a general group (habitually teachers) to create (or author) educational content and LOs that can be usually integrated in a Learning Management System [4].

In TEL a great variety of research and practical applications exist in the area of recommender systems [1]. They are not used only in LO repositories but also in other TEL environments like learning networks and teaching communities [5] or personal learning environments [6]. In addition, they are not exclusively used to recommend interesting LOs but other users and activities [7].

Finally, as Verbet et al. show in their recent survey [2], the use of context-aware recommender systems is becoming relevant in the area of e-Learning. These systems take advantage of contextual information [8] about the user and his/her circumstances so as to increase the level of personalization in the suggestions provided. One specific research line that is getting very popular associated to utilize context is the introduction of *proactivity*, giving rise to proactive context-aware recommender systems [9]. These systems push recommendations to the user when the current situation seems appropriate, without explicit user request, going beyond traditional recommender systems. [10] propose a proactive recommender system in computer-supported learning that works on LO repositories and adapts to a student's profile. Whereas in [3] we propose a proactive context-aware recommender system capable of recommending both, LOs and

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similar peers in an e-Learning social network based on social, location and user context-awareness information.

III. A Model for Proactive Context-Aware Recommendations in Authoring Tools

Fig. 1 presents the general model to incorporate proactive recommendations into e-Learning authoring tools. It covers the following use cases that appears attending to its temporary nature from the point of view of a user utilizing the authoring tool in a general scenario: 1) *Recommending when the user is starting the creation process*, 2) *Recommending while the user is creating the learning object* and 3) *Recommending novel resources when reviewing or editing learning objects*.

A. Context

Using context-awareness information is now a common feature to improve recommender systems in e-Learning on the basis that the more information you have from a user, the more personalized and accurate the results provided will be [2].

We understand context as any information that can be used to characterize the situation of an entity [8]. Therefore, our system is based on two context categories to provide proactive recommendations on relevant educational content related to the LO creation process the teacher carries out: *User context*, i.e. the current activity of the user during the creation process in the authoring tool (e.g. idle or checking educational content like a video); and *Educational context*, i.e. the information related to the educational resources the teacher is using for creating a new LO (e.g. topic, language or target age).

B. Initial Input

The model begins with an optional step consisting of providing initial input about the main educational context values related to the LO the teacher wants to create, like the general topic (e.g. biology), the target level of his/her students (e.g. 14-15 years old), the language (e.g. English) or the target device where the LO will be consumed (e.g. mobile device or desktop computer). Having such kind of data since the beginning would help the system to focus the recommendations sooner, achieving this way the use case 1.

This initial input also covers the use case 3 presented above. When a teacher reviews a LO previously created or edits a LO in a draft state, all the resources used on it are considered to generate an initial educational context input. This allows the recommender to look for novel resources in the same area that did not exist or maybe were not considered relevant in the past.

C. Phase I: Resource Profiling

This is the first step of the 3-phase loop illustrated in Fig. 1. It is in charge of gathering all the metadata related to the resources used during the creation process in order to answer the question *What kind of content have been used?*. This set of metadata conforms the educational context of the LO the teacher is creating. Therefore, the more information the system knows about the resources the teacher is using, the more accurate would be the recommendations provided in the third phase. As a result, the educational context is generated and sent to the next phases.

D. Phase II: Situation Assessment

The second phase tries to answer the question *When to make a recommendation?*. To do it the system calculates a score S1 which is a number between 0 and 1. If S1 exceeds a threshold T1, the third phase will be initiated. If S1 = 1, the highest possible value, then a recommendation would be triggered in any case. If the current situation does not warrant a recommendation, no matter how high a particular resource score, S1 is set to 0 and the recommendation process is aborted without considering resources to recommend. Note that this phase does not take properties of resources into account (i.e. the educational context previously generated). However it considers the current user context represented by the teacher's activity in the authoring tool. For instance, a situation would be more appropriate for a proactive recommendation if the user is idle or browsing resources in the system, compared to a situation in which the teacher is viewing a resource (e.g. a video) to decide if it is suitable or not. This appropriateness factor can be derived by the level of interruptibility allowed by the users in every situation involved in proactive systems. As Gallego et al. [9] shown, the system should avoid disturbing the user if he/she is focused on other important task.

That contextual information related to the user is needed as a prerequisite to calculate S1. In our model, the user context is provided by the platform through the connections between the authoring tool and the recommender system. The parameters related to this user context are domain dependent, and have to be studied for each specific scenario.

Furthermore, the score S1 has an impact on the threshold T2 of the third phase, i.e. the higher S1 is, the lower T2 is set. Therefore, the threshold T2 is a function of S1 in the form: $T2 = |1 - S1|$.

E. Phase III: Resource Assessment

The third phase evaluates the suitability of particular resources trying to answer the question *Which resources to recommend?*. Any recommender algorithm that considers the educational context information provided is valid. A content-based [11] would be a good option as it recommends items that are similar to those that a user has utilized or liked in the past, or as in our case, has selected in the current LO creation process. Hence, various candidate resources would be compared with other previously used by the user and the best-matching resources are recommended. This can be improved by adding the information store in the recommender data base that allows the system to increase the weight of those resources that have been used intensively by other teachers, meaning their relevancy in that area of knowledge.

The result must be a score S2 normalized to [0, 1] (with S2 = 1 being the best possible score) for each resource in the candidate set. S2 corresponds to the predicted rating of the recommendation algorithm selected. The candidate resources

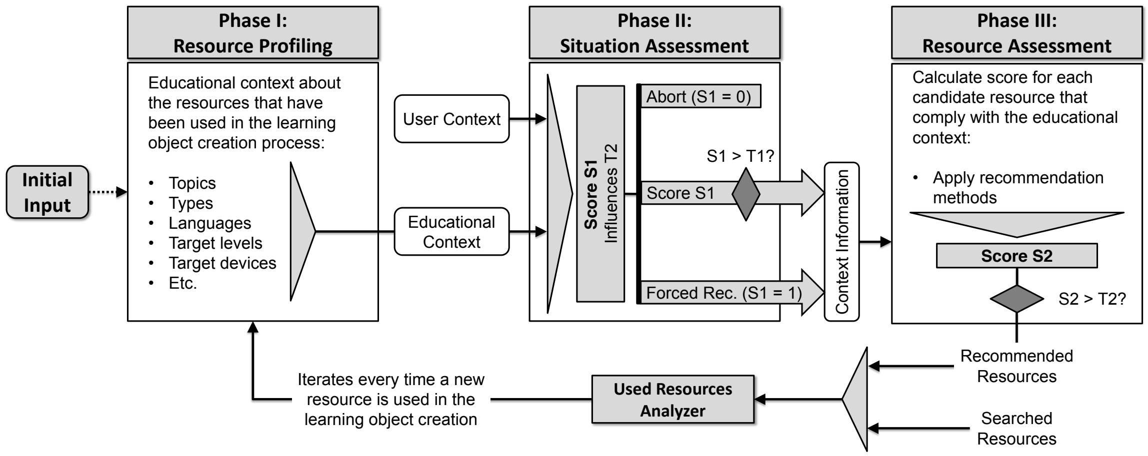

Fig. 1. Model for generating proactive context-aware recommendations in e-Learning authoring tools.

would be ranked according to S2 and tested against the threshold T2. If S2 $>$ T2 for a resource, then it is finally considered for recommendation and the user is notified. If no resource score S2 exceeds the threshold T2, then no one is recommended, the process is aborted and restarted when the condition to loop again is met.

After the recommended items are communicated to the teacher, he/she might select one of them or might not (i.e. by accepting or rejecting the recommendation). This occurs also with the resources the teacher looks for in the authoring tool (as they can be suitable or not for his/her interests). In Fig. 1 this is represented by the loop linking the last phase with the first one. It takes into account all the resources (i.e. recommended or searched) to be evaluated by the *used resources analyzer*. Each time a new resource is added to the LO the teacher is creating, the analyzer fires a new loop that initiates the model again (as new resources information is available for the first phase). As a result, the use case 2 is achieved because the loop is continually repeated while the previous condition is reached.

IV. Conclusion and Future Work

In this paper we have presented a novel model for generating proactive context-aware recommendations in e-Learning authoring tools. It is based on analyzing the current user activity as well as the educational context related to the resources the teacher selects during the learning object creation process to recommend similar resources. This is done in several temporal instants: at the beginning of the creation process, during the process itself and when the learning object is reviewed or edited to be improved with novel material after it has been created. The recommendations are provided in a proactive way when the situation seems appropriate without explicit user request.

The model has been designed to support a general scenario in which no previous information about the user is needed, being the only requirement the necessity of having connection to online general content providers and educational learning repositories.

Open challenges consists of implementing the model in a real scenario related to an existing online e-Learning authoring tool in order to validate it. In relation with this, studying the impact in the user experience of teachers having such kind of proactive recommendation in an authoring tool would be an interesting research line to investigate.

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Improving student outcomes in distance learning mathematics classes

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***Abstract*— Participation in online courses has significantly increased in recent times. Student performance in online mathematics classes lag behind their counterparts in other subject areas. We hypothesize that one of the main reasons for this is the lack of technological tools for effective communication of mathematics via the Internet. We propose to test our hypothesis by implementing new technologies and evaluate the difference in course performance and attrition rates between the students who use these technologies and a control group.**

Keywords—distance education; mathematics education; developmental algebra; learning technology

I. Introduction

In the past decade, demand for distance learning courses has soared due to the entrance of many nontraditional students into the realm of higher education [1]. For courses that require only reading and discussion, online environments provide the medium for students to share their ideas and communicate. Where mathematics is concerned, however, the situation changes. Mathematics students are expected to learn specific objective skills which often have a prescribed set of concepts that must be successfully mastered. Because of the notation and computations required, students often have difficulty communicating ideas in a distance learning mathematics course [2].

Since online courses rely heavily on written communication, one can see how problematic this situation may be. While online course management systems do have the technology to incorporate mathematical equations and formulas into discussion boards, they are usually only rudimentary in nature [3]. That is, the students are able to insert equations and mathematical notation into documents and discussion boards, and not much else. The technologies that do exist may be insufficient and/or cumbersome to implement. Although typesetting of mathematics is typically done with LaTeX in an offline environment, a universal standard for displaying equations on the web does not exist, although there are several tools that can be used to publish LaTeX on web pages.

Research shows not only that the attrition rates in distance learning humanities courses is significantly lower than in mathematics courses but also that there is not a significant difference in attrition rates of humanities and mathematics courses in the traditional classroom [4]. Not only that, but additional research exists that indicates course management systems need to be diversified across disciplines to meet the very different course objectives that each discipline requires [5]. Many of the existing course management systems seem to be created with generalization in mind. In fact, some research indicates that students in different disciplines use course management systems very differently, accessing different types of available course resources [5]. Clearly, one size does not fit all, and we see from prior research that the online courses in the discipline of mathematics need additional specialized tools to help students overcome the challenges they present.

With this information in mind, we can infer that there is something amiss in the delivery of mathematical content via distance learning. We conjecture that the difficulty in online communication of mathematics is a significant portion of the reason that students do not succeed in distance learning mathematics courses, and that many existing course management software packages do not include sufficient support for mathematics content, even if some support is already included.

II. Discussion

Besides a coherent and thorough curriculum, the most obvious need that must be met for students taking distance learning mathematics courses is an effective medium of communication. Many of the discussion board functions of popular course management systems do not offer anything beyond rudimentary means of displaying mathematial equations, and even so, users did not feel they were effective tools [6]. This, however, is not entirely the fault of the software developers. Given that there is no defined standard for displaying mathematical equations online in addition to the limited research on distance learning in mathematics, software developers may be unaware that a need exists or are waiting for a broad standard to be defined before spending a significant amount of time and funds on these functions.

The lack of software solutions provided by the developers of popular learning management systems has not impacted third-party software creation, however. An example of software developed for use in online mathematics courses is Wiris Editor [7]. Wiris Editor is a cross-platform solution used to include simple and complex mathematical formulas and graphs within discussion forum posts and other areas in an online classroom. This enables both instructors and students to include a variety of mathematical content in an online course

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without cumbersome technological workarounds and difficulties. Due to the cross-platform nature of Wiris Editor, it can be utilized with many different course management systems seamlessly.

Additionally, there is an expanded version of Wiris Editor called Wiris CAS [8], which is a full computer algebra system that also has graphing capabilities. This further expands the students' ability to communicate using multiple representations of mathematical concepts and techniques as well as providing them with just in time computational and graphing abilities to verify answers. By using these tools, students will be able to explore a variety of topics that are taught in both developmental and credit college mathematics courses.

Finally, a third technology, which uses Wiris CAS as an engine for its computations is called Wiris Quizzes [9]. This application is a flexible addition to an online mathematics course, allowing an instructor to assess students, or even by providing a way for students to obtain additional experience with the types of problems taught in the course. Wiris Quizzes allows for parameterization of questions, so each student receives a unique problem to work. While this is useful for assessment, it is also an excellent method to provide students with a virtually limitless set of practice problems to master the objectives of the course.

By providing students with enhanced means to to display complex equations and provide explicit examples online for both their instructor and their peers, we believe that they will gain facility in communicating mathematically. Not only this, if students have questions, they will be able to ask the community within the class for assistance, or even test hypotheses and conjectures themselves by using the computational components of these tools to assist them. Tools like the Wiris suite allow a student to be more eloquent and precise in their explanations, thus making it easier for the online community to pinpoint and remedy the confusion they are experiencing. We believe that the more support students have, the more likely they are to succeed in the course. Mathematical learning can be frustrating and slow when working in isolation, especially for those who struggle with mathematics in a traditional classroom.

III. Research Plan

We are at the beginning stages of this endeavor. Our plan is to study several developmental distance learning mathematics classes at a large community college in the southern United States starting in Fall 2013. Our primary goal is to determine if providing additional technological tools within a distance learning mathematics course will have an effect on the attrition as well as the passing rate of the students in the given courses. Since there are many possible reasons for attrition and/or failure in an online mathematics class, our study will be a multidimensional quantitative study with use of blocking to reduce confounding variables. Our pilot will include at least four classes with approximately 50 students in each of them. The classes studied will be randomly assigned to either receive the treatment (consisting of the Wiris Editor, Wiris Quizzes, and Wiris CAS software used within the course) or the control group, which will receive no treatment and only use the basic online course system with no modifications. Since we must also control for outside factors, we will also block by type of problem, such as computation, graphing/visual, and word problems to see if the type of problem has an effect between groups.

Additionally, to control for unexplained variation in the results, the courses will use the same assessments and be graded with the same rubric by the grader. In an ideal situation, we would like the courses to have the same instructor, but for practical purposes, we will attempt to study classes where the instructors have similar levels of experience teaching the course. At the end of the courses, we will examine the data to see if there is a significant difference between assessment results (summative unit assessments and final examinations) from the experimental group versus the control group. We will also see if the attrition rate is different between the two groups.

As a basis for comparison, we will request attrition and grade distribution data for the same course taught within the community college in a traditional classroom environment. We will then compare the three groups (modified distance learning, unmodified distance learning, and traditional classroom) to see what differences may exist between all the methods of delivery. Finally, we will collect demographic and other academic information (such as overall GPA and SAT/ACT score) to determine if there are overarching external factors that may attribute to students' likelihood for success in distance learning mathematics courses. We may also investigate any other anomalies or unexpected results discovered during the course of data analysis since we are collecting a large amount of data on the participants in the study.

If our pilot study shows significant gains in the treatment versus the control group, we will expand the study for at least one further semester to increase our sample size and see if the pilot study's results can be replicated.

Closing Remarks

By investigating the use of technology to provide students with better opportunities to read and communicate mathematics in an online environment, we hope to take the first steps in improving the success rate of those in distance learning mathematics courses. With the rapid expansion in numbers of students taking courses in this fashion, it is imperative that we address these issues and work toward successful outcomes for these students.

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INFLUENCE OF ENTREPRENEURIAL APTITUDE ON TECHNOLOGY ENTREPRENEURSHIP COURSE PERFORMANCE

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Abstract -- In a computing technology entrepreneurship course offered in fall 2011, students were separated into teams of three and four students and taught the concepts and skills of teamwork, innovation, and entrepreneurship. They applied these concepts and skills to an open-ended project for a niche market financial or healthcare information technology product. Each team produced a product supported by a business plan and PowerPoint presentation as the project deliverable. The course was supported by mentors for the teams and guest lecturers. In spring 2011, a Data Mining course was offered where no direct instruction in teamwork, innovation, and entrepreneurship was provided, but the student teams were assigned a similar open-ended project. The objective of this exploratory study is to evaluate students and teams' relative increase in entrepreneurial aptitude. The two courses' performances were determined by the project quality and course grades (average in-class and final examinations) supplemented by a post survey of student perceptions of course related gains and changes in attitudes. As expected, the quality of the team projects produced and the correlation analysis of the examination grades in the Technology Entrepreneurship course showed relative improvement over those produced in the Data Mining course.

Keywords— Technology Entrepreneurship; Data Mining; Entrepreneurial Aptitude; Teamwork; Innovative Intelligence; Financial Projects; Healthcare Projects

I. INTRODUCTION

In order for engineering and computing professionals to become effective leaders in industry and government, they need to acquire the skills of well-rounded individuals who are not only versed in disciplinary knowledge, but who are also proficient in such professional skills as communication, teamwork, interpersonal, problem solving, critical thinking, and entrepreneurial skills [1, 2, 3, 4, 5]. To ensure that engineers and computing professionals acquire both technical and professional skills, these skills must be given emphasis during their education and training. For example, engineering and computing students should be taught and trained in teamwork and innovative thinking skills as well as business skills through technology entrepreneurship experiences. Moreover, there are sufficient explicit and implicit ABET engineering and computing criteria supporting the need to also train today's graduating students in these professional competencies [3, 4, 5]. During teamwork experiences, students should utilize the complementary skills of technical and functional expertise, problem solving and decision making, and interpersonal skills as well as exercise good working relationships among team members in order to get challenging task successfully completed [6, 7]. Entrepreneurial companies are the current backbone of the American economy. They tend to create more jobs than other companies. In addition, they are the engine of innovation; they produce more technological innovations per research and development dollar and more innovation per employee than large companies [8]. Within large corporations, entrepreneurial individuals tend to be relatively more productive than other employees, thereby providing added and critical values to their organizations [9, 10, 11].

Over the past 40 years, entrepreneurship has become a rapidly growing discipline within the United States of America and across the globe being promoted by industry, governments, and academia [9, 11, 12, 13, 14, 15]. Its presence is felt from K-12 through college and in industry. Entrepreneurship education at all levels is a global phenomenon [11].

In a 1999 survey of business school graduates, Charney and Libecap [9] found that the entrepreneurship program graduates were typically more highly paid and wealthier. Reynolds et al [16] reported that Americans of all ages over 18 years old engage in entrepreneurial endeavors with many started by teams of individuals and that ethnicity/race, gender, education, household income, and demography affect entrepreneurial propensity. Entrepreneurs who are highly skilled and more experienced tend to be more successful over time [8]. Moreover, it was reported in Wadhwa, et al [13] that most founders of technology companies held bachelor's and master's degrees – 44% and 30% respectively -- with nearly 50% of the degrees being STEM related disciplines and 33% being business related. The report also revealed these technology company founders graduating from computing disciplines entered their first business venture sooner after

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graduation than those graduating from engineering disciplines; but that engineers started business ventures at about three times the rate of computing professionals. The higher incidence of entrepreneurial ventures among engineers might be caused by the higher prevalence of engineering entrepreneurship education compared to computing related entrepreneurship education at the baccalaureate level [12].

Integral to entrepreneurship is creativity, innovation, and teamwork. Innovation is applied creativity in a business context [8, 11, 17, 18, 19]. “Since World War II, entrepreneurial firms have been responsible for half of all innovation and 95 percent of all radical innovation in the United States!” [11]. Similar findings are reported in Zimmerer and Scarborough [8] as stated earlier. As reported in Weiss [19], innovative intelligence is as critical to an entrepreneur as analytical and emotional intelligence. It endows the entrepreneur and his/her team with the ability to understand and solve seemingly complex problems. Altshuller [17] subdivided innovative problems into five levels of complexity with each level consisting of six stages that can be systematically solved once the appropriate heuristics for the problem solution is found, but that heuristics for problems at levels four and five may have to be developed.

Since many new ventures are started by teams of individuals as previously stated, it is imperative that aspiring entrepreneurs know and practice the value of completing a task on schedule while maintaining working relationships and keeping the mechanisms for team cohesion intact [6, 7]. Teaching students about teamwork and training them in its practices can help students develop greater awareness and appreciation for its inherent professional skills such as communication, decision making, conflict management, social, leadership while acquiring them [1, 20]. Moreover, Passow [21] found that undergraduate engineering alumni consistently rated teamwork, communication, data analysis, and problem solving more highly than any other ABET related competencies.

The pervasiveness of entrepreneurship today has direct implications not only in industry, but also in academia. Although the research and adoption of entrepreneurship activities are still ongoing, entrepreneurship currently is emerging as an independent discipline. Entrepreneurship education and training can be experienced in life sciences, architecture, liberal arts, engineering, music, medicine, and pre-college [11]. There is an increasing body of research in recent years that supports the theory of entrepreneurship as a discipline [10, 14, 15]. Nonetheless, there is still an apparent general lack of an agreed upon body of educational content and appropriate assessment instruments for evaluating student experiences in entrepreneurship courses [22, 23]. At the core of this theory is the entrepreneurial process [10]. Other related concepts include the entrepreneur, organizational context, resources, business concept, performance, impact, and the environment [10, 15]. To create a new business, the entrepreneur needs a compelling story about the venture and a business plan [8, 11, 18]. The survival and growth of the new venture will directly or indirectly depend on the “entrepreneur’s traits, skill, and motivation” [14, 15, 24].

It is becoming imperative, that all institutions of higher learning prepare their graduates for the uncertain workplace that most of them are likely to face upon graduation. The world of work is changing to one of mainly contingent workers regardless of where you are on the globe [12, 23]. According to an Intuit 2010 report [25], over 80% of big corporations expect to significantly increase the percentage of contingent workers in the future. By 2020, the number of contingent workers in the United Stated is projected to approach 50%. This suggests that few graduating students can expect a traditional career with full benefits. Most graduates can expect to become contingent workers who are responsible for their own career as well as medical and pension benefits. As contingent workers, they will become more dependent on their co-workers for referrals, collaborative endeavors, and an awareness of the intricacies of conducting a business. Being trained in entrepreneurship, innovation, and teamwork will help students to better cope with the “rapidly changing” workplace they are increasingly more likely to experience. Today, an increasing number of engineering schools [3, 12, 26, 27, 28] and to a much lesser extent computing schools [29] are implementing programs to educate and train future engineering and computing graduates in entrepreneurship and innovation to make them more career ready.

This is a comparative case study of two courses with different entrepreneurship instructional methods. In fall 2011, a Technology Entrepreneurship course was offered to computing and business students at a private university in the New York City metropolitan area. The students were primarily undergraduates, but two of them were graduate computing students. The students were educated in the principles of teamwork, innovation, and entrepreneurship and were trained in applying these principles to either financial or healthcare practical problems. The principles of the course were supplemented by case studies as well as guest lecturers from academia and industry. To complement the principles taught, student teams were created and trained in teamwork. In addition, each student team was assigned a project to identify and solve a financial or healthcare problem for a niche market. They were required to develop a business plan to support the problem solution. The training of each team in entrepreneurship and innovation was aided by an assigned mentor who was an industry professional at the managerial level or an independent practicing entrepreneur. Each team was required to meet with its mentor regularly for advisement on its project idea, feasibility and scope, design and development, and supporting business plan as well as to provide progress reports and obtain feedback and guidance. The students and teams were assessed on the project and exams. Two external evaluators helped with the in-class project evaluation process. In addition, an independent educational project evaluator reviewed the Technology Entrepreneurship products (business plans and PowerPoint presentations) and Data Mining products (project reports and PowerPoint Presentations) to determine their relative intellectual merits and potential societal impacts, and concluded that the Technology Entrepreneurship products were better.

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II. COURSE DESIGNS

The Technology Entrepreneurship course covered three major topics inclusive of teamwork (two lessons), innovation (two lessons), and entrepreneurship (four lessons). While most lessons were given in one weekly session, two lessons were given in two weekly sessions, and one was given in three weekly sessions. One class session was devoted to the submission and presentation of the assigned team project and one class session was devoted to the final examination. The lessons covered such topics as teams and teamwork; team development, and teamwork skills; innovation, innovative intelligence, and innovative thinking; applied creativity; economic growth, opportunity, and technology entrepreneur; vision, competitive strategy, business model, innovation strategies, and risk and return; business and marketing plans; and ventures, knowledge, learning, design, and contemporary issues in technology entrepreneurship. The two textbooks used to produce the lessons were [17, 18] in the reference list. These textbooks were supplemented by six reference books: *Innovative Intelligence* (Weiss and Legrand) [19], *How to Think about Algorithms* (Edmonds), *Information Technology Entrepreneurship and Innovation* (Zhao), *Entrepreneurship for Scientists and Engineer*s (Allen), *The Wisdom of Teams: Creating the High-Performance Organization* (Katzenbach and Smith) [6], *Teamwork and Project Management* (Smith and Imbrie) [7], and two entrepreneurship related magazines -- Entrepreneur and INC. The lessons were complemented with case studies of successful and unsuccessful entrepreneurial ventures and supplemented by guest lecturers who presented on such topics as innovation and technology entrepreneurship, business plan development, and marketing and selling as well as mentors who coached and advised the student teams on their project idea, feasibility and scope, product design and development, and business plan development. The project description required each student team to identify a potential product, service, or process in finance or healthcare that satisfied the need of a niche market of consumers in New York City and beyond, and is supported by a business plan for a real or fictitious financial or healthcare information technology company. No team had to implement its developed product design beyond the algorithmic level because of the time limitation of one semester. Forty percent of the course grade was assigned to the project and 20% to team and class participation inclusive of interactions with mentors. The final examination accounted for 24% of the course grade while the remaining 16% was divided equally among five in-class quizzes. The project deliverable included a business plan and a PowerPoint presentation.

Of the 12 students enrolled in the Technology Entrepreneurship course, 10 were undergraduate and two were graduate students. Two of the undergraduates were business students who were grouped into separate teams with computing students. One business student majored in business management and the other double majored in entrepreneurship and finance. The two graduate students were computing majors – one majored in computer science and the other in software development and engineering; they were grouped together to form a team. There were three undergraduate teams: two with three students and one with four students. The teams were purposefully designed by the professor using demographic and learning style type information respectively obtained from the students through a questionnaire and an adopted multiple intelligence test used a proxy for learning style. Undergraduate students with similar learning style type were grouped together in teams. It was assumed that students with similar learning styles would function better in a team with less interpersonal conflict, retention of team members, and smoothly transition from forming to performing [1]. Moreover, 50% of the undergraduate and graduate students worked at least part-time; 80% of the undergraduate students and 100% of the graduate students had self-reported grade point averages above 3.0; and except for one of the business undergraduate students being a sophomore, the other undergraduate students were either juniors or seniors. Furthermore, the teams were monitored and supported through regular interviews, surveys, and feedback on in class performance, interactions with their mentors, and project development issues.

The Data Mining course enrolled 19 graduate students and five undergraduate students. As in the Technology Entrepreneurship course, the teams in the Data Mining course were designed and maintained in the same ways with undergraduate and graduate students grouped separately. The project was a similar type open-ended assignment with a project report and PowerPoint presentation of a financial or healthcare problem solution for a niche market as the project deliverables. The Data Mining course covered a single topic: *data mining*. There were other differences with the Technology Entrepreneurship course: the graduate students were not assigned mentors; the project accounted for only 15% of the course grade while the final and in-class examinations were 35% and 30% respectively; no lessons were given on teamwork, innovation, or entrepreneurship, but students were expected to function well in their teams as well as be innovative in their problem solution, and entrepreneurial in their product design and development. Two external evaluators assisted in scoring the student teams in-class PowerPoint presentations.

The external evaluators used in the in class project evaluation process in both courses assisted in judging the student teams' project deliverable through the team's PowerPoint presentation based on five criteria: creative ability, computational thinking, thoroughness, technology entrepreneurial skills, and presentation skills with creative ability having the highest allowable score of any category: 24 points. This adopted team project scoresheet was originally developed for the evaluation of student computing products in the annual New York City Science and Engineering Fair. The evaluators were trained in the use of the project scoresheet by the professor who has several years of experience in using this instrument as a project evaluator for the New York City Science and Engineering Fair. Based on this experience with the evaluation instrument, the professor determined that ±10 percent would be an acceptable margin of error for all evaluators' total scores. Moreover, the evaluators were familiarized with the course objectives beforehand as well as they shared their prior experience in the evaluation of other related student projects at local competitions at the project

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evaluation training sessions. The professor participated in judging the presentation, and graded the business plans/reports.

After both courses were offered, the independent educational project evaluator reviewed and evaluated the business plans and PowerPoint presentations for the Technology Entrepreneurship products as well as the project reports and PowerPoint presentations for the Data Mining products to determine their relative intellectual merits and potential societal impacts. This person is an experienced program evaluator and assessment developer with background that includes review and revision of performance based instruments to determine their validity and reliability and evaluation of projects to determine their intellectual merit and broader impacts. In the capacity of independent reviewer for both courses, this person assessed the relative merits and potential impacts of the student projects with respect to each other to determine if they were consistent with the general rubric for team products as specified by the professor. The independent evaluator's product/service ratings were not factored into the teams' project grade.

III. ENTREPRENEUR TEST

The entrepreneur test used was adopted from previously used entrepreneur propensity self-administered tests obtained from online sources. These sources include the U.S. Small Business Administration, Entrepreneur magazine, and the Center for Rural Entrepreneurship. The adopted questions relate to creativity, risk taking, self-motivation, work ethic, and teamwork. Since all of the questions on the test were adopted from previously validated entrepreneur tests, the test offered to the students was assumed to be valid and a reliable predictor of entrepreneurial propensity. This test was given to students twice during the semester: on the first day of class and on the last day of class.

IV. DATA

For Technology Entrepreneurship course the data used to determine the relative changes in student entrepreneurial aptitude were obtained from the individual pre- and post-entrepreneur test as well as the overall post-course survey, Students Assessment of their Learning Gains (SALG), but for the Data Mining course only SALG was used. There were 25 items in the entrepreneur test, with each item having a yes or no response. The course survey had one multiple choice item that dealt with student interest in taking another course in the subject area as well as several open-ended items where students could indicate the impact of the course on their entrepreneurship understanding and attitudes. The students' responses provided information on learning gains and changes in attitudes and knowledge resulting from taking the course. Additional data from both courses were related to students' performance: team project quality, project grades, and the average in-class and final examinations. These data provide a holistic view of student performance; those produced in the technology entrepreneurship course were compared to similar ones in the data mining course.

V. RESULTS

In the Technology Entrepreneurship course, the pre-test mean percentage of correct responses on the entrepreneur test was 77% for undergraduate students as compared to 78% for the two graduate students. The mean percentage of correct responses on the post-test entrepreneur test was 82% for the undergraduates compared to a mean percentage of 80% for the graduates indicating that the percentage of correct responses increased for both groups of students. The average percentage change in test scores was 8% for the undergraduate students and 5% for graduate students. These positive findings were corroborated through correlation analysis of the undergraduate students' entrepreneur test and course grade. There was statistically significant moderately high correlation between the pre- and post- entrepreneur test scores of 0.586 with significance level within 10% (0.08) as well as statistically significant moderately high correlation between the post entrepreneur test and the course grade of 0.637 with significance level of 5% (0.05). Moreover, 60% of the undergraduate students indicated that they had at least a "good gain" in interest in taking another course in the subject area and 100% of the graduate students stated that they had a "great gain" of interest in taking another course. These data illustrate that most of the students were very much interested in pursuing technology entrepreneurship study.

With regard to the relative course performance of the Technology Entrepreneurship students in comparison to the Data Mining students, their performance was generally better than the Data Mining students. Specifically, the Technology Entrepreneurship student teams' project grades were generally higher by about 10% while the graduate team's project grade was higher by 7%. In addition, the scores that were given by the two external evaluators and the professor to each Technology Entrepreneurship team for the business plan PowerPoint presentations were within ±10% of each other. For the Data Mining teams' project report PowerPoint presentation, the three evaluators' scores were generally within the 10% margin of error. Moreover, the independent evaluator's comparative review and assessment of the project deliverables (business plans/reports and PowerPoint presentations) of the Technology Entrepreneurship and the Data Mining courses found that the business plans of the four Technology Entrepreneurship teams indicated that the teams each had innovative projects that covered all aspects of the project assignment including discussion of the strengths of their product in contrast to alternative solutions as well as the product's ability to meet an identified need. This evaluator also found that the project presentations and reports of the Data Mining student teams generally did not contain a discussion of the strengths of their product in comparison to alternative solutions, thereby providing relatively less intellectual merit information; there was also limited discussion regarding the potential broader societal impact of the proposed product/service. Moreover, the Technology Entrepreneurship student teams' average of the in-class and the final exams also indicated better course performance than the Data Mining student teams. The undergraduate Technology Entrepreneurship teams' had an overall average score increase of about 15% over the undergraduate Data

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Mining teams. This relative performance relationship was maintained by the graduate teams from each course with the Technology Entrepreneurship graduate students achieving an overall 20% increase over the Data Mining graduate student teams. These findings were further substantiated through correlation analyses. For the Technology Entrepreneurship course, the correlation between the in-class and final examinations was weak to moderate and statistically not significant (0.15) for undergraduate students with a value of 0.491 and moderate and statistically significant (0.06) for the entire class with a value of 0.552. For the Data Mining course these correlation values were weak and statistically not significant being 0.139 for both the undergraduates and the entire class with significance values of 0.861 and 0.528 respectively. As to the review of student statements on the post-course SALG survey of changes in course related knowledge, skills, attitudes, and aspects that will be carried over into the students future life, most students in both courses made positive statements; although the percentage of positive statements were greater in the Technology Entrepreneurship course.

VI. DISCUSSION

The entrepreneurship pre- post-test data as well as the other the aspects of course performance indicate that the students in the Technology Entrepreneurship course out-performed those in the Data Mining course. These results might imply that direct instruction in teamwork, innovation, and entrepreneurship contributed to the positive impact on course performance. For example, statistically significant moderately high correlation was found between undergraduate student post entrepreneur test and the course grade. Nonetheless, other factors might have also contributed to the relatively better results: some students may have had family histories of entrepreneurship, some might have simply liked the course because they saw the potential value to themselves, and the inclusion of business students in two of the undergraduate teams might have also helped to improve the course outcomes. Yet, the students in the Technology Entrepreneurship course seemed to have scored higher than those in the Data Mining course on all the metrics used including exams. In fact, there was greater consistency between the in-class and final examinations in the Technology Entrepreneurship course as revealed in correlation analysis. Moreover, it is interesting to note that the student products in the Technology Entrepreneurship course were more innovative and students were better able to address a particular market niche problem in finance or healthcare than the students in the Data Mining course. This too might have been partially influenced by the direct instruction in teamwork, innovation, and entrepreneurship. Souitaris, et al [30] found that the teaching of entrepreneurship is very beneficial to some students in that it increases their "attitudes and the overall entrepreneurial intention." In fact, some of the products produced by the Technology Entrepreneurship teams showed market potential. For example, an undergraduate Technology Entrepreneurship team's business plan for a prescription transaction machine that would eliminate customer waiting time for pharmacy's to fill a prescription was judged by one of the external project evaluators to be worthy of further product development and implementation; this evaluator is a senior manager in the healthcare industry. This type of endorsement corroborates the growth in students' understanding of course content and objectives in innovation and entrepreneurship.

Students' perceptions of both the Technology Entrepreneurship and Data Mining courses were generally positive, but were more positive in the Technology Entrepreneurship course. Some examples of the responses from undergraduate students in the Technology Entrepreneurship course are the following as reported on the Students Assessment of their Learning Gains (SALG) post course survey:

One student commenting *on how his understanding of technology entrepreneurship changed* as a result of taking the Technology Entrepreneurship course stated the following: *I did not really know what to expect but after the class started everything changed. Being an entrepreneur is the way to go right now.*

Another student commenting on the *skills* gained from taking the technology entrepreneurship course reporting the following: *Teambuilding, motivating others, identifying opportunity and innovating*.

A third student commenting on how the technology entrepreneurship course *changed his attitudes* towards the subject reported the following: *I am no longer intimidated by entrepreneurship as I once was.*

A fourth student commenting on what will be carried *with him* into other classes or other aspects of …his life reported that *I will carry just about everything I've learned in this course into my life because every aspect holds value to me*.

A fifth student commented on how the technology entrepreneurship class activities helped his learning stated that there could have been more activities: *I wish there had been more*.

The students in the Data Mining course also had mainly positive comments on the SALG post course survey as the following examples shows:

One student commenting on how his *understanding* of data mining *changed* as a result of taking the course said that *the course has taught me to be more disciplined and organized when dealing with complex issues*.

Another student commenting on the *skills* gained as a result of taking the data mining course said that the skills were *teamwork, taking initiative, delegation of tasks, cooperation/collaboration*.

A third student commenting on how his/her *attitudes* changed towards the data mining course said: *Entrepreneurship in data mining*.

A fourth student in commenting on how the class activities helped his/her learning said the following: *There weren't any class activities*.

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The comments from the Data Mining course students seemed to suggest that these students generally were less engaged in the teamwork and entrepreneurship aspects.

Despite students' generally positive comments, they could have gained more from the Technology Entrepreneurship course had they more fully utilized the services of the mentors. One of the four mentors commented that the team he mentored did not sufficiently take advantage of his entrepreneurial skills, knowledge, and time in practice after their first valuable meeting, and felt the team members missed out on preparing communications in a way to attract an investor eye as well as perhaps the use of invaluable contacts.

VII. CONCLUSION

As anticipated the Technology Entrepreneurship students' team projects produced relatively better products than the Data Mining students. This might have been influenced, in part, by direct instruction on teamwork and innovation along with entrepreneurship. Nevertheless, the Technology Entrepreneurship teams could have yielded even better outcomes had they more fully utilized the services of the mentors while gaining their friendship, an important contact for workplace references and potential employment. Another mentor commented that the students in his team tended to view the project more as a regular class assignment rather than an actual workplace assignment. This seemed to have been truer in Data Mining than in Technology Entrepreneurship as evidenced by the students' post SALG survey comments and the correlation analyses that may be partially because there was no teamwork and entrepreneurship direct instruction. In future offerings, the Technology Entrepreneurship course will be made project based inclusive of time-tables for deliverables, with deliverables and their presentations replacing standard in-class exams. This will be done to address some of the concerns of the mentors as well as to make the project aspect of the course emulate an industry perspective as much as possible. With regard to the Data Mining course, direct instruction in teamwork and entrepreneurship will be provided.

Three implications that can be derived from these exploratory case studies relates to the direct instruction of teamwork, innovation, and entrepreneurship; apparent link between entrepreneurial propensity and course grade, and the positive impact of the mentors on the student teams. Direct instruction on teamwork, innovation, and entrepreneurship seemed to have positively influenced students' attitudes towards these professional skills as evidenced by the relatively greater number of students in Technology Entrepreneurship commenting on the gains made in these skills. The statistically significant positive relationship between the post entrepreneur test and the course grade seemed to suggest that entrepreneurial propensity may link to work ethic. The consistent use of mentors with the undergraduate students of both courses seemed to have positively impacted student attitudes to the open-ended project. A student from Technology Entrepreneurship reported the following in the SALG survey: *The mentor was informative; she aided us with our understanding of business in general*. A similar statement was reported by a student of the Data Mining course.

This study is exploratory in nature with regard to the evaluation of two case studies – a Technology Entrepreneurship course relative to a Data Mining course with emphasis on changes in entrepreneurial aptitude as evidenced through the products student teams produced, course examinations, and the SALG post course survey. There are some inherent limitations. They include small sample size, uneven mixed populations, and dissimilar courses and course design. Therefore, the results produced are only suggestive, and should not be generalized without confirmation from a more comprehensive follow-up study.

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Innovation-Directed Experiential Learning Using Service Blueprints

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***Abstract*—An analysis of hiring patterns showed emerging trends: the complexity of information technology (IT) is shifting from development to post-deployment and integration needed for services. Given the complexity of deployed service systems, generated big data, and the national dialogue on educating engineers, we asked ourselves related questions. Do our graduate students have evaluation skills needed to work at the most advanced level of Bloom's taxonomy? Can they learn to frame and solve the problems within complex industry environments while applying the current research? How do we structure a graduate curriculum and an environment that provides experiences in innovation within the constraints of the academic calendar? Here we present an interdisciplinary curriculum comprised of three components: a service interaction blueprint for framing the industry problem, agile principles focusing on aspects of the solution, and Christensen's theory-building to frame the next iteration of research. The environment for industry problems was created through an National Science Funded Industry & University Cooperative Research Center. The feedback from a pilot graduate-level class is positive and provides insights for further research. We show through feedback discussions that it is possible to have translational activity at the industry-university enterprise boundary resourced in by advanced experiential learning.**

Keywords—complex systems, design, innovation, performance metrics, services science, technology management

I. Innovations for Complex Enterprise Systems

As early as 2004, an analysis of graduate student hiring patterns within industry showed several emerging trends: the complexity of information technology (IT) was shifting from the development phase to post-deployment. Enterprise IT departments were becoming brokers of cloud, social, mobile and information services [3]. And there is significant interest in converting data pumped out by these service complexes into actionable intelligence within enterprise workflows. This is now popularly known as the *big data problem* [4]. At the same time, we found little within the academic programs that teach the skills to frame problems related to the use of complex systems, learn from solutions and failures, and extract research that can provide real, perceptible value to their sponsors.

Computer science graduate students enter their second year with little insight into what it means to deliver services in the context of a complex enterprise system. They are mostly familiar with development methods and typically take the viewpoint of a programmer when approaching projects. . We use the term *complex enterprise system* here to mean both intra-enterprise and inter-enterprise services that collectively enable a business goal. As in [1, 2], we view these as networks (e.g. a value chain, supply chain, or service value network) with nodes as agents (i.e. humans, organizations, software and hardware) that are all creating, communicating, or consuming information.

The environment of the case study reported here is the specific National Science Foundation Industry & University Cooperative Research Center (I/UCRC) for Experimental Research in Computer Systems (CERCS). This is a multi-university center with CERCS at Georgia Tech researching complex enterprise systems, including their hardware, communications and system-level software, and applications. Complementary to this, the CERCS research site at The Ohio State University, the Center for Enterprise Transformation and Innovation (CETI), studies the applications of technology to achieve innovation. Thus by emphasizing the experimental method, CERCS promotes the creation of knowledge through the design, implementation, and measurement of large-scale systems. The goal is to conduct research that involves graduate students in industry research projects, yet is of interest to both the industry and the university [5].

Bridging the gap between technology consumers and technology providers is a key goal of CETI and the curriculum design discussed here. To accomplish this, graduate students need to think of how their services, when implemented, will benefit their sponsors and consumers, rather than focus on providing a technology implementation alone. However, we found that dealing with continually increasing dynamic complexity within the enterprise and its accompanying *wicked problems* [6] is rarely addressed in the typical graduate computer science curriculum. Often, even when an idea is adequately developed, the solution may not yield perceptible value to the enterprise, in that it fails to deal with the reality of delivering services with product and process innovations. Nevertheless, this is still good feedback for researchers and technology developers.

In order to address these gaps, we developed a graduate-level computer science course in applied information technology. We selected a set of interdisciplinary methods that focus on innovation-directed experiential learning and teach problem framing and

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research skills. Keeping in mind the time constraints present in the academic curriculum, we used a set of simple yet effective frameworks comprised of:

- *service blueprints* [7] for problem framing;
- *agile development practices* [8] as the process for delivering value to sponsor; and
- Christensen's *theory building process* [9] to extract the research statement from the project.

We assume here that by 1) framing problems to derive an innovation and development plan that applies within their sponsor companies, and 2) identifying research towards improving existing theories, the students will demonstrate evaluation skills to deliver improvements to complex systems. Thus they will function at the highest level of Bloom's taxonomy [10].

In this paper we begin with how we used the service blueprint to bridge from the *technology providers* (e.g. industry research labs, engineers in academia) to *technology consumers* within complex enterprise systems. Using this framework, we show how students use agile practices in their projects and extracted research statements from their project, all within one semester. We present feedback from students and offer insights toward improvements. We conclude with discussions of how graduate students can benefit project stakeholders (including themselves) through innovation-directed experiential learning.

II. Design of Curriculum Bridging Technology Consumers and Providers

We begin with issues in experiential learning and then introduce and justify the methods for use in the curriculum.

A. Importance of Context for Design

It is now well established that engineering design requires 1) an understanding of the context or environment for the correct framing of the problem, and 2) interdisciplinary approaches to solution development. For example, architectural design is viewed as its own integrated field of study, and is compared to other engineering disciplines; it is multi-disciplined, since the field seeks integration of electrical, plumbing, lighting, and other systems within its overall building design. Capture of contextual knowledge as *design patterns* was also first introduced by the architect Christopher Alexander [11, 12]. These design patterns are a way of making tacit knowledge explicit. Design patterns have been enthusiastically endorsed by software engineers leading to many framework technologies that improved the development of software. However, far less has been done in integrating interdisciplinary frameworks[1] related to complex enterprise services within the graduate software and systems engineering curricula.

Recent NSF workshops have looked at the process of introducing design thinking into the engineering curriculum [18, 19]. In addition, *grounded theory* provides a systematic methodology in the social sciences involving the discovery of theory through the analysis of data captured in the field [20]. It is mainly used in qualitative research, but is also applicable to quantitative data. All these ideas and methods bridge the gap between technology development and technology consumption in industry.

Finally, related to technology, engineering research continues to focus primarily on normative theories related to technology while business, such as management information systems, and healthcare focus more on descriptive or operational aspects, leaving a gap to be bridged. To address this *design science* [21] emphasizes the need for the information systems researcher to bridge the gap between existing knowledge and its context of use.

B. Experiential Curriculum Needs

In experiential learning, students learn to solve an industry-sponsored problem and the solution and outcomes are not predetermined. Many have identified the need to develop an advanced engineering "workforce of the future" capable of working more effectively with complex systems [22], the related need for advanced education that creates "T-shaped" individuals in technology areas [23], and new IT roles, such as a data architect or data scientist, with the appropriate complex skills [24].

While there is considerable focus on undergraduate education and accreditation, less national dialogue exists at the master's level. Related to software engineering master's requirements, the Integrated Software and Systems Engineering Curriculum has identified experiential capstone skills that "[can] reconcile conflicting project objectives, finding acceptable compromises within limitations of cost, time, knowledge, existing systems, and organizations. [25]" This type of work is at the highest levels of Bloom's taxonomy.

To address this curriculum need, we return to the technology consumer-provider gap and note that traditional engineering curricula have focused primarily on the creational (technology provider) aspects of software and hardware. To some extent, courses in management information systems cover operational (technology consumer) aspects. With the exception of industry best practices - TOGAF and ITIL – Enterprise Architecture curriculum assets that cover complex technology infrastructures and their related continuous improvement are limited. The challenges of enhancing the overall functionality and performance of a deployed complex system are left unaddressed within the curricula, with negative consequences illustrated below.

Problem-driven experiential learning is often interdisciplinary and questions that arise require faculty and

[1] Examples used by CETI include basic frameworks include: lean software development [13], TOGAF [14], ITIL [15], the balanced scorecard [16], and Porter's Five Forces model [17]. These frameworks are covered within different disciplinary silos.

practitioners from different disciplines to at least start with a shared understanding to develop solutions in a timely manner. To use a simple example, for a typical software engineer the word "activity" refers to a node in a finite state machine; for an industrial engineer this refers to a workflow task; and for a typical business graduate this term refers to an entire organization. While these terms are related in the field, they are rarely related in the disciplinary curricula.

Similar points are made in the emerging interdisciplinary field of Services Science, Management, Engineering and Design. Educators and researchers have pointed out that despite the increasing contributions of services to economic growth, there is no common understanding of what phenomena underlying services and the dynamics of services ecosystems create and drive value [26]. It has been argued [27] that existing models, traditionally used for describing the exchange of physical products, will not apply in the services context, in which close interactions between suppliers, service providers, and customers exist, where knowledge is created and exchanged, and experiences, capabilities, and relationships are an integral part of the transaction. In summary, an advanced experiential curriculum is important, difficult to resource, and demanding in terms of knowledge and needed skills.

Finally, students have limited available credit hours in their programs for the experience needed to correctly frame problems and solve them. Thus the methods selected for the course had to be simple to introduce, but effective in providing a structure for future growth as innovators. These methods are presented below.

C. Service Blueprint

In an effort to capture the needs of the service consumers of a complex enterprise, we selected a tool that is used in consumer sciences known as the service blueprint [7]. This framework identifies the core, peripheral, and enabling services within the enterprise. In the service blueprint, the core requires the student to identify the customer experience, from a tangible and emotional perspective. The blueprint is augmented with other services (organizational and technology) that have to be in place, thus requiring the student to elaborate on how a customer interaction moves through the organization. The service blueprint builds on methods of both computer and consumer sciences.

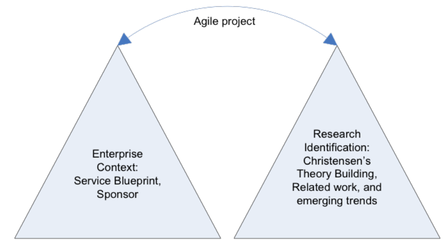

Fig. 2: The course frameworks and relationships: Service Blueprint for discovery, Agile for development; and Christensen for research identification.

D. Translational Process

Translation usually uses research to improve the methods of working to producing goods and services. The result is an innovation. The term *complex innovation* is innovation related to complex enterprise services. Complex innovation requires students to fully understand the underlying translational process cycles that are needed. These cycles often start from *in situ* observations and

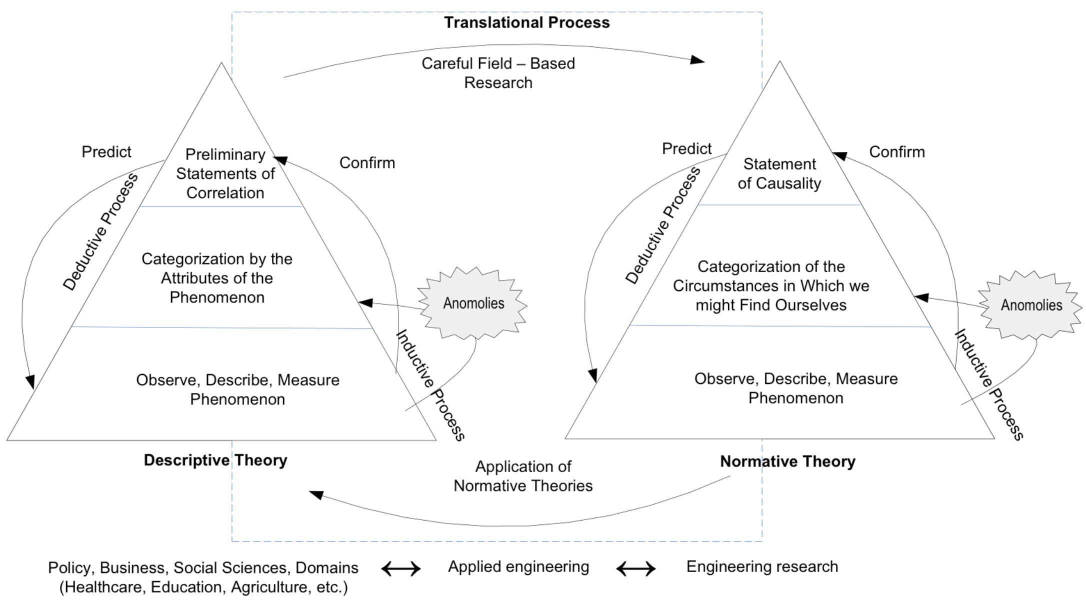

Fig. 1: The Engineering Translational Process bridging from descriptive to normative theories, based on [9].

understandings, i.e. development of descriptive theories (Fig. 1, left). Next, these lead to subsequent cycles of theory building that are well explained in [9]. In particular we next wish to build on key points about theory building that Christensen makes and relate them to the translational process involving, in particular, engineering innovation research.

First, the descriptive stage of theory building (Fig. 1, left) is viewed as a preliminary stage because translational engineers must understand the context and causalities that occur in the real world, e.g. the complex healthcare system. They then pass this understanding on to the development of a normative theory (Fig. 1, right). The right side is the typical realm of more academic engineering researchers. Normative theories have the ability to predict outcomes of interest, not just what is correlated in the field. Anomalies are treated with great interest as they often refine theories. We use the term *translation* here for the process bridging between descriptive and normative theories in order to cycle between understandings to causalities.

Second, the translational process (as in Fig. 1) is not simply a one-way process of taking ideas from university labs out to be applied in industry. Careful field-based research, anomalies and correlations must also move back to inform technology and engineering research in the university.

This deeper, normative understanding of predictability and repeatability is exactly what is needed as the basis for service automation and the development of enabling technology. For example, the design of telemedicine solutions must be based only on theories of automation because they are also repeated in human interactions. Care must be taken not to over-automate at the expense of usability. This type of nuanced understanding begins with observations and the development of a descriptive theory regarding the context of use.

The typical innovation goal is often initially stated in broad terms (e.g. social media can be used to improve the health care enterprise). Such a claim may never be warranted by existing underlying research, yet the innovation might be successful. In contrast, each academic research hypothesis and its accompanying goals are typically narrow and rigorous (e.g. text analytics tools can be used to extract the positive sentiment of entities in micro-blogs). In other words, within complex systems we may never complete all the research (e.g. due to wicked problems [6]) and we may have to acknowledge that a single good research result might not have a perceptible impact on the economic performance of the whole system.

There also is no guarantee that research investment will be successful in practice. Innovation may be the result of research and development, but also more rarely, it could be due to a "Eureka" moment. Thus, many wicked problems and different disciplinary perspectives need to be addressed for a typical complex system innovation. And, to achieve results, many translational cycles will typically be involved. Ways to enable translational activity within the university are discussed in [28].

E. Agile Translation

Last but not least we introduced agile development practices, which form the process used to conduct the projects. It consists of the following principles, based on [8]. Since the industry sponsor approves all work products based on achieving a translational goal state that is also funded, we point out that the work products are of value to an industry process or product. Thus, each work product contributes incrementally to a final innovation.

III. Implementing Innovation – Directed Experiential Learning

The students taking the course in Advanced Enterprise Architectures in Services were first- and second-year master's and doctoral students seeking real-world experience. Most were new to research and most had a year of previous work or project experience. The steps in the course (see Fig. 2) and curriculum is as follows:

1) Project triage: At the start of class the students were assigned projects and industry sponsors to work with. These projects are typically in the domains of healthcare, education, insurance and finance, and government services. The industry projects serve as a living laboratory or sandbox, meaning the projects represent the full messiness and complexity of real-world enterprises. In this early phase, the students were mainly introduced to the problem.

We assigned team members as follows: the team leader was a doctoral or second year master's student. The remaining team members were first year students with an interest in the project topic. Thus there was a mentoring relationship.

2) Develop service blueprint: In this phase, the students had to distill the messiness of the problem into an abstraction that identified, from the consumer's perspective, the true value of the final project. They were given a lecture on Service Blueprint.

3) Follow agile practices: On an on-going fashion, the students interacted with their sponsors and created project implementations. Concurrently, they did background and secondary research on related emerging trends.

4) Identify research: Using Christensen's theory building framework, the students began to understand and document where the unique contributions of their work might lie and developed a future project plan. They were introduced to Christensen's theory in two lectures.

5) Wrap-up: The groups present to their sponsors the project plan and the value of the project. And, they produce a research report describing their publishable work.

The course format was a hybrid online-offline classroom. Required reading materials were posted to the course website prior to class and five classes (of a total twenty-four) were spent on lectures. Thus more time was spent on in-class project discussions applying theory building and service blueprint methods.

The project environments included weekly activity tracking of students, kept private between the student and faculty advisor, and a project environment with blogging for team collaboration. Google sites were used for access to the work products by sponsors.

IV. Results

Twenty students took the pilot course in Spring 2013: six doctoral students, five second-year master's students, eight first year master's students, and one non-traditional undergraduate. The course was being offered for the first time so we had little understanding on what to expect. Thus we viewed the course as a way to discover and frame hypotheses for future research.

To assess the effectiveness of this course and the instruction method, we therefore prepared a survey for a longitudinal study to capture improvement in students' evaluation skills consequent to their instruction with the service blueprint. Christensen's framework was presented at the end of the class (they had previous knowledge of Agile).

We asked the same questions week three and week ten:

How do you define computer science research? How well do you feel you are equipped with methodological knowledge for research? How do you define computer science innovation? How well do you feel you are equipped with methodological knowledge for coming up with innovations? Do you consider innovation skills to be essential for employment? Do you consider research skills to be essential for employment?

The three groups are – *group 1:* nine first year masters students including one senior, *group 2:* nine second year masters, and *group 3:* three doctoral (playing mentor roles).

We administered these questions at the start and towards the end of the semester. Given small numbers and absences, we found no statistically significant change between the pre-instruction and post-instruction surveys. But taken the responses taken along with additional feedback solicited at the end of the class from each group was insightful and useful for developing hypotheses for further research. We have thus organized our results from the perspective of hypotheses forming evidence below.

Hypothesis: Graduate students understand the need for evaluation skills at the highest level of Bloom's taxonomy. They can define terms like service, innovation, and research and state the importance.

Group 1: Several saw the need for project skills but did not see the value of research and innovation skills for their future job search. They saw that the structure of the course as "different", "more autonomous", "bigger picture', and "not just "start coding". They could see that they have to gather requirements and understand what they are doing. Relationship with companies leading to internships is a plus; multidisciplinary perspective is a plus (much higher-level class, more than coding, gives aspects of industry that s/he's never seen). Suggestions for the course: "precisely define the terms", "give examples of hypothesis – unsure what it looks like", "good on-boarding", "started off seeming like an implementation course, and not a research course".

Our observations: We did not structure the relationships between project and research adequately enough to ask more precise questions. In retrospect, we think this was because the class was a combination of project and lecture based, with project discussion dominating. Thus the students focused on the Agile project aspects, but did not focus on the vocabulary even though that was presented and tested.

Hypothesis: Technology Graduate students can be taught to focus on technology consumers and innovation with Service Interaction modeling.

We noted by examining the project work products, that with the introduction of the service blueprint each team shifted its thinking process from implementation (technology provider mentality) to the consumer value. Most teams modified their blueprints several times as they thought more globally. In addition three Group 2 masters students developed satisfaction questionnaires for the technology consumers of their own innovations based on this. This was an important behavioral shift we were attempting to achieve. Consequently in the next iteration of the class, we plan to have work product related questions.

Hypothesis: Mentoring is helpful.

Group 1: "discussions with the team were helpful", "enjoyed working with partner (mentor), who is helpful", "class lectures were unclear; I now understand enterprise projects, so the class was helpful".

Group II: Several group II students mentioned "benefitted a lot from working with a Ph.D. student". Suggestions for the course: "start earlier with Christensen's Theory Building", "too long of a warm-up period, not enough time to do the research", "no direct tie between the EA (enterprise architecture) foundation and the class work, improve teaching of EA".

Hypothesis: Graduate students need to be taught all three frameworks and the relationships between them.

Group III: "Was previously unsure of how to write an academic paper", "the time wasn't too short, as s/he came in with more preparation"; "got good insights for own personal research"; "didn't know previously how to proceed with research, now has some sense on how to do research", "difficult to extract research from projects". Out observations, Group II and Group III were more able to see the benefits of the service interaction model and the relationships to the Christensen's model.

These responses provide some overall guidance on how to improve the experiential learning:

1) Include more explicit in-class discussions on the terminology.

For instance, include an explicit discussion about both Christensen's theory building model and innovation versus research. One way to proceed, given limited time, is to introduce a class simulation that illustrates the differences between research and innovation and the different types of reasoning processes.

2) Make the doctoral student experience more explicit.

Doctoral students gain because they get several teams working on exploring different ideas related to their research. This needs to be made more explicit.

3) Poor access to relevant knowledge.

We also make other, broader observations related to the environment. The conduct of an experiential curriculum and its accompanying translational activities is knowledge intensive and the resourcing has related challenges, as the faculty member has to have both explicit research background and deep industry experience. Confronted with typical sponsor needs in industry, we have also found that the typical academic research paper is often too narrow to solve the whole problem and show benefits to the end consumer. This, we believe, makes it increasingly difficult to derive innovations in short academic timeframes.

For example, during the problem framing stage it is typical to find thousands of academic publications that match keywords of interest. A simple search in Google Scholar for "adaptive complex enterprise" yields over six million results. Even so, most academic research papers do not address the whole problem and are too discipline-specific. Practice papers are too generic or vendor-specific. More integrative approaches to presenting research and practice must be explored to further the translational process. In particular, new approaches to the publication of translational work products and data sets related to the paper should be considered.

V. Conclusions

There is a growing gap between technology consumers and technology providers. This is also mirrored as the related gap between academic research rigor and effectiveness in practice. Thus, from an I/UCRC perspective, we are interested in asking: can advanced graduate students within experiential courses become the engine for translational activities and innovation related to complex systems?

The challenges to be addressed include lack of understanding of the 1) enterprise context, and 2) research and innovation processes. To address this we have proposed an advanced interdisciplinary curriculum framework integrating service blueprints from consumer science, Christensen's theory building from business, and agile practices from software engineering. We provide specifics of implementation and observations based on a pilot implementation.

Our preliminary results show that, while the application of technology increasingly depends on consumer context, this context can be quickly abstracted using available tools like service blueprints. Subsequent agile management of projects and extraction of research abstractions using Christensen's theory building is feasible within the constraints of one semester.

This approach has the potential of a sustaining industry-university structure that can benefit graduate student learning experiences and translational researchers. We have shown that students can acquire all the needed knowledge and deliver value within a limited time.

Acknowledgment

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inVenTs:

Improving retention Among STEM majors through a living learning community

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***Abstract*— Studies have identified institutional or programmatic interventions that can be implemented to address lack of fit and related individual variables that may impact success and retention in engineering programs, especially among underrepresented groups in science, technology, engineering, and math (STEM) fields. One such intervention is a living-learning community (LLC). Informed by best practices in the literature, inVenTs is a new interdisciplinary residential community offered at a Research I university that is designed to encourage the development of innovative and entrepreneurial thinking skills while at the same time offering programming that is linked to retention and success. Linked to the activities being offered in this residential community, our research is examining what curricular and co-curricular initiatives have been shown to retain undergraduates and at the same time develop students' ability to be innovative. This paper discusses initial findings from assessment efforts and future assessment plans as findings are being used to inform future programmatic initiatives.**

Keywords—innovative thinking skills; living learning communities, retention

I. INTRODUCTION

InVenTs is a new interdisciplinary residential community offered to engineering, science, and business undergraduates that is designed to encourage the development of innovative and entrepreneurial thinking skills while at the same time offering programming that is linked to retention and success, especially among students from under-represented groups. Providing this opportunity to students targets two areas of international importance by offering targeted programming that can improve retention and to what extent that programming can improve innovative thinking skills among STEM majors. Several recent reports have highlighted the need for innovative thinking skills as the U.S. looks to maintain a viable national economy[1, 2]. These skills include the ability to exercise innovative and entrepreneurial thinking skills[3, 4]. As calls for retention and graduation rates for engineering graduates that can provide innovative solutions mount, there are clearly great gains to be made in the numbers of under-represented minority (URM) students earning engineering degrees.

African Americans, Latinos, and females of all racial and ethnic groups are woefully under-represented within the engineering profession in comparison to their representation in the general population[5]. We would anticipate that students that participate in the inVenTs community would be better prepared to enter into the workforce as well as be retained at a higher rate than non-participants given the support and engagement that is part of the LLC.

II. CONCEPTUAL FRAMEWORK

Research provides two separate bodies of knowledge that are providing the foundation for the inVenTs initiative and related research study. First, several studies document the important role that support and engineering self-efficacy play in the retention and success of under-represented groups in engineering [6,7]. Increasing student confidence and providing them with mentoring, role models that they can readily identify with, and opportunities to practice and apply content knowledge among a supportive peer group has been shown to have a positive relationship to increased self-identification with engineering as a major and career choice, or increased sense of "fit"[6,8]. Studies have identified institutional or programmatic interventions that can be implemented to address lack of fit and related individual variables that may impact success and retention in engineering programs. One such intervention is a living-learning community (LLCs)[9]. LLCs can create a critical mass that increases the supportive peer interactions taking place among women and other underrepresented groups[10] and can also alleviate negative stereotypes[11]. Other interventions

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such as mentoring and placement with role models have also been identified as important ways to mitigate isolation and improve retention, especially among underrepresented groups [9,12].

Part of the programming associated with inVenTs is designed to provide opportunities that can counteract negative influences; thereby, facilitating support, increasing fit and retention to degree. For instance peer mentoring, weekly seminars that bring in role models, and block scheduling residents in first year courses so they have ready-made study partners are part of the programming offered to participants. The new inVenTs program, instituted in Fall 2012, is sponsored by the Center for the Enhancement of Engineering Diversity (CEED) within the College of Engineering at Virginia Tech and builds off of four existing programs, Hypatia and Galileo for engineering undergraduates, and Cajal and Curie for science undergraduates. The inVenTs community in its first year of implementation has pulled together these four communities into one community that also includes business majors. Approximately 500 students are participating this fall in the interdisciplinary inVenTs community that is designed to build innovative thinking among undergraduates.

When considering the body of literature that surrounds the development of innovative thinking skills among engineering undergraduates several studies provide a framework that creates the inVenTs living-learning experience. Literature has attempted to highlight skills that innovative engineering undergraduates would demonstrate[3,4,13]. Using problem-solving methodologies, and a variety of corporate based literature as references, engineering educators suggest that students would be able to set goals for their own learning and identify when they need to seek new knowledge to solve problems. Innovative thinkers should be able to give and receive feedback on new ideas as well as possess the ability to represent those ideas visually and contextually. Students should also be able to think critically so that they can assess the value of their prior knowledge and elaborate, translate, and summarize known and new information[14,15,16]. Activities that have students use concepts in new and different contexts such as those provided by open-ended problems that need to be solved and then sharing that information with others for critical feedback can help develop innovative thinking [17,18,19]. Based then on what is known about the development of innovative thinking, in addition to what is currently offered in the way of academic and social support, inVenTs residents have the chance to engage in hands-on activities that are designed to encourage and develop innovative thinking. Residents are involved in activities that allow for direct involvement in the full chain of innovation from research and transition to translation and commercialization.

Linked to the activities being offered in this residential community, our research is examining what curricular and co-curricular initiatives have been shown to retain underrepresented minorities and at the same time develop students' ability to be innovative. Quantitative and qualitative methods being employed to study what factors impact retention and development include student surveys, focus groups, and direct methods of observation of skills demonstrated during design competition. A control group of STEM students that have not participated in a LLC is being used for comparison of findings. Results related to this research will share the best practices identified and resources that can help educators in teaching innovation, while at the same time encouraging retention and success among engineering undergraduates.

This paper reports on the assessment efforts linked to three weekend design competitions that were offered to the inVenTs students. Using different topics the competitions have provided students with problem-based learning opportunities and the chance to design solutions through hands-on applications and resources provided to students. Similar assessment tools have been used across the competitions. Student activities and interactions in their teams are observed and their behaviors are recorded using a rubric. In addition, after the event students are given a follow-up survey online that they complete individually that asks them whether participating in these activities have enhanced key innovative skills as proposed by Zheng[19]. In addition, students are asked to report on what they enjoyed about the activity and what they found frustrating through open-ended comments.

III. FINDINGS

A total of 46 students participated in the design competitions and responded to the survey. Students reported their perceptions of the impact they felt the design competition had on their innovative thinking skills. As shown in Table 1 students reported a positive impact in several areas.

TABLE I. STUDENT SELF-PERCEPTIONS OF INNOVATIVE THINKING SKILL DEVELOPMENT AFTER PARTICIPATING IN DESIGN COMPETITION (N=46)

Question	**Student Self-Perceptions**	
	Survey Question	***M***
1	Participating in this activity helped me think about things I already knew in new and different ways.	4.12
2	Participating in this activity allowed me to test out different ideas to see if they would work.	3.96
3	Participating in this activity allowed me to generate new solutions, processes, and ideas.	4.14
4	Participating in this activity helped me make connections between solutions and ideas being generated and how they could be applied to solve other problems.	4.19
5	Participating in this activity allowed me to think about how to commercialize the ideas, processes, or solutions generated.	4.10

In terms of the external observations of the stages of innovation among competition participants, in the first competition two reviewers used a rubric to observe and then score teams on innovative thinking skills demonstrated during the competition. Criteria that captured the different stages of innovation were listed in the rubric and a scoring key was used to rate the level of innovative skill development (Not Observed = 0; Below Average = 1; Average = 2; Above Average=3; Not Applicable = NA). The reviewers met prior to the competition to establish common expectations for what might be observed among students and how they would score the range of different skills they might observe. After rating the students the reviewers again met and discussed how they rated participants and provided justification based on field notes as to why those teams were scored accordingly. Any discrepancies in scoring were resolved through this discussion. This process was used to establish inter-rater reliability. Following is the list of the stages of innovation demonstrated during the competition that participants were assessed on: a) Demonstrates critical thinking and effective generation of new ideas; b) Demonstrates application and integration of science/engineering content knowledge; c) Demonstrates ability to organize new information/ideas/products in an understandable way; d) Demonstrates ability to communicate ideas to peers, faculty, and potential industry representatives in presentation; e) Demonstrates effective use of technology/tool selection in design process; f) Demonstrates complex thinking process that transforms creative ideas into useful services/products; g) Demonstrates potential for prototyping/commercialization

IV. Discussion and Conclusion

In terms of the stages of innovation demonstrated in the first competition among teams, participants demonstrated below average to average innovative thinking. The level of innovative thinking demonstrated would be expected given the participants were made up primarily of first-year engineering students. The related survey responses indicate that students are benefitting developmentally from participating in the design competition activities. The open ended comments collected among students indicated that the competition gave them an opportunity to think about concepts they are learning in their classes in new and different ways.

In order to build off what was learned during the first competition the following activities are being undertaken. Doing so might benefit all of the participants as well as future participants in the design competitions. A seminar will be offered where the more highly ranked teams discuss the approach they used for each stage of innovation (e.g., criteria in the rubric). This could allow participants to learn from one another and gain skills they are lacking. We will conduct interviews with students in order to have them provide more detail about why they responded in certain ways to the items in the self-assessment. Results could be further analyzed to determine what training or activities could precede the design competitions in order to enhance the innovative thinking skill development of students. Our next steps will be to correlate participation in these activities with the retention and continued enrollment of participants and examine whether there is a different between students that participate in these activities and those that do not in their reported innovative thinking skills and progress towards degree attainment.

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An Innovative Classroom that Produces Innovative Students

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***Abstract*—"BitLab" is an innovative classroom that integrates scientific history, sensor technology with quick prototyping and public speaking in a team-based interactive learning environment. In order to inspire the students' spirit of innovation, everything in this classroom is built by small "Bit". Electronic sensor-based "BitLab Bricks" enable the students to conceive their own innovative design, which covers daily life applications. A prototype is then built using geometric shapes. In the end, each team writes up a description of their "product" and gives a presentation on its features and functionalities. The interactive learning platform is delivered through team-based "BitLab Curriculum". The status and impact of BitLab in Chinese schools are presented.**

Keywords*—*Classroom teaching; Engineering Education; STEM; Public Speaking; Innovation.

I. INTRODUCTION

In an increasingly globalized and technology-driven world of 21st century [1], students need multi-dimensional abilities in order to solve complex problems, such as the so-called "7Cs" [2], which consists of critical thinking and problem solving; creativity and innovation, collaboration and teamwork; cross-culture understanding; communications and information literacy; computing and ICT (Information & Communication Technology); career and self-learning. To address this challenge, innovative methods of teaching, learning and new-type classrooms are required to make the connection between theories and practical applications.

The traditional examination-based teaching method based on well-defined problems and formal definitions is still widely used at schools in China [3]. In general, such teacher-led approach consists of lecturing, doing exercises, and testing. This approach engages a low level of learning as students gather information from lectures and memorize facts and procedures in order to pass exams. These students often possess ineffective habits and skills, which hinder their future learning and working abilities in real life.

In this paper, we present a new type of classroom, called "BitLab", designed to foster effective problem solving skills under traditional learning environment. This innovative classroom integrates scientific history, sensor technology with quick prototyping and public speaking in a team-based interactive learning environment. In order to inspire the students' spirit of innovation, everything in this classroom is built by small "Bit". Electronic sensor-based "BitLab Bricks" enable the students to conceive their own innovative design, which covers daily life applications. Then, the students conceive a conceptual design to house the electronic components using transparent geometric shapes of different colors. In the end, each team writes up a description of their "product" and gives a presentation on its features and functionalities. The interactive learning platform is delivered through the team-based "BitLab Curriculum".

We will first describe the hardware, sensor bricks and geometric bricks. Then, we'll describe the curriculum. In the end, we see that the curriculum is well-received by the students. More than 100 patents have been filed from ideas created by the students.

II. THE HARDWARE

The materials used in BitLab consist of three parts: (1) Self-assembled sensor-equipped chairs and desks with transparent desk surface for tablet computer use; (2) Sensor-based electronic bricks with real-life applications; (3) Eight transparent geometric shapes of different colors, used to build 3-D prototype of student inventions.

Fig. 1. The BitLab classroom with chairs and desks

A. Self-assembled sensor-equipped chairs and desks with transparent desk surface for tablet computer usage

The desks and chairs in Chinese classrooms are individual-based units. It is not suitable for team-work activities. It is difficult to repair as the entire desk or chair is one piece and cannot be dissembled. We design desks and chairs in BitLab so that they are built using same-sized building blocks. The frames of desks and chairs are made of iron or wood, as shown in Fig. 1. The desk top is made of transparent acrylic material. Students can put textbooks and tablet computers under the transparent surface while doing the experiment on the table. Students can assemble their own tables and chairs for different team-work configurations.

B. Sensor-based electronic bricks with real-life applications

The electronic bricks contain different sensors, such as light sensor, sound sensor, ultrasonic sensor, motion detector, temperature sensor and so on. Some sensor-based electronic modules are shown in Fig. 2.

These electronic bricks can be connected together, using a common interface connection, to build real-life applications, such as a sound-activated light or a smoke detector. In BitLab, just by connecting electronic bricks together with standard wires and connectors, one can easily build a home safety monitoring system controlled by mobile phones. Students are much more motivated since school work is closely coupled with real life.

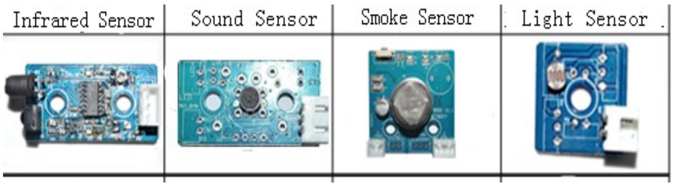

Fig. 2. The sensor-based electronic brick

The real-life applications built in BitLab can be categorized into four areas: energy saving and environmental protection (motion-activated light to save electricity), home security with smart control (smoke alarm and home monitoring system) game and entertainment (iPad or cell phone controlled car), sports and health (pedometer to measure the number of steps taken).

By using BitLab's electronic bricks, the time and effort one needs to build these real-life applications is greatly reduced. With different combinations of these electronic modules, it enables students to quickly build an electronic prototype for various applications. It also enhances the students' interest in the design of electronic systems, and stimulates students' creative thinking and hands-on abilities.

C. Eight transparent geometric shapes of different colors, used to build 3-D models.

In order to allow quick prototype of students' creative design, eight basic geometric shapes are used. The electronic bricks are affixed onto the geometric shapes, which resemble a house, a helicopter or any form from the students' imagination. These eight basic geometric shapes consist of square, triangle, quarter circle, rectangle, circle, small rectangle, small square and angle, as shown in Fig. 3. These bricks are made from colorful acrylic material. Specially designed push-pull rivets and plastic screws and nuts are used to connect acrylic plates into 3-D models.

The 3D body design provides an innovative hands-on design platform that enable students to transform their abstract ideas into a physical prototype without much effort.

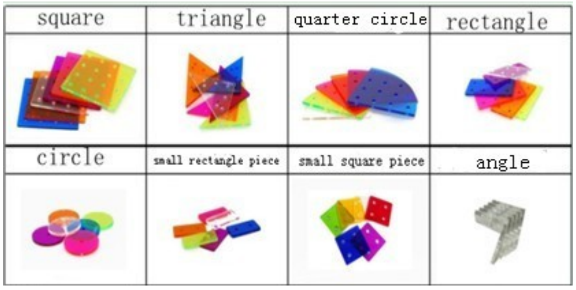

Fig. 3. 3D building blocks of BitLab

III. CURRICULUM

The interactive learning platform is delivered through team-based "BitLab Curriculum", which consists of four components: inventor's story, technology introduction, design and prototype, and product presentation. Each team consists of 3 to 4 students of various abilities and both genders.

A. Learning inventors' story

The purpose of this part is to stimulate students' desire for knowledge and curiosity and to inspire students' spirit to explore and innovate. There are some great inspiring stories such as: How did Edison invent the electric lamp? Who discovered the infrared light? What is the history of the invention of the thermometer?

B. Building electronic sensor-based systems

Students assemble the electronic bricks into a real life application, such as a door bell with a voice recorder or an infrared activated radio receiver or a light-sensor activated LED (Light Emitting Diode) lamp.

C. Building 3-D body

It gives students a good exercise to conceive and implement their design for real-life applications. The students build different kinds of prototype with electronic systems, such as "Penguins radio", "World Expo China Pavilion", "Intelligent Home", "Environmental Protection Car", "Animal House" and even "Space Shuttle". Some creations made by students are shown in Fig.4.

D. Presentation and public speaking

Each team writes up a description of their "product" and gives a presentation on its features and functionalities.

It encourages the students to give a speech to talk about his own design in front of other people, including the naming and creative process, comment on other people's ideas. As the students have made their own product in a team, they feel proud of themselves and speak out more naturally. This greatly increases student's speech confidence and leadership ability.

A student once said: "I'll never forget the first time speaking: shyness, the second time : improving, and the third time : excellent."

Fig. 4. Student's creationresult

In China, there are 30 BitLabs built since 2009, including 13 primary schools, 12 secondary schools, 3 tech museums and 2 public youth centers. A survey is conducted at Nanhu Primary School, where a total of 228 students, including 116 boys and 112 girls, attended fifteen BitLab lessons over one semester. Each lesson is 45 minutes; which sums up to 11.25 hours in one semester.

At the start of the course, each student filled out a self-evaluation score chart for ten abilities. After a semester study each student filled out the score chart again. Each ability is measured on a scale of 1 (poor) to 10 (excellent).

Fig. 5 shows the percentage of improvement of ten abilities. For example, a student has a score "2" of creativity at the beginning, and a score "6" at the end. The percentage of the improvement of creativity can be calculated as (6-2)/10 x 100% = 40%.

Analysis: As seen from the bar graph, for boys, the hands-on ability and creative ability are generally improved; for girls, the innovation ability, leadership ability and hands-on practice ability are generally improved.

We have collected hundreds of creative ideas from the students who had BitLab lessons. The students are encouraged to first find problems in daily life and then try to solve these problems with his/her inventions. Among them, more than one hundred patents have been filed.

IV. CONCLUSION

BitLab is an innovative classroom that integrates scientific history, sensor technology with quick prototyping and public speaking in a team-based interactive learning environment. The interactive learning platform is delivered through the team-based "BitLab Curriculum", which consists of four components: inventor story, technology introduction, design and prototype, and product presentation.

BitLab has made a great impact on education in China, but it still faces the barrier of the traditional examination-based education. Most Chinese parents think that college entrance examination is the only way to success. So it is necessary to set up a new evaluation standard for Chinese students in order to find talented students.

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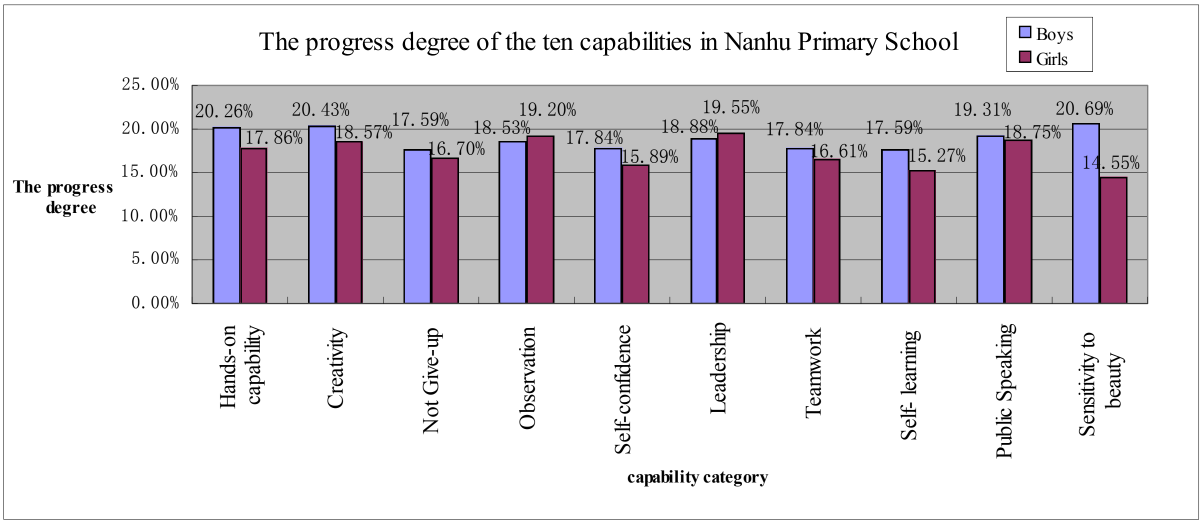

Fig. 5. The progress degree of the ten abilities in Nanhu Primary School

Innovation in Graduate Projects: Learning to Identify Critical Functions

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***Abstract*— Design-by-analogy is considered to be a powerful tool for engineering design. The difficulty of finding suitable analogies for solving a given design problem gives rise to the current efforts on computational tools for analogy-based design. In searching for analogies, the critical functions in a design problem are potential search criteria. The study described in this paper investigates whether novice designers identify an expert-derived critical function in a design problem under three scenarios: when they are asked to report the important functions in the problem, when they are directly asked to report the critical function and when they are asked to use design-by-analogy. It is observed that student designers do not identify the expert-derived critical functions when directly asked or when asked to list important functions. However, they inherently use the expert-derived critical functions in their analogical mapping process. This suggests that, during analogical reasoning, designers tend to identify and use the same critical functions regardless of experience, and also that critical functions are valid search criteria for deriving analogies from a computational database. This insight is highly valuable for current efforts to develop computational tools for analogical reasoning.**

Keywords—Analogy; Critical functions; Design by Analogy; Graduate Design Projects

I. INTRODUCTION

Innovation and creativity are highly sought after skills in engineering design. Generating novel design ideas is a very challenging task. Design-by-analogy is an effective tool that can help designers in this process [1-5]. In design-by-analogy, designers derive their inspiration from an analog system that they have or gain familiarity with. These systems may be derived from nature, engineering products, or their own day-to-day experiences. However, finding an analog suitable for a particular design problem is not an easy task, especially when the analog is from a field that the designer is not familiar with [6]. The ongoing efforts to develop computational tools to aid analogical reasoning supplement this process.

In order to develop an efficient computational tool, it is important to understand how designers naturally search for analogs during design. Anecdotal observations suggest that highly innovative products often add or improve the performance of one or more functions in an existing product [7]. Such functions are called "critical functions" further in this paper. The open question asks whether student designers effectively identify these critical functions on their own or whether they need help with that process. If they can identify the critical functions, those functions can lead them to effective analogies and subsequently to innovative design concepts. The study presented here aims to answer this question.

This study aims to investigate the use of critical functions by student designers as compared with an expert designer. Two different hypotheses are investigated here: (1) when instructed to identify critical functions, students will list the same critical functions as an expert designer and (2) during design-by-analogy, students will identify and use the same critical functions as an expert designer. The students in a graduate design class are given specially designed homework assignments to investigate these hypotheses. The details of the homework assignments along with a detailed discussion of the results are available in the further sections of this paper.

II. BACKGROUND

Design-by-analogy is an effective technique for design innovation. Naturalistic studies of design-by-analogy along with anecdotal evidence demonstrate that analogy is a common and effective strategy for design innovation [1-5]. Controlled experiments further demonstrate the power of analogy as a design tool [8, 9]. Designers often borrow ideas from the systems they are familiar with, without realizing that they are using analogical reasoning. Further, studies show that both expert and novice designers use analogies frequently in their designs [1, 10-12].

Analogies do have an undesirable potential to cause "design fixation" [13-17]. When designers fixate on an initial idea or an example, they think of similar ideas and most of the ideas generated are the variations of their initial ideas or the analogy. However, distant domain analogies carry little risk of design fixation and have shown potential to overcome fixation [15, 18]. Retrieving distant domain analogies is a challenging task and most of the existing efforts to develop computational tools for analogical design aim to supplement this task [19-23].

Most of the computational tools for analogy retrieval rely upon databases of analog systems [19, 24-26]. The analogs relevant to a given design problem are retrieved from such databases using various search criteria including functions, behaviors, and other keywords. However, it can be suspected

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that when designers naturally derive analogies in their design process, they use a few functions that are critical to the design problem. Hence it can be argued that these critical functions can be particularly effective search criteria for analogy retrieval from computational databases. For the purpose of this study, a critical function is defined as follows:

"A critical function represents significant design decisions within a functional model that significantly influence the performance of a design".

The purpose of the study presented in this paper is to understand if student designers use critical functions in their idea generation process, specifically in design-by analogy. It also investigates if novice designers can identify the critical functions of a design problem when they are instructed to do so. The following hypotheses are investigated further in this paper:

Identification Hypothesis: When instructed to identify critical functions in a design problem, novice designers will list the same critical functions as an expert designer.

Mapping Hypothesis: When searching for analogies, novice designers will identify and use the same critical functions as an expert designer.

III. Method

A classroom study was conducted to investigate the similarity between the search criteria followed by novice designers and an expert in analogy mapping. Three different scenarios were investigated in this study: identification of the most important functions, identification of critical functions, and analogy mapping. According to the hypothesis presented above, the students were expected to identify critical functions in these scenarios. In the first scenario, the students were asked to list the most important functions in the design problem to obtain the unbiased opinions of students about the functions they perceive to be important. In the second scenario, a definition of critical functions is included to see if that affects their opinions. The third scenario investigated how students identified and used critical functions for an analogy search.

A. Data Collection

The data for this study were collected from a graduate design course offered in the Mechanical Engineering Department at Texas A&M University. In this one semester course, graduate design teams were trained in the engineering design process outlined by Otto and Wood [27]. Throughout the course, the students were guided through community service-based and industry-sponsored projects. The teams were expected to cover all the stages of the engineering design process beginning with the customer needs identification and ending with the testing of proof-of-concept models. Teams consisted of three or four students, and project topics ranged from industry-sponsored issues to challenges related to developing countries. As the students were involved in realistic design situations, this course presented an ideal opportunity to collect data related to real-life designs by novice designers.

In order to collect data relevant to the current study, specially-designed assignments were employed. A set of three homework assignments were developed and assigned to the class by the instructor. The students were given one week to complete them. Figure 1 shows the timeline of data collection. The students were informed that their assignments would be used for research purposes, but the actual research aim was not mentioned to them. A total of 21 students volunteered to participate in this study and their assignments and team reports were analyzed for the purpose of this study. The participants received extra credit in their class for their participation. Some additional data were collected from the final reports submitted by the design teams.

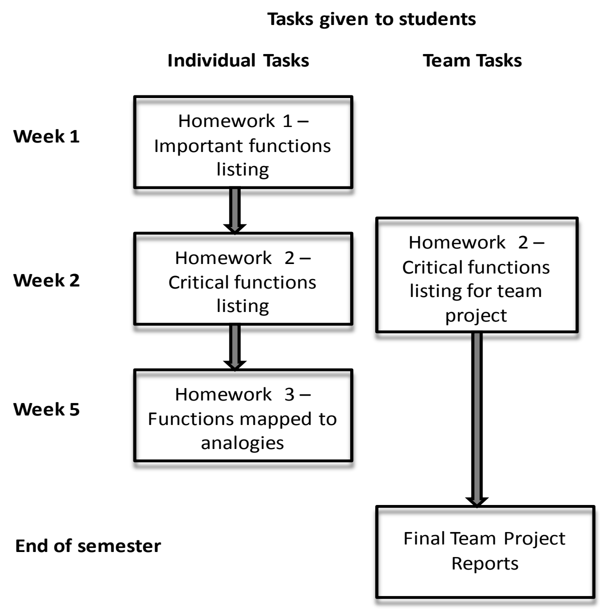

FIGURE 1. TIMELINE OF DATA COLLECTION

B. Design Problem

For this study, a specifically developed "can opener" design problem was used. The problem instructed students to design a simple and portable device to open cans for the aging population. The customer requirements given to the students included quickness in opening cans, use of minimum human force, non-electric operation and avoidance of any sharp edges after removing the lid. The problem of opening a can was familiar to most of the students; hence this design problem was appropriate for the study presented here. The functional model for this problem was neither too simple nor too complicated (Figure 2), again making it ideal for the study.

C. Details of Homework Assignments

The first assignment instructed the students to develop a function structure for the can opener design problem and list the most important functions in their function structure. This assignment was assigned a week after teaching them about the functional modeling. The students were expected to use the functional basis [28], so that their functional models were standardized. They were given a template that required them to list the important functions they perceive and the rationale for their choices. The template had five rows, so that they could list up to five important functions, but were not expected to fill all the rows. However, on the first trial of this assignment, it was observed that students tended to fill all the rows. This could lead to the listing of the functions that the students did not perceive as important. In order to avoid this problem, this homework was reassigned (homework 1-redo) to the class a week later, with specific instructions clarifying that they were not expected to fill all the available rows. This was also explained to them by the instructor while reassigning the homework. The students were also told that there was no single "correct" answer to this assignment and they were instructed to use their own judgment to fill in the table.

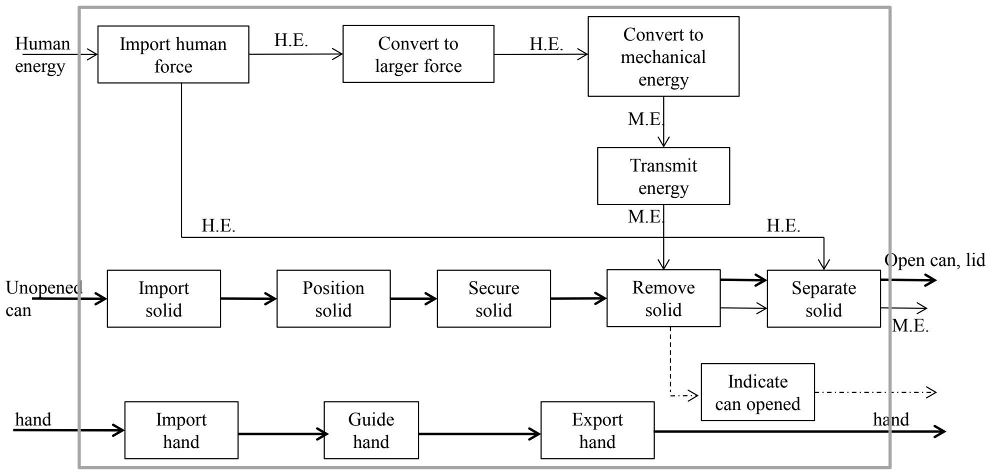

FIGURE 2. FUNCTIONAL MODEL DEVELOPED BY THE EXPERT FOR THE CAN OPENER DESIGN PROBLEM

The second assignment instructed the students to identify the critical functions from the function structure and list them. It defined a critical function as follows: "A critical function is one that represents critical design decisions within a functional model that significantly influences the performance of a design". A functional model developed by the authors for the can opener problem was provided to the students in this assignment. The students were given a template to record the critical functions they identified and the rationale for their choices. As with homework 1, they were told that it was not necessary to fill all the rows in the table. Again, they were told that there was no single "correct" answer and to use their own judgment. In addition to identifying the critical functions in the can opener design problem, the students were instructed to identify the critical functions in their team design project too. Each design team was expected to submit one assignment for their team project.

The third assignment instructed the students to identify analogies that could help to solve the can opener problem. It was given to them after they were taught design-by-analogy and the word tree method for analogy mapping. In this assignment, they were instructed to report the analogies they identified along with the functions they mapped between the analog and the design problem (TABLE I.). The template shown in table was provided to them for reporting these. The research aim of this assignment was to understand whether they identified the same critical functions during analogical reasoning as an expert would for the same design problem.

In all the assignments, the students were given specific instructions to list functions based on the functional basis [28] in order to get a standardized set of functions for analysis. However, a few students listed customer needs instead of functions in their first assignment. The instructor clarified the differences between a function and a customer need to them and instructed them to resubmit the assignment. Even in the re-submissions, two students listed customer needs. They repeated the same mistake for their remaining two assignments as well. Hence their data were removed from the analysis, bringing the sample size to 19 students.

TABLE I. TEMPLATE GIVEN TO STUDENTS IN HOMEWORK-3 TO REPORT THE ANALOGIES IDENTIFIED AND THE FUNCTIONS MAPPED

Analogy identified	Function(s) mapped to the can opener

Additionally, we sought to observe how students identified and used critical functions for analogy search in their team project. These data were collected from their final reports. In the reports, the teams were expected to describe identified analogies and concepts generated from analogies. These data were collected from the reports by one of the authors. However, some of the final reports were missing data, as the teams failed to follow reporting instructions. The available data were collected and analyzed for this study.

D. Data Analysis

All the homework data were analyzed to find the occurrences of critical functions in the can opener design problem. Prior to the study, one author developed a function structure for the can opener and identified the critical functions. The author denoted "Separate solid" as the critical function in this design problem. This function was designated as the "expert-derived" critical function, and all students' responses were compared against this function in our analysis.

The functions listed by students in each assignment were tabulated and the frequency of occurrence of each function from the functional basis [28, 29] was studied. If most students identified a particular function as critical in each assignment, the frequency of the function should be significantly greater than the other functions.

In order to study the identification of critical functions by teams in their design projects, the team assignments listing the critical functions in their design problems were also analyzed. Additionally, we also analyzed the data from team final reports on the functions they mapped to analogies. Since each team worked on a different design problem, these data were directly tabulated and appear in the next section.

IV. Results & Discussion

To understand students' use of critical functions and evaluate our hypotheses, the frequency of identified critical functions in the can opener problem was studied for each scenario. The following subsections outline the results obtained.

A. Homework 1 – Listing Most Important Functions

We observe that students list a variety of functions as important functions in their functional model for homework 1. Figure 3 shows frequencies of students' listed functions. As evident from the figure, students list "Convert energy" most often as an important function in the design problem. "Separate solid/material" only appears 6 times among 19 students, showing that most novice designers do not identify the expert-derived critical function when reporting the most important functions.

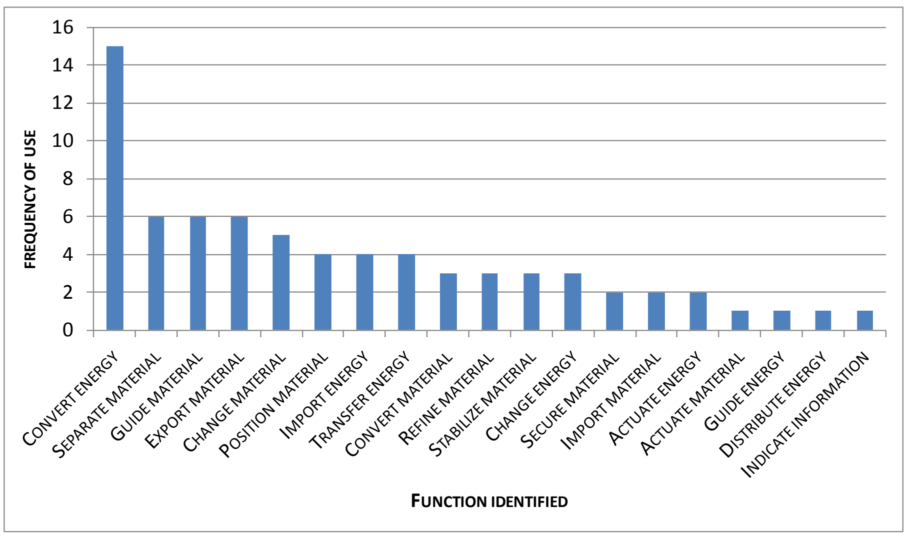

Figure 3. Frequencies of functions in homework-1 (listing of most important functions)

B. Homework 2 – Listing Critical Functions

According to the Identification Hypothesis, after students are instructed to identify critical functions, they will identify the same critical functions as an expert would. In homework 2, the students are given the definition of a critical function and instructed to list critical functions from the provided functional model of the can opener. However, despite receiving instruction on critical functions, most students again do not identify the expert-derived critical function. Figure 4 shows the frequency of functions that the students listed as critical functions. As with homework 1, most students considered "Convert energy" as a critical function. 8 of 19 students identified "Separate material" as a critical function, but 11 did not do so. Students do not identify the expert-derived critical function when specifically instructed to do so, which contradicts the Identification Hypothesis.

C. Homework 3 – Analogy Mapping

The functions mapped by the students during analogical reasoning in homework 3 reveals a very interesting trend. Figure 5 shows the frequency of various functions used in analogy mapping. As evident from the figure, in most of the cases, students list "Separate material" as a primary search criterion in analogical reasoning. They also use other functions for analogical reasoning, but the expert-derived critical function of the design problem appears most frequently in this scenario. This is consistent with the Mapping Hypothesis.

TABLE II shows the number of students that identified each function as critical in each scenario (assignments 2 and 3). It appears that more students identify the expert-derived critical function of the design problem when doing analogy mapping than when directly identifying critical functions. A Chi-square test of independence [30] is used to confirm this difference statistically. The results indicate a significant difference ($\chi^2 = 8.88$, $p < 0.01$). In other words, even though the students do not list the expert-derived critical function when asked to list critical functions, they do identify critical functions during analogy mapping.

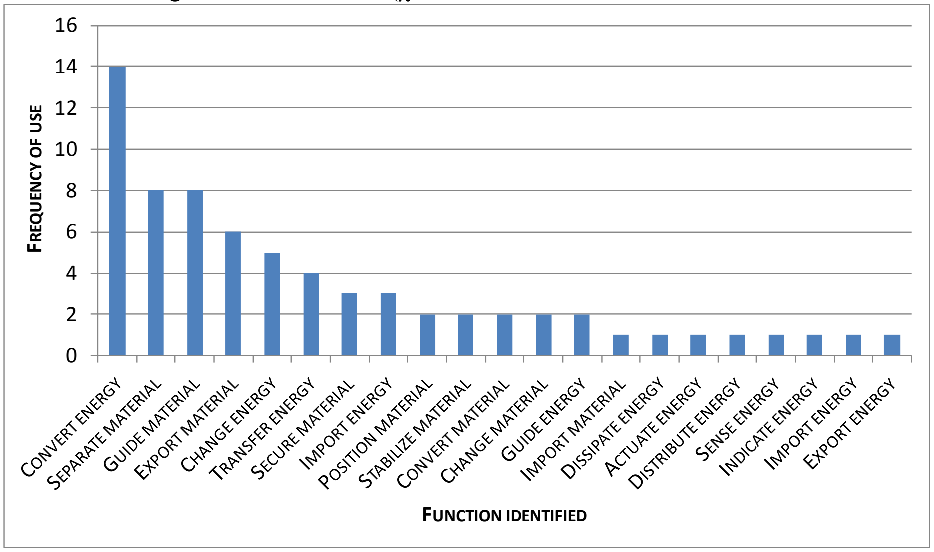

FIGURE 4. FREQUENCIES OF FUNCTIONS IN HOMEWORK-2 (LISTING OF CRITICAL FUNCTIONS)

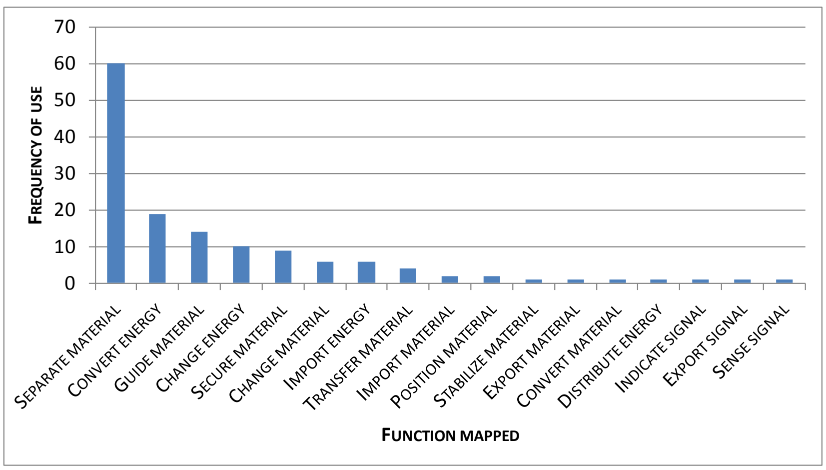

FIGURE 5. FREQUENCIES OF FUNCTIONS IN HOMEWORK-3 (ANALOGY MAPPING)

D. Identification of Critical Functions in Team Projects

The ability of student teams to identify critical functions in their design problems is studied using data from team assignments and final reports. These appear in TABLE III. Though some data are missing, the table shows that in most cases, the teams identify the expert-derived critical function during analogy mapping but do not do so in their critical function listings. These results are similar to those from the can opener problem.

The low occurrence of students identifying the expert-derived critical function of the design problem may stem partially from the instructions they received. The definition of critical functions given to the students is very simple; however, it may not have conveyed the correct idea to the students. Due to the time constraints of the course, re-running the assignment with a different definition of critical functions was impossible and will be completed in future work.

In addition, there may be alternative explanations for why novices do not identify the expert-derived critical function. For example, perhaps "Separate solid" is more amenable to the analogy mapping exercise, or perhaps students took a differing perspective that led most them to believe "Convert energy" was more critical toward performance, in contrast with the expert opinion, even when looking at the same functional model.

TABLE II. NUMBER OF STUDENTS WHO IDENTIFIED THE EXPERT-DERIVED CRITICAL FUNCTION IN EACH SCENARIO

Scenario	Identified Expert-Derived Critical Function?	
	Yes	No
Asked to list critical functions	8	11
Asked to use analogy mapping*	16	2

* One student did not submit the analogy mapping homework

TABLE III. IDENTIFICATION OF CRITICAL FUNCTIONS BY THE DESIGN TEAMS FOR THEIR DESIGN PROJECTS

Team	Did the team identify/use expert-derived critical function?[1]		
	Listing critical functions	Searching analogies	Idea generation with analogies
1	No	Yes	Yes
2	No	Yes	Yes
3		Yes	
4	Yes[2]	Yes	
5			
6	No	Yes	Yes
7	No	Yes	Yes

1. Empty cells show that the corresponding data are missing
2. Identified one out of two critical functions

The most interesting result from this study is the identification of critical functions by novice designers during analogical reasoning. In most cases, experienced designers use critical functions in analogy mapping, which often leads them to innovative designs [7]. One of the open questions is whether novice designers need help in identifying the same critical functions for analogical reasoning, so that they can identify the most effective analogies for improving design performance. The results from this study show that they identify the same critical functions as an experienced designer without much trouble during their analogy mapping process. This is a very valuable insight for ongoing efforts to develop automated tools for analogical reasoning too. Currently, the authors are developing a tool for analogy retrieval based on critical functions in design problems [31]. This tool assumes that designers can agree on what functions are critical in a design problem, regardless of their experience. This study validates this assumption and suggests that the use of critical functions may be a very effective approach for the analogy retrieval tool.

According to the observations made on the data collected from the design teams' final reports, student teams often face problems with analogy searching. They try to map surface features in many occasions or search for functions that are not critical to the given design problem. Still, most teams use analogies mapped by critical functions for their further idea generation. Since analogies identified using critical functions are more potentially useful, we need to devise more methods or techniques that can help students identify critical functions and map them to find effective analogies. This will be done in our future work.

V. CONCLUSIONS

Anecdotal observations suggest that highly innovative products often add or improve the performance of one or more functions present in an existing product [7]. We refer to these as "critical functions". Prior data indicate that the potential for product innovation is likely to be improved by focusing on critical functions. The purpose of the study is to investigate the identification and use of critical functions by graduate students while solving a realistic design problem. This study uses the problem of creating a can opener for the elderly. Prior to the study, one function of the can opener is determined to be critical by an author and denoted as the expert-derived critical function. In the study, students are first asked to create a functional model of the can opener and then to identify the most important functions. Later, they receive a definition of a critical function along with a functional model of the can opener and asked to identify the critical functions. Lastly, they are asked to identify analogies that are useful toward solving the can opener problem, along with the functions that they use for analogy mapping. Additionally, they are instructed to list the critical functions in their team projects, and these are also studied through their reports. The results show that while graduate student designers are very effective at finding innovative solutions, they do not identify the expert-derived critical function early in the design process. However, at a later stage, most of them use the expert-derived critical functions during analogical mapping, leading them to useful analogies and highly innovative solutions. These results support efforts to develop computational analogy retrieval tools that use critical functions as primary search criteria.

ACKNOWLEDGMENTS

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Improving Learning of Computational Thinking Using Creative Thinking Exercises in CS-1 Computer Science Courses

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***Abstract*—Promoting computational thinking is one of the top priorities in CS education as well as in other STEM and non-STEM disciplines. Our innovative NSF-funded IC2Think project blends computational thinking with creative thinking so that students leverage their creative thinking skills to "unlock" their understanding of computational thinking. In Fall 2012, we deployed creative exercises designed to engage Epstein's creative competencies (Surrounding, Capturing, Challenging and Broadening) in introductory level CS courses targeting four different groups (CS, engineering, combined CS/physical sciences, and humanities majors). Students combined hands-on problem solving with guided analysis and reflection to connect their creative activities to CS topics such as conditionals and arrays and to real-world CS applications. Evaluation results (approximately 150 students) found that creative thinking exercise completion had a linear "dosage" effect. As students completed more exercises [0/1 - 4], they increased their long-term retention [a computational thinking test], $F(3, 98) = 4.76$, $p = .004$, partial $Eta^2 = .127$ and course grades, $F(3, 109) = 4.32$, $p = .006$, partial $Eta^2 = .106$. These findings support our belief that the addition of creative thinking exercises to CSCE courses improves the learning of computational knowledge and skills.**

Keywords—CS1, Creative Thinking, Computational Thinking, College, Computer Science

I. Introduction

Computational thinking is an approach to solving problems, building systems, and understanding human behavior that draws on the power and limits of computing [1]. Computational thinking includes skills such as conceptualizing at multiple levels of abstraction, defining and clarifying a problem by breaking it down into relational components, and testing and retesting plausible solutions. Already considered to be one of the top priorities in computer science (CS) education, computational thinking is becoming more important in both STEM and non-STEM disciplines given the reliance of these disciplines on computational techniques for data collection, archiving, processing, and analysis. In this way, computational thinking has become an *enabler* that promotes problem solving in a wide range of disciplines and a *bridge* that allows for interdisciplinary innovation and discovery. It has even been argued that computational thinking is as fundamental as skills such as reading, writing and arithmetic [2].

The increased demand for computational thinking has led to numerous articles in educational research venues such as the proceedings of FIE and the communications of the ACM. These articles demonstrate the increasing momentum of research addressing the need for effective education in computational thinking, both for CS and across the broader spectrum of STEM and non-STEM disciplines. This research is diverse, ranging from course specifications to course development, from community building to setting policies, and from teaching and learning to assessment [2][3][4][5][6][7].

However, there is a potentially serious problem for expanding computational thinking from CS into STEM and non-STEM disciplines. The students in non-CS disciplines come from diverse backgrounds and many are likely to ***have limited understanding of computing concepts*** that are used as the basis for computational thinking. Without a basic level of understanding, these students will have a very difficult time developing computational thinking fluency. As noted by Epstein et al. [8] and Shell et al. [9], one cannot think beyond the boundaries of one's cognitive tools or knowledge. Students who are forced to use computational thinking based on concepts that they do not understand may become frustrated, potentially lowering both their motivation and their self-efficacy. As both student motivation and self-efficacy are strongly connected to student learning [10][11], if learning computational thinking leads to lowered student motivation and self-efficacy, then ***it could actually be detrimental—reducing learning for students in STEM and non-STEM disciplines alike—instead of being beneficial***.

Our innovative solution is to improve the learning of computational thinking by blending it with creative thinking. Creative thinking is thinking patterned in a way that tends to lead to creative results [12]. Creative thinking is not limited to the arts but is an integral component of human intelligence that can be practiced, encouraged and developed within any context [13][14][15]. Epstein's Generativity Theory breaks creative thinking down to four core competencies: *capturing* novelty, *challenging* established thinking and behavior patterns, *broadening* one's knowledge beyond one's discipline, and *surrounding* oneself with new social and environmental stimuli [8]. By blending computational and creative thinking students can leverage their creative thinking skills to "unlock" their understanding of computational thinking [9]. As an example, rather than trying to directly explain multiple levels of abstraction in computer programming, we ask students to think about why a corporation is organized using layers. Students are likely to reach the conclusion that having executives who are experts on a single layer is the most efficient and effective way to identify and solve problems. Thus, by using creative thinking skills students have unlocked why programs use multiple layers of abstraction. In this way, we make computational thinking more generally applicable to STEM and non-STEM disciplines where students may have creative thinking skills but lack understanding of computing concepts. The reverse is also true: students who understand computational thinking could leverage it to improve their creative thinking skills.

We have designed four creative thinking exercises that blend computational and creative thinking. These exercises are designed to provide instruction on CS concepts such as conditionals, arrays, modular programming, and debugging. However, these exercises completely lack any programming code. Instead, these exercises involve tasks seemingly unrelated to CS such as individually writing the chapters for a story based on separate plot points and then working in a group to revise the story to make the content more cohesive. These exercises are designed to foster development of Epstein's creative competencies by engaging multiple senses, requiring imaginative thought, presenting challenging problems and combining both individual and group efforts. During these exercises, students are given explanations, which we call CS Light Bulbs, which relate the tasks directly to the CS topics. Finally, the students answer analysis and reflection questions designed to further promote both computational thinking and creative application of computational skills.

We deployed these creative thinking exercises during the Fall 2012 semester at the University of Nebraska, Lincoln. Over 200 students in four different introductory CS courses took the exercises and the exercises counted as part of their final course grades. Each course was tailored to a different target group (CS majors, engineering majors, combined CS/physical sciences majors, and humanities majors) and so these courses contained a mix of students with both computational and creative thinking skills. Our evaluation results found that after completing the exercises creative competency was significantly correlated with computational thinking as measured by a computational thinking test. Further, completion of the exercises improved both long-term retention of course content and course grades—even when student motivation was factored in. Overall, these results support the effectiveness of blending computational and creative thinking.

II. Creative Thinking Exercise Design

All our exercises combine hands-on problem solving with written analysis and reflection and are designed to be completed by a group of students working collaboratively in order to facilitate creative thinking from students with multiple backgrounds. Each exercise requires approximately 1-2 hours per student but students are given two weeks to work on the exercises because of the collaboration required. The exercises have four common components (Objectives, Tasks, CS Light Bulbs, and Questions) described in more detail below. Exercises are designed so that the students have hands-on and group tasks first, in Week 1, and then reflect on their Week 1 activities in Week 2 by answering questions. Both Week 1 and Week 2 are graded.

Objectives. The Objectives component, at the beginning of the exercise handout, lists the computational and creative thinking objectives for the exercise. These objectives help the student understand why they are doing these exercises by showing how an exercise lacking any programming code is related to CS concepts and how students can use relevant creative thinking skills (described in terms of Epstein's core competencies of Surrounding, Capturing, Challenging and Broadening) to solve the exercises.

Tasks. The majority of the content of an exercise handout is the Tasks component which lists all the tasks the group of students must complete during the two weeks of the exercise. These tasks require students to work collaboratively (and may require individual contributions as well). Tasks are designed to engage group members with different backgrounds, to encourage creative approaches and to promote open-ended discussions as the group produces concrete, specific artifacts.

CS Light Bulbs. The CS Light Bulbs are self-contained explanations which make explicit the connections between the exercise tasks and a set of CS topics. By being embedded in the exercise handout within the Tasks, the Light Bulbs help students stay aware of the underlying computational thinking skills while they are performing the creative thinking tasks.

Questions. The Questions component, at the end of the exercise handout, uses open-ended questions that require collaboration among students as they engage in both analysis and reflection. To answer these questions, students must apply *creative thinking* to CS problems and revise the results of their original tasks using *computational thinking*. Questions thus build upon the CS Light Bulbs and reinforce the connections between the creative thinking fostered by the tasks and the computational thinking in the CS topics.

III. Individual Exercises

Here we describe each of the creative thinking exercises in more detail. We developed four different exercises for the Fall 2012 deployment: (1) Everyday Object, (2) Storytelling, (3) Cipher, and (4) Exploring. These exercises, each of which has the set of components described above, are summarized below, but due to space considerations we provide just one example for each exercise of the multiple CS Light Bulbs. Furthermore, we highlight Everyday Object and Storytelling exercises and only summarize the other two.

A. Everyday Object Exercise

Objectives. ***Computational***: (1) Learning about the description and design process for modular programming by describing an everyday object in detail including why the object is needed and how the object functions; (2) Learning about abstraction and function characterization by identifying properties of an everyday object

Creative: (1) Surrounding: looking at an everyday object in new ways, using all of your senses to understand how it's made and how it functions; (2) Capturing: using written language to describe all the different details and characteristics of this everyday object so you can work with it in new ways; (3) Challenging: describing the operations of an everyday object with words and also as a computer program; (4) Broadening: imagining that this everyday object doesn't exist and acting like its inventor who is trying to fulfill a need by creating something new and useful

Tasks. For the next two weeks, you will be using language to try to clearly and thoroughly describe the functions of an ordinary object that you might use every day. You will be acting like the inventor of that object, imagining that it does not yet exist and trying to describe what need would be fulfilled by your (new) object and how (specifically) it will function.

Your group will choose a common, everyday object from the list. Your challenge is to imagine that this object does not exist and to describe in written language (1) the mechanical function of your object, (2) what need is fulfilled by this object, and (3) the physical attributes and characteristics of your object.

You must describe the object's function, the need it will fulfill and its attributes in clear, non-technical language which any user could understand. Your description must be specific enough so that someone who had never seen the object could recognize it and understand how it works and understand what benefits it provides.

Note: Students were given a list of objects (zipper, mechanical pencil, binder clip, Ziploc bag, scissors, tape measure, stapler, nail clippers, umbrella, flashlight, can opener, clothespin, sticky notes, toilet paper holder, revolving door) from which to choose.

CS Light Bulbs. This description process is very important for developing algorithms in computer science. An algorithm consists of the series of steps necessary to solve a given problem. By using algorithms, we can solve problems without having to constantly "reinvent the wheel" and spend the time, money, etc. to figure out each step ourselves. However, if one or more of these steps are unclear, we can have difficulty following the algorithm which can lead to serious repercussions as described in the following two examples. First, if the formulation algorithm used to mix the concrete for a road or bridge is unclear, workers may make a mistake during pouring leading to reduced service life. Second, if the business plan algorithm for a new company is confusing, venture capitalists may be reluctant to invest leading to failure of the business. To avoid these repercussions, the developer should make every effort to make the algorithm's description as clear as possible for all steps. In other words, characterization of processes is key; it allows us to abstract a process and then convert it into a formal problem or solution. *Note: The handout also includes three other Light Bulbs on writing functions in CS, the diagramming process, and abstraction in programming languages.*

Questions. ***Analysis***: (1) Consider your object as a computer program. Draw a diagram that shows all its functions as boxes (name them), and for each function, its inputs and outputs. Are there shared inputs and outputs among the functions? (2) Consider the list of physical attributes and characteristics. Organize these such that each is declared as a variable with its proper type. Can some of these attributes/characteristics be arranged into a hierarchy of related attributes/characteristics?

Reflection: (1) Consider your response to Analysis 1, are there functions that can be combined so that the object can be represented with a more concise program? Are there new functions that should be introduced to better describe your object such that the functions are more modular? (2) Have you heard of abstraction? How does abstraction in computer science relate to the process of identifying the functions and characteristics as you have done in this exercise?

B. Storytelling Exercise

Objectives. ***Computational***: (1) Learning about how large programs are developed using modular programming by separately writing chapters for a story which are connected with fixed story points at the beginning and end of each chapter; (2) Learning about the need for the debugging and testing process by revising the chapters to make the flow of the story more logical and cohesive; (3) Learning about the need for a methodical and logical debugging process to make sure that a program's observed output matches the expected output; (4) Learning about identifying logical inconsistencies in a product or solution and using methodical approaches to resolve them

Creative: (1) Surrounding: using your senses of sight, sound, smell, touch and your imagination to connect two seemingly unrelated things (two story points) in a logical and coherent way; (2) Capturing: learning to take novel and spontaneous outputs (your two story points) and use language to fill in the blanks by writing your way from one point to another; (3) Challenging: applying computational debugging to a story by taking independently generated chapters and editing them so they form a consistent narrative; (4) Broadening: increasing your ability to problem-solve and to collaborate by taking the inputs of others (your group's individual chapters) and making them into an effective and functional whole—a logical and cohesive story.

Note: The following is an example of the story points to be developed as chapters: (1) "OPEN UP! THIS IS THE POLICE!", (2) Panting, Kevin ran down the unfamiliar alley, hoping there would be an exit ahead, (3) The pendant wasn't particularly remarkable, but something drew his eye to it…something he couldn't quite put into words, and (4) "It doesn't respond like that for everybody," the green-eyed girl said. "You're the first person it has activated for in over 25 years."

Tasks. For the next two weeks, your group will be telling a story with several short chapters. However, you won't write the story as a linear line from A to B. Rather, you will be given a series of story points. These story points will be the pivotal moments in the story. They will act as inputs and outputs to your individual chapters. Each person in your group will write a chapter of the story that falls between two story points. You will all write your chapters independently of each other. All you know is how the story (and each chapter) starts and how it ends up; the input and the output.

During Week 1, group members will separately write the chapters. You will not consult with your group members and you are not allowed to share your chapter with your group members. You will shape your chapter solely on the story points.

During Week 2, review the chapters which have been written by your group members. Most likely not all of your chapters will make sense in the context of each other (this is normal and expected). After you review all of your group's chapters, you need to reconcile the differences. Pick one chapter as the anchor and make minimal changes to it. Then revise the other chapters so that they logically fit with this anchor chapter.

CS Light Bulbs. Writing a chapter based on story points is similar to how we write functions in computer science. To make the design of large programs feasible, the inputs and outputs for a function are generally known before that function is written. In a sense, the way the code for the function is written is less important than whether it produces the correct output value for a given input value. Of course, the function must mesh seamlessly with all the other functions in the program. Additionally, the function must work for all possible input values not just one or two. For example, a function which controls airbag deployment must work for all manner of collisions not just one at 30 mph. Meanwhile, a program solution is often made up of a sequence of functions, where the output of the first function is fed into the second function as input, and the second function's output is fed into the third function, and so forth.

Note: The handout also includes two other Light Bulbs on the debugging and testing process and finding logical errors in programs.

Questions. ***Analysis***: (1) What was the most difficult part of "debugging" your story? Did entire chapters need to be rewritten? Or could you manage to reconcile between each chapter with each other by making only minor changes? (2) What would you have changed about your initial story telling process to make the debugging process easier? Would you have made your story more straight forward and logical, or more ridiculous and expansive? Essentially, how would you go about writing the story so that it includes the fewest number of "bugs"?

Reflection: (1) Compare this process to working in a large team on a software project. In what ways are the two processes similar? In what ways are they different? (2) How would you change the rules of the assignment to guarantee that a minimal number of "bugs" are created? Assume that all chapters must still be written simultaneously.

C. Cipher Exercise

For the Cipher exercise, student teams are required to come up with three ciphering rules to "code" several questions during Week 1. In Week 2, all teams will try to decipher these coded questions by answering the questions in the same code. Computational objectives include (1) Learning about the code generation process for ciphers and encryption programs by creating rules and a one-to-one mapping to encode messages and (2) Learning about the trial-and-error code breaking process by trying to guess the mapping to read coded messages; while creative objectives include (1) Capturing: creating new outputs and using new ways to represent and save data by inventing, testing and documenting a simple system of rules to transform English sentences into a cipher so that their meaning is obscured; and (2) Broadening: acquiring new information and skills by understanding how just three simple rules can generate complex products (ciphers) and how your everyday experience with the English language or with the world can inform your code-generating and code-cracking efforts

In the Questions component, the analysis questions include: (1) Analyze the questions asked by other teams. Were they too easy to answer? Were the questions faulty? (2) How easy would it be to implement your cipher in a computer program? What would your concerns be with implementing your cipher? Reflection questions include: (1) How strong are your rules? Are they clear, or is there some level of ambiguity? Could anybody follow them and understand them? How could you improve your rules? (2) Reflect on your "code cracking" approach. What kind of weaknesses and strengths did it have? Imagine you had to decode over 9000 characters rather than just the 26 in the English alphabet. Could you scale your approach? Would brute force work (i.e. simply try to determine a mapping of characters to their cipher)?

D. Exploring

In this exercise, each group is required to pick a location on campus from one of ten locations on a campus map. Each member of the group must make several observations at the group's location, as well as taking a photo of him- or herself making observations at this location. They are also required to use a data collection form to record their results and to verify that they have gathered sufficient data.

Computational Objectives include: (1) Learning about the data collection process used in many fields by making observations about a specific location on campus; (2) Learning why the ability to brainstorm and visualize the "big picture" is important for writing programs; (3) Learning why the data collection process is important for evaluating existing products and programs; and (4) Learning about capturing and representing different aspects and patterns of an environment for solving a problem

Creative Objectives include: (1) Surrounding: looking at a familiar location on campus in a new way and using all of your senses (sight, sound, smell, touch and thought) to become more aware of what is around you; (2) Capturing: Making a written inventory of everything you observe at a site—plants, animals, people, sounds, and smells—and also documenting your observing by taking a photo of yourself at the site; (3) Broadening: Increasing your ability to solve problems by looking at tables of data in new ways. What did you expect to observe at the site? What did you actually observe? What does the data document about the site and your experience at the site? What does it leave out?

In the Questions component, the analysis questions include: (1) What would be the benefits and drawbacks of using arrays, cell arrays, or structures to store the data you have collected? (2) After completing the previous analysis, you must now analyze the applications of the data you collected. To do this, each team member must brainstorm at least three different real world applications of the data—"Be bold, think big, do not constrain yourself to feasibility or practicality!" Reflection questions include: (1) What other data (that you might ordinarily ignore) could be collected that could be manipulated programmatically and exposed to solve some problem? (Think along the lines of Google scanning and analyzing millions of books to observe long term cultural and language changes.); (2) Speculate on how you might broaden the classes of data, and on how you might capture overlooked data.

IV. Exercise Deployment

The exercises were deployed using the Written Agora system [16]. This is a wiki system designed to facilitate online collaboration between groups of students. The wiki system includes a content page where students can work together on completing the tasks and an online forum where students can discuss, with group members, the responses to the analysis and reflection questions. As the wiki was always online, students could log in and work on the exercises whenever it was convenient. The wiki also kept track of all the revisions so that we could determine which students were contributing to the group.

The exercises represented 3-5% of the final grades depending on the course. After completing the tasks and answering the questions, students in each group were assigned individual grades based on their contributions to the group's wiki page.

V. Evaluation Methods

Students voluntarily participated in evaluation data collection which was approved by the UNL Institutional Review Board. The courses had 241 students initially enrolled and 196 students who completed the courses. Of those who completed the courses, 150 students (133 male; 17 female) consented to participation in the evaluation and 129 students (114 male; 15 female) consented to the use of their course grades and university grade point average. Not all students completed all measures. Sample for specific analyses are shown in Table 1.

Course grades were used to determine impact on student achievement in the course. Retention of core computational thinking knowledge and skills was assessed by a test developed by CSCE faculty [17]. The computational thinking knowledge test contained 13 conceptual and problem-solving questions for the core computational thinking content common to all CS-1 classes. The coefficient alpha reliability estimate was .76. The computational thinking test was administered on a Web platform (Survey Monkey) during the last week of classes as part of evaluation data collection. Students reactions to the exercises were obtained in two ways: (1) after each exercise, 3-6 volunteer students participated in a focus group; (2) using instruments adapted from Shell, Snow, and Claes [18] students were asked to rate exercises and provide open-ended comments in surveys done as part of evaluation data collection. Students' overall GPAs were obtained from university records and were used as a covariate for analysis.

VI. Results

A. Impacts on Student Learning

We used Analysis of Covariance (ANCOVA) to test whether the number of exercises completed (0-1, 2, 3, 4) was associated with higher course grades and computational thinking test scores. We included students' cumulative Grade Point Average (GPA) adjusted to remove the grade for the course as a covariate to control for differences that might be attributable to students' general level of academic ability.

Cumulative GPA was a significant covariate with course grades ($F(1, 109) = 56.26$, $p <.0001$, partial $\text{Eta}^2 = .340$) confirming that students' achievement in the class generally reflected their overall achievement record. With GPA controlled, the number of exercises completed was significantly associated with course grade (Table I: $F(3, 109) = 4.32$, $p =.006$, partial $\text{Eta}^2 = .106$). There was a significant linear trend (p=.0001) from 2 to 4 exercises completed.

TABLE I. Mean Scores By Exercise Completion

	Computational Thinking Test			***Course Grade***[a]		
Exercises Completed	***M***	***SD***	***N***	***M***	***SD***	***N***
0-1	4.31	3.09	13	2.48	1.38	14
2	6.91	3.20	23	2.33	1.16	26
3	7.41	3.22	29	3.24	1.17	33
4	8.21	2.26	38	3.53	0.59	42

[a]Grade=12-point scale from 0=F to 4.0=A.

For the computational thinking test, cumulative GPA was not a significant covariate ($F(1, 98) = .296$, $p = .588$). This suggests that long-term retention of course content is not necessarily the same as course achievement reflected in grades. This distinction was also confirmed by the relatively moderate correlation of $r = .35$ between course grade and the computational thinking test. The number of exercises completed was significantly associated with computational thinking test score (Table I: $F(3, 98) = 4.76$, $p =.004$, partial $\text{Eta}^2 = .127$). There was a significant linear trend ($p < .0001$) from 0-1 to 4 exercises completed.

These findings indicate an apparent "dosage" effect, i.e., learning and course achievement increase with each additional creative thinking exercise completed. The increases are not trivial. Students completing 2 or fewer exercises averaged approximately a C to C+; whereas, students completing 3 exercises averaged a B and those completing 4 averaged a B+. Similarly, students improved on the knowledge test by about 2 1/2 points from 0-1 to 2 exercises completed, another 1/2 points from 2 to 3, and over 3/4 points from 3 to 4. Results for the knowledge test did not differ for CS majors and non-CS majors. Non-CS majors; however, appeared to benefit more in relation to grades with an increase from 1.67 for 0-1 exercises, to 2.33 for 2 exercises, to approximately 3.5 for 3 and 4 exercises. CS majors did not exhibit as sharp of increase but those completing all 4 exercises achieved a 1/2 grade point higher score than any other group. In relation to traditional findings for classroom educational interventions, these are strong effects. They also demonstrate meaningful "real world" impact. Of course, we cannot conclusively determine that the results are solely due to the exercises; however, by controlling for students' cumulative GPA, we can say that the results are not due to students who are better students in general completing more exercises than poor students.

B. Student Reactions to the Creative Thinking Exercises

One focus group was conducted for each of the four exercises with each done in one of the four participating classes. A majority of students reported that they did not enjoy completing the exercises and found it difficult to understand how they related to course objectives. These comments were mirrored in open-ended survey responses. When asked general questions in focus groups and in the survey about impacts on computational thinking and computing, most students indicated little impact expressing that exercises were unrelated to the concepts covered in the class. Most reported that the exercises did not have enough payoff in terms of grades or learning to justify the amount of time they took. Students expressed difficulty communicating with classmates outside of class which impacted their willingness and ability to complete assignments. Students felt that instructor facilitation of the exercises was too limited and they found it problematic that little class time was devoted to discussion of the exercises.

When asked to rate exercise effectiveness, about 75% of students indicated that they thought the exercises were either not effective or *neither* effective *nor* not effective in preparing them to use computational and CS tools in their field, helping them problem solve more creatively, and helping them creatively apply computational thinking in their field. These ratings of effectiveness were not significantly correlated with the number of exercises completed suggesting that perception of effectiveness was not a motivating factor for doing the exercises. The usefulness and interestingness of the story telling and cipher exercise were rated somewhat higher and received more positive responses in focus groups.

This dissatisfaction and self-assessment of impact is in stark contrast to the significant 'dosage' effect identified for exercise completion on grades and computational knowledge. However, when probed in focus groups for exercise impacts on specific computational thinking and computing skills, many students indicated that these were improved by completing the exercises. Furthermore, students stated that the exercises were successful in helping them understand how programming relates to the world around them and how they might apply concepts in a practical setting. These findings suggest that students are not necessarily able to recognize the value of educational activities for enhancing their learning, especially in their first or general impressions of an activity. But, if prompted to reflect further, they may begin to recognize the value.

VII. LESSONS LEARNED AND NEXT STEPS

Completing the exercises appears to have benefited student achievement and learning. Both their long-term retention (as measured by a computational thinking test) and their course grades improved the more exercises they completed. It appears that the use of creative thinking skills does help students "unlock" their understanding of computational thinking as we proposed. Students did not always recognize these benefits, however. They generally expressed dissatisfaction with the exercises and thought they were unrelated to the course and did not help their learning of course content. Only when pushed for specific impacts did students begin to recognize positive impacts of the exercises on their understanding and problem solving. To explain, the creative thinking exercises involve a level of abstraction that may mask the connections between the exercise activities and the underlying computational thinking principles. As a result, students may not be able to see these connections, leading them to question the relevance and benefits of doing the exercises.

This student feedback demonstrated the need for us to better and more specifically explain how creative thinking helps CS students and how the creative exercises relate to specific CS topics. This feedback also made clear the need to improve the logistics of exercise deployment. To address these student concerns and to make the benefits of the exercises more visible to students, we have taken the following steps for future deployment: (1) continually revised the objectives in all the exercises to make their connections to CS topics more explicit, (2) designed an "Exercise 0" so students can practice using the system before the graded exercises are assigned, (3) bundled the exercises together with learning objects on those same topics [19] to provide more detail on CS topics, and (4) assigned students to groups so that there were fewer delays in forming groups and so that students were on an equal footing in groups.

We discovered that the logistics of exercise deployment—how large the class was, how often it met, whether students took other courses together, whether they interacted outside of class—had a greater impact than we anticipated on how smoothly the exercises ran and how satisfied the students were with their experience. Students were especially sensitive to difficulties working with other students in their groups. Accordingly, we are in the process of identifying how to combine real-time experience (such as in-class explanations of the exercises) with these improvements to the exercises and with improvements to the online wiki in order to minimize student frustration with the logistics of the exercises. Given the evidence of real benefits to the students from our blending of computational and creative thinking, it is now our creative challenge to improve our exercise design and delivery so that students are eager to complete the exercises and recognize their value in enhancing their learning of computational thinking.

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An Analysis of a Pre-Engineering Program Model Used to Predict a Student's Persistence to Graduation

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Abstract— **This paper presents the evolution and implementation of the pre-engineering program at the joint Florida A&M University-Florida State University College of Engineering. The program was initiated in 2004. It was revised several times between 2004 and 2009. These revisions were made to accommodate unexpected or unattended consequences in the program's implementation. The current program consists of five courses taken by engineering students including First-Year Engineering Laboratory, Calculus I, Calculus II, General Chemistry I, and General Physics I. Chemical engineering students replace General Physics I with General Chemistry II Between 2004 and 2008, almost 2000 first-time in college (FTIC) engineering students participated in the program. The analysis suggests that students who successfully complete the pre-engineering program graduate from the college with a degree in engineering at a very high rate. Additionally, it appears there are no statistically significant differences in graduation rates among pre-engineering program completers with respect to home institution, gender, and race/ethnicity.**

Keywords—Pre-engineering program; First-Year Engineering, Freshman Engineering

I. INTRODUCTION

The Florida Agricultural and Mechanical University – Florida State University (FAMU-FSU) College of Engineering is a unique joint college between Florida Agricultural and Mechanical University (Florida A&M University, or FAMU) and The Florida State University[1]. Florida A&M University is the largest single campus historically black university in the United States. It had a Fall 2012 enrollment of over 11,000 students. Florida State University had a Fall 2012 enrollment of over 40,000 students. In the early 20th century, it was known as the Florida State College for Women. In 1982, the Florida Legislature authorized the two universities to offer engineering degrees with a mission to "attract and graduate a greater number of minorities and women in professional engineering."

As of Fall 2012, the total college enrollment was over 2500 students with 2200 undergraduate students and 300 graduate students. Undergraduate students complete all of their general education course work (e.g., English, mathematics, science, humanities, and social sciences) on their home campus. However, all of their engineering coursework is taken on a separate engineering campus. After completion of their curriculum requirements, students are awarded a degree by their home institution. The engineering campus is a shared facility of the two institutions. The faculty, staff, and facilities virtually belong to both institutions. In this way, resources are leveraged for engineering students.

The college currently offers six undergraduate engineering degrees: chemical, civil, computer, electrical, industrial, and mechanical. It also offers M.S. and Ph.D. degrees in biomedical, chemical, civil, electrical, industrial, and mechanical engineering. All undergraduate degree programs are accredited by the Engineering Accreditation Commission of ABET, Inc., http://www.abet.org.

In the fall of 2004, the college implemented a major reorganization of its undergraduate programs. Instead of enrolling students directly into one of its degree-granting majors, first-time-in-college (FTIC) students and transfer students matriculated into a new pre-engineering program major. This change was primarily made to provide some uniformity in the experience of new students. But, more importantly, it introduced an academic milestone new students would need to meet in order to progress towards earning an engineering degree.

Models for pre-engineering (also known as first-year engineering or freshman engineering) programs have been reported for other institutions [2]-[4]. Underlying factors for persistence in engineering also have been examined[5],[6]. This paper presents a quantitative study of the pre-engineering program at FAMU-FSU to predict a student's persistence to graduation based on academic performance in specific courses designed to be completed during a student's first year.

II. PRE-ENGINEERING PROGRAM HISTORY

Although a pre-engineering program did exist at the college prior to the fall of 2004, it was informal, voluntary, and primary involved undecided engineering majors. The formal program began with the entering FTIC class of 2004. Any student already coded as "pre-engineering" was included in the new program. Returning students who were already classified in a degree granting major were "grandfathered" and not required to satisfy the new requirements.

The program has had four major revisions since its initial inception in 2004. It has maintained (with one exception) the following three features: (1) an unconditional transfer component, (2) a conditional transfer component, and (3) a "not permitted to transfer" component. Under an unconditional transfer, a student has met all pre-engineering program requirements, and he or she is permitted to transfer

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from pre-engineering to the engineering degree program of his or her choice.

A conditional transfer permits a student who partially meets the pre-engineering program requirements the ability to complete additional coursework to transfer into an engineering degree program. These courses are specified by the academic program and generally consist of the entry-level course for the degree. A student who does not meet the full or conditional requirements is not permitted to transfer from pre-engineering. These students are assisted in transferring to a non-engineering degree program.

Another common feature of all revisions is the list of courses which constitute the pre-engineering program curriculum. They include: First Year Engineering Laboratory (FYEL) (1 semester hour), Calculus I (4 semester hours), Calculus II (4 semester hours), General Chemistry I (3 semester hours), and General Physics I (4 semester hours). In the summer of 2006, General Physics I was replaced with General Chemistry II for chemical engineering majors. This is described in detail below.

Revisions to the program were made to account for unexpected or unintended consequences or to streamline its implementation. These changes were designed not to adversely penalize students who matriculated in previous years.

A. Pre-Engineering Program Requirements – Summer 2004 to Summer 2005

The initial program requirements were implemented in the Summer 2004 semester. For an unconditional transfer, a student needed: (1) a grade of "C" or better in the First-Year Engineering Laboratory course (one repeated attempt was permitted), and (2) a cumulative grade point average (GPA) of 2.5 or better in Calculus I, Calculus II, General Physics I, and General Chemistry I. One course repeat could be excluded from the GPA calculation. Students who had a cumulative GPA between 2.3 and 2.5 were considered conditionally. Student who had a cumulative GPA below 2.3 were not permitted to continue. Laboratory courses were not included in the calculation unless a single grade (i.e., laboratory and lecture) was given for the course.

B. Pre-Engineering Program Requirements – Summer 2005 to Summer 2006

The first program change occurred during the next academic year. Florida State University uses a plus ("+") and minus ("-") grading scheme and a grade of "C-" is considered passing. Additionally, FSU does not permit a student with a passing grade to repeat the same course again. Because the program requirements excluded one repeated attempt, it was theoretically possible for a student to get a "D" in a course, repeat it with an "A" and be permitted to continue. Conversely, another student could receive a "C-" in the same course, not be allowed to repeat, and not satisfy the GPA requirement. This could lead the "C-" student to consider purposely receiving a grade of "D" or "F" in order to repeat the course again.

To prevent this possibility, the requirements were change to allow a student to "substitute" a higher level course for a lower level one. For example, a student could substitute his or her grade in Calculus III for a "C-" grade in Calculus I or Calculus II. However, a student could not use both substitution and exclusion in his or her GPA calculation.

C. Pre-Engineering Program Requirements – Summer 2006 to Summer 2007

As the program entered its third year of implementation, the college was informed that the program might not be in compliance with a state-level education regulation. Specifically, permission must be granted by a state board to use cumulative GPA requirements for degree progression above university minimums. However, there is a provision in the rule which granted programs the authority to use individual course grade requirements in place of a cumulative GPA. Additionally, the State of Florida has very strong regulations regarding the transfer of students from its community college system into one of its state universities. In short, programs could not add additional first- or second-year requirements that could not be obtained at a community college.

Based on the new information, the program was revised by replacing the cumulative GPA with specific course grade requirements. A student now needed a grade of "C" or better, from any institution attended, in Calculus I, Calculus II, General Chemistry I and General Physics I. Also, a change was made to accommodate chemical engineering majors by replacing General Physics I with General Chemistry II.

Students were permitted a single repeated course attempt and a course substitution if a student earned a grade of "C-" in the first attempt. Additionally, transfer students were given an exemption for the First-Year Engineering Laboratory course, if the student satisfied all of the other course requirements. That is, a transfer student who had completed the four other courses prior to transferring to the college would be placed directly into an engineering degree program after completion of an orientation session. Otherwise, the student would be required to complete the FYEL course along with the student's remaining pre-engineering course requirements. The conditional transfer category was removed. And, the "Not permitted to continue" category was redefined as a student who needed two or more repeated attempts or had more than two grades of "C-."

D. Pre-Engineering Program Requirements – Summer 2007 to Summer 2009

The conditional transfer was re-introduced during the Summer 2007 semester. Students with two repeated attempts or two or more grades of "C-" were now considered conditional. The "Not permitted to continue" category was redefined to include students with more than two repeated attempts. This modification was made to account for the student who failed to obtain a grade of "C" or better in two courses during his or her first semester at the university. The re-introduction of the conditional category gave this student another opportunity to succeed. Also, this revision permitted the “C-” grade to be considered “partially” passing instead of failing.

E. Pre-engineering Program Requirements –Summer 2009 to Current

The present pre-engineering program requirements have remained stable since 2009. The last change was the inclusion of the First-Year Engineering Laboratory (FYEL) course in the main list of pre-engineering courses. Previously, for an unconditional transfer, a student could have a separate repeated attempt in FYEL in addition to the single repeated attempts in one of the other four courses. Now, the five courses are considered as a single group and a student may only have one repeated attempt in the five. For a conditional transfer, a student may have two repeated attempts in the five. This change simplified the program requirements making it easier to verify and explain to incoming students. The current pre-engineering program requirements are as follows:

“All first-year engineering students (first-year in college or first-year transfer students) are initially coded as pre-engineering students until they satisfy the following pre-engineering requirements: Students must have an overall GPA of 2.0 or better and achieve a grade of ‘C’ or better, from any institution attended, in First Year Engineering Laboratory, Calculus I, Calculus II, General Chemistry I and General Physics I to be admitted to an engineering major. Intended chemical engineering students shall replace General Physics I with General Chemistry II. A single repeated attempt in only one of the five (5) courses listed above with no more than one grade of “C-” is allowed.

Students completing a second bachelor’s degree, or who have completed a similar course at another institution, or who transfer into the College already with credit for all of the other pre-engineering courses listed above may be eligible to receive an exemption from having to complete the First-Year Engineering Laboratory course. Any student who needs two repeated attempts to complete the five courses or has two or more grades of ‘C-” may be considered for continuation in engineering if additional grade and coursework requirements are satisfied. Any student who needs more than two repeated attempts to complete the five courses listed above does not satisfy these requirements and will not be allowed to continue in the engineering program. There are NO exceptions to these requirements. Grades of “W” are not considered as a repeated attempt.”

Although the program does not consider a “W” or course withdrawal as an attempt, students are limited in the their total number of course withdrawals between the seventh and tenth week of each semester.

III. Implementation Details

The pre-engineering program is managed by the Office of the Associate Dean for Student Affairs and Curriculum. Each university has assigned to the college dedicated full-time academic advisors to advise their pre-engineering program students. These individuals have offices on their respective main campus as well as at the College of Engineering. Although these advisors are under the direct supervision of their home university, they work very closely with the college staff to ensure clear communication of degree requirements to students. Pre-engineering majors must see their academic advisor at least once a semester. In addition, the college provides advising and academic support to all pre-engineering students.

Prospective students are informed of pre-engineering program requirements during each university’s Spring Preview session. This is an event which allows these students to visit the campus. Admitted students are further informed during their summer orientation session when they are registering for their fall semester classes. After students arrive on campus, enrolled students are given an in-depth instruction and examination of pre-engineering program requirements in the First-Year Engineering Laboratory course.

After a student has completed pre-engineering program requirements, the student makes an appointment to see his or her academic advisor. The advisor checks the student’s transcript against the current requirements. If the student does not satisfy current requirements, the advisor checks the student’s transcript against all requirements in place since the student’s initial matriculation to the college. In general, the later requirements are more relaxed than the former ones. If the student does not satisfy any of the requirements, the student is assisted in transferring to a non-engineering major.

IV. Findings

A quantitative study of the academic performance of first-time-in-college (FTIC) students who matriculated to the College of Engineering from the Summer/Fall 2004 semester through the Summer/Fall 2008 semester is presented below. Although, as described above, specific aspects of the pre-engineering program naturally evolved over this period, the core principles of the program remained the same. Incoming FTIC students are informed they are expected to achieve a specific level of academic performance in order to continue in the engineering program. Students are told that satisfying pre-engineering program requirements should be considered the “first graduation requirement” toward earning an engineering degree. Beginning with the Fall 2011 semester, the college presented students who completed the program with a “College of Engineering Pre-Engineering Program Completion” lapel pin as a small token of recognition of their achievement in reaching this important milestone.

A total of 1997 FTIC students matriculated into the pre-engineering program between 2004 and 2008. Their distribution by university and cohort is given in Fig 1. The difference in enrollment between the two universities is approximately the same as their overall undergraduate student population ratio. Table I provides the gender and

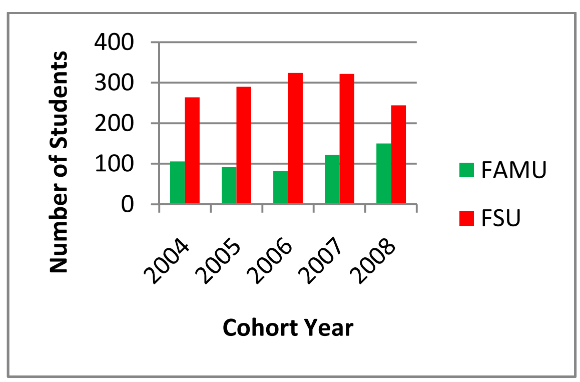

Fig. 1. College of Engineering Student Distribution by univerity and cohort.

race/ethnicity distribution of engineering students from both universities. Fig 2 shows the percentage of the population by university and demographic group. While white males are the largest single demographic population at the college; almost half of the college's overall undergraduate student population is composed of groups historically underrepresented in engineering including African-Americans, Hispanics, and women.

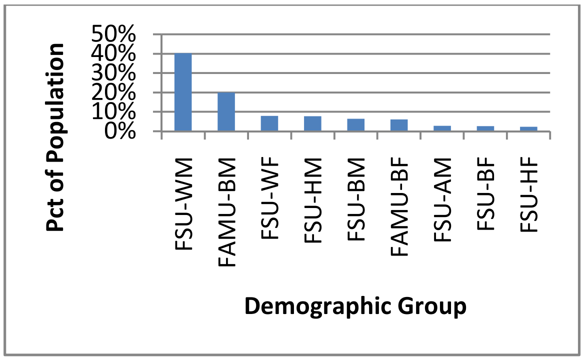

Fig 2. College of Engineering Demographics Distribution . W=White, B=Black, A=Asian, H=Hispanic, M=Male, and F=Female

The degree progression model used to analyze the performance of these groups is given in Fig 3. All students are initially classified as pre-engineering majors. At the first transition point, students are either: (A1) are still enrolled in pre-engineering, (A2) have completed the pre-engineering program, or (A3) did not complete the pre-engineering program. For students in the A2 or A3 categories, they are either (1) still enrolled, (2) have graduated, or (3) are not enrolled. For students who completed the pre-engineering program and have graduated, they either (A) graduated with a degree in engineering or (B) graduated with a non-engineering degree.

Student data are given for the overall population and by gender, race/ethnicity, and race/ethnicity/gender in Table III below. For example, of the 1997 total students in the 2004 to 2008 cohorts, 14 are still in enrolled in pre-engineering, 799 (or 40%) satisfied pre-engineering program requirements, and 1184 (or 60%) did not complete the program. Of the 799 completing pre-engineering, 149 are still enrolled in engineering, 5 are still enrolled in a non-engineering major, 579 have graduated, and 66 are not enrolled. On the other hand, of the 1184 not completing pre-engineering program requirements, 152 are still enrolled, 380 have graduated, and 652 are no longer enrolled.

V. Analysis of Findings

Since the pre-engineering program is designed to provide entering engineering students an early milestone towards attainment of an engineering degree, it is instructive to analyze the data comparing non-completers and completers of the program. Table II shows retention rates and graduation rates between the two groups for the population categories given in Table III. The overall retention rate for pre-engineering program completers (92%) is more than double that of the non-program completers (45%). The same results are also seen for graduation rates with 72% of the pre-engineering program completers graduated by the end of the Spring 2012 semester compared to only 32% of the non-completers. The last two columns in the table examine the engineering graduation rate. The overall rate is 68% for all pre-engineering program completers. If currently enrolled engineering students are excluded from the total, this rate increases to 83%. In other words, more than four out of five students who have completed the pre-engineering program and are no longer enrolled have graduated with a degree in engineering.

A statistical analysis using SPSS version 21 shows that there is no statistically significant differences in the engineering graduation rates (excluding currently enrolled engineering students) based on home university ($\chi^2 = 1.16$, $n = 645$, $p = 0.31$), gender ($\chi^2 = 0.443$, $n = 645$, $p = 0.61$), and race/ethnicity ($\chi^2 = 9.39$, $n = 645$, $p = 0.153$). Therefore, any student who satisfies pre-engineering program requirements has approximately the same chance of graduating from the College of Engineering with a degree in engineering.

VI. Pre-Engineering Program Conversion Rates

However, when the pre-engineering conversion rate is examined, which is defined as the percentage of pre-engineering program completers to the total number of pre-engineering students, we do find statistically significant differences between some population groups. The largest difference occurs between students at the two universities. At Florida State University, the overall conversion rate is 46%. While at Florida A&M University, it is approximately half the rate at 25%.

It was assumed that students were not completing the pre-engineering program because they were "failing" more than the allotted amount of course attempts forcing them to change majors from engineering. However, for students enrolled through Florida State University, less than 10% of the non-completers actually had three or more failing attempts in one

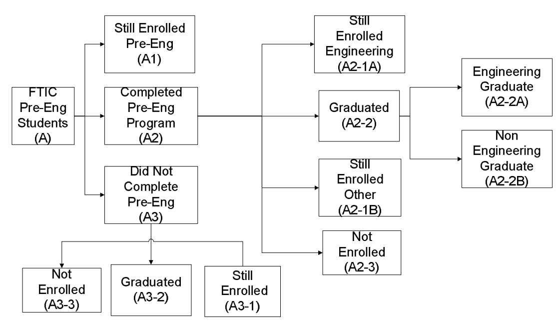

Fig 3. College of Engineering Degree Progression Model

or more pre-engineering courses. In fact, almost 60% of the Florida State University non-completers had zero (0) "failing" attempts in any of the pre-engineering courses. When examined more closely, it was discovered that including course withdrawals 17% of the non-completers did not complete a single pre-engineering program course.

To gauge the motivation of students to pursue an engineering degree, we examined the performance of students in First-Year Engineering Laboratory (FYEL). Again, to our surprise, 44% of Florida State non-completers never completed FYEL. Less than 10% of the non-completers received a grade below “C” in the course. Apparently, failure to satisfy the academic requirements for the pre-engineering program was not a significant factor in explaining why Florida State students did not complete the pre-engineering program.

At Florida A&M University, the results were almost completely opposite. For Florida A&M University students only 11% of the non-completers had zero attempts in any of the pre-engineering courses. On the other hand, over 32% of non-completers had three or more “failing” attempts in one or more of the pre-engineering courses. Additionally, about 28% of Florida A&M University non-completers never took the First-Year Engineering Laboratory course.

For this group of students, academic performance appeared to have an effect on degree progression. The course which seemed to give students the most difficulty was General Chemistry I, which accounted for almost 30% of the total “failing” attempts. The Department of Chemistry at Florida A&M University has since instituted a new placement protocol for all students registering for this course.

VII. Summary

The history of pre-engineering program at the joint Florida A&M University-Florida State University College of Engineering has been presented. After its initial implementation in 2004, the program has remained stable since 2009. The retention and graduation rates obtained from the first five classes suggest that the completion of the pre-engineering program requirements is a strong indicator of successfully obtaining an engineering degree from the college. The data also suggest that the graduation rates for pre-engineering program completers are statistically equivalent regardless of the student’s race, ethnicity, gender, or home university.

The analysis of the pre-engineering conversion rates shows that there is a difference between the two institutions. Additionally, the behavior of non-completers in their motivation to obtain an engineering degree also appears to be substantially different between the two universities.

TABLE I. Engineering Gender and Race/Ethnicity Distribtion

Characteristic	Number of Students				
	FAMU		*FSU*		*Total*
Gender	N	%	N	%	
Male	428	27	1166	73	1594
Female	125	31	278	69	403

Characteristic	Number of Students				
	FAMU		*FSU*		*Total*
Race/Ethnicity	N	%	N	%	
White	14	1	960	99	974
Black	520	74	180	26	700
Asian	8	10	69	90	77
Hispanic	4	2	201	98	205
Native	7	32	15	68	22
Multi/DNR	0	0	19	100	19

TABLE II. Retention, Gradution, and Engineering Graduation Rates for Select Population Groups

Population	Retention Rate		Graduation Rate		Engineering Graduation Rate	
	PRE	***Non-PRE***	***PRE***	***Non-PRE***	***PRE***	***Ex****
Overall	92%	45%	72%	32%	68%	83%
University						
FAMU	91%	33%	68%	16%	61%	76%
FSU	92%	51%	73%	40%	69%	84%
Gender						
Female	94%	45%	79%	32%	73%	86%
Male	91%	45%	71%	32%	66%	82%
Race/Ethnicity						
White	91%	51%	74%	41%	70%	85%
Black	91%	40%	67%	23%	59%	75%
Asian	86%	50%	71%	38%	66%	77%
Hispanic	96%	35%	76%	25%	71%	88%
Race/Ethnicity/ Gender						
White Female	93%	52%	82%	44%	78%	88%
White Male	91%	50%	72%	40%	69%	85%
Black Female	94%	42%	77%	23%	69%	83%
Black Male	90%	40%	63%	22%	55%	72%
Asian Female	86%	71%	57%	57%	57%	80%
Asian Male	86%	46%	75%	34%	68%	76%
Hispanic Female	100%	31%	83%	23%	70%	84%
Hispanic Male	94%	36%	74%	26%	71%	89%

* = Excludes enrolled students

TABLE III. DEGREE PROGRESSION DATA FOR SELECT POPULATIONS

Population	Number of Students												
	A	***A1***	***A2***	***A3***	***A3 -1***	***A3 -2***	***A3 -3***	***A2 -1A***	***A2 -1B***	***A2 -2***	***A2 -3***	***A2- 2a***	***A2 -2b***
Overall	1997	14	801	1182	152	379	651	149	5	580	67	541	39
Gender													
Female	403	4	171	228	31	72	125	26	0	135	10	124	11
Male	1594	10	630	954	121	307	526	123	5	445	57	417	28
Race/Ethnicity													
White	974	0	453	521	51	213	257	79	0	335	39	319	16
Black	700	14	206	480	85	108	287	44	6	138	18	122	16
Asian	77	0	35	42	5	16	21	5	0	25	5	23	2
Hispanic	205	0	93	112	11	28	73	18	0	71	4	66	5
Race/Ethnicity/Gender													
White Female	158	0	76	82	7	36	39	9	0	62	5	59	3
White Male	816	0	377	439	44	177	218	70	0	273	34	260	13
Black Female	172	4	62	106	21	24	61	10	0	48	4	43	5
Black Male	528	10	144	374	64	84	226	34	6	90	14	79	11
Asian Female	14	0	7	7	1	4	2	2	0	4	1	4	0
Asian Male	63	0	28	35	4	12	19	3	0	21	4	19	2
Hispanic Female	49	0	23	26	2	6	18	4	0	19	0	16	3

ACKNOWLEDGMENT

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Integrating Cohorts to Improve Student Career Self-Efficacy

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***Abstract*— Past research on student efficacy shows that students felt more confident in their selection of career field when they were able to "try it on for size." Students have a desire to get their hands dirty and try using engineering tools early in the curriculum. Additionally, students often report a great deal of uncertainty about the curriculum and their ability to be successful in their academic and future careers. In this paper, we describe the integration of a discipline's introductory course within the rest of the discipline's curriculum. Student reported self-efficacy in the introductory engineering course was measured before and after the course activity was completed. Four questions were used to assess efficacy on a 5-point Likert scale. The largest increase in score was seen on the final efficacy question (M_{pre4}=3.59, M_{post4}=3.87). The average efficacy for all students and all questions was 4.04 (*sd*=1.01). Inferential results based on student classification, gender, prior work experience, and perceptions of the mentoring activity are discussed. Finally, implications and suggestions for the use of cohort integration in engineering programs are discussed.**

Keywords—self-efficacy; introductory course

I. INTRODUCTION

Student self-efficacy is often the focus on engineering education studies, as it has been shown to accurately predict student success in engineering (Figure 1). Efficacy has been shown to influence student behavior [1], persistence [2], and success [2]. The use of efficacy is critical in large introductory classes, where retention and attrition tend to be magnified, and where students tend to leave an engineering major before they may have a firm understanding of the career field in front of them [3-4].

A number of past studies have examined how introductory courses can serve to improve self-efficacy [5-8]. Introductory course design, including the specificity related to the chosen major, including projects or lab activities, and assigning team tasks are all capable of improving self-efficacy [9-11]. Past studies have shown a positive influence on introductory students when including upperclassmen on projects, in courses, and through mentoring [12-13].

The objective of this study is to investigate the impact of integrating cohorts on students' self-efficacy. A class module was developed to expose students to a hands-on industrial engineering project early in the curriculum. The project involved applying industrial engineering principles from the field of human factors to the redesign of a device. Learning objectives of the class module project include:

- Increase students' awareness of tasks and jobs performed by industrial engineers
- Expose them to the industrial engineering field of human factors and ergonomics
- Increase their skills, abilities, and confidence in industrial engineering

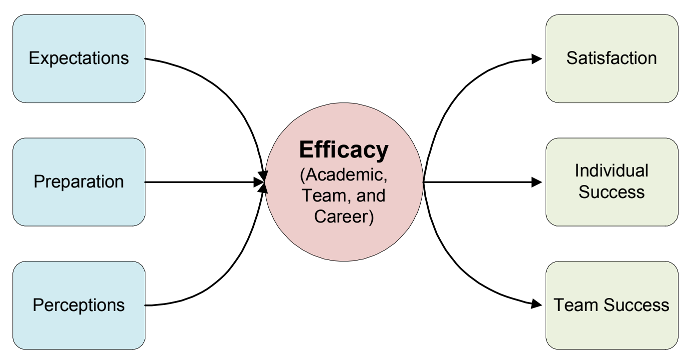

Fig. 1. Overview of student self-efficacy

II. METHODOLOGY

A. Participants

The participants of this study consisted of 54 students (38 females, 16 males). The average age was 19.679 with a standard deviation of 1.851.

This study was conducted primarily in a required introductory course, Introduction to Industrial Engineering, a required undergraduate course in the Department of Industrial and Systems Engineering at Mississippi State University. An advanced level course, Industrial Ergonomics, also participated in this study, acting as the consultants for further design evaluation.

B. *Class Material*

The module is designed to supplement the other topics presented in the introductory level course. It includes lecture material, quiz and homework material, activity guidelines, and pre and post-activity survey questions. This material is intended to expand the students' knowledge and awareness of the field of human factors and to expose them to real world tasks industrial engineers might perform on the job.

Lecture. In class the students received a lecture summarizing some of the core principles of Human Factors and Ergonomics and how to apply them to the design of processes and products. The topics covered in the lecture include:

- Scope and terminology definitions within Human Factors and Ergonomics
- Importance of research in this area in the design of many systems
- Techniques used to quantify aspects of human capabilities

Activity. For the activity the students are split up into easier, working groups. The activity is intended to have the introductory students put the information and knowledge collected in the lecture into practice. They were given a device, a single-hole puncher, and were asked to evaluate its performance and suggest a redesign to improve its capability. The students were also required to set up a consultation appointment with "experts", the advanced level students in the Industrial Ergonomics course, to further enhance their knowledge of ergonomic principles and collect suggestions for improved redesigns. The Industrial Ergonomics class consisted of 36 advanced students who were trained as part of their course lab assignment. For consulting, the advanced class was split into groups of four to five people and each group served one or two of the introductory design groups. The advanced groups provided the same information, but the feedback and advice varied based on the introductory student groups' designs.

C. *Procedure*

Pre- and post-activity surveys were used to assess the effectiveness of the class module, as well as assess student perceptions of industrial engineering. These surveys consisted of both structured and open-ended questions. The structured questions aimed at determining the students' confidence in their choice of and ability to succeed in industrial engineering (Table 1). The level of confidence was measured on a 5-point Likert scale. The open-ended questions were used to gain a sense of the students' general feelings toward industrial engineering. These questions can be found in Table 1. Furthermore students also completed a quiz and homework assignment to assess their retention of the information presented in the assignments.

III. RESULTS

A. *Student Efficacy*

The descriptive statistics for the efficacy questions are shown in Table 2. Paired t-tests were conducted to examine significant differences between pre- and post-activity responses. The first three questions inquire about the students' confidence to gain the skills needed in industrial engineering and given the challenges within this field, their confidence to overcome these to be successful. These questions, at their base, asked students' to assess their work ethic in accomplishing tasks and goals presented.

The fourth question inquired about the students' confidence in choosing industrial engineering as a long term career. Therefore, this question specifically inquires about their attitudes toward industrial engineering as a whole, versus simply the ability to gain the skills within this field.

TABLE I. SURVEY QUESTIONS

Efficacy Questions	
E1	I am certain that I can be successful in my industrial engineering program.
E2	I am confident that I can master the skills needed for the field of industrial engineering.
E3	I am confident that I can overcome challenges in my industrial engineering career.
E4	I am certain that industrial engineering is the right career choice for me.
Open-Ended Questions	
Q1	The most appealing thing about industrial engineering is___.
Q2	The most intimidating thing about industrial engineering is __.
Q3	When I think about a career in industrial engineering, I am most confident in my ability to __.
Q4	When I think about a career in industrial engineering, I am least confident in my ability to __.
Q5	I feel __ about a career in industrial engineering.
Q6	Why did you choose to major in industrial engineering?

TABLE II. EFFICACY QUESTION RESULTS (MEAN (SD))

	Question			
	1	*2*	*3*	*4*
Pre-activity	3.98 (1.11)	3.98 (1.09)	4.00 (1.10)	3.59 (1.16)
Post-activity	4.07 (1.01)	4.07 (0.99)	4.13 (0.93)	3.87 (1.10)
Change	0.09 (1.14)	0.09 (1.07)	0.13 (1.15)	0.28 (1.07)

Although none of the questions showed significant differences (α=0.05), responses to question 4 were broken down to examine the impact of demographics on students' confidence in choosing industrial engineering as a career. With regards to gender, males had higher increases in question 4 scores (M=0.3947, sd=1.128) than females (M=0.000, sd=0.8944) upon completing the class module, though the difference was not significant ($t(35)$= 1.37, p=0.181). When assessing the differences in class, upperclassmen reported the highest increase on efficacy question four (M=0.55, sd=1.30), compared to underclassmen (M=0.094, sd=0.856), though the difference was not significant ($t(33)$= -1.43, p=0.162). Furthermore, those with prior work experience had higher increases on question 4 (M=0.4103, sd=1.1173) than those without (M= -0.0667, sd=0.8837), although this difference was not significant ($t(32)$= 1.64, p=0.110). Finally, question 4 was evaluated assessing students' whose parents attended college or not. Those whose parents did not attend college reported a higher change in efficacy score (M=0.6667, sd=1.6330) versus those whose parents did attend college (M=0.2292, sd=0.9944), though the difference was not significant ($t(5)$= -0.64, p=0.549).

B. Open Ended Responses

The students in the Introduction to Industrial Engineering class were also asked a series of pre- and post-activity questions, listed in Table 1. Both pre- and post-responses were divided into categories unique to each question. Student responses were categorized by student research assistants in order to evaluate patterns in the data. Categories with less than five responses were not included in the analysis. Only categorized responses are shown below.

Student perceptions regarding the appealing and intimidating characteristics of industrial engineering are shown in Figures 2 and 3. Before the class activity, the most appealing factor for students was job availability. After the activity, the appeal of jobs was still high, but more students were interested by the task variety and human aspects of the major. Students reported being intimidated by the coursework required in the major.

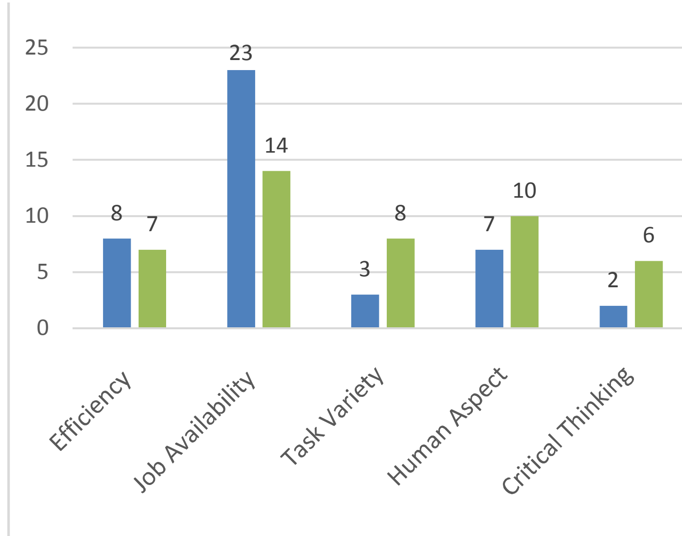

Fig 2. The most appealing thing about industrial engineering (Q1), pre- and post-activity

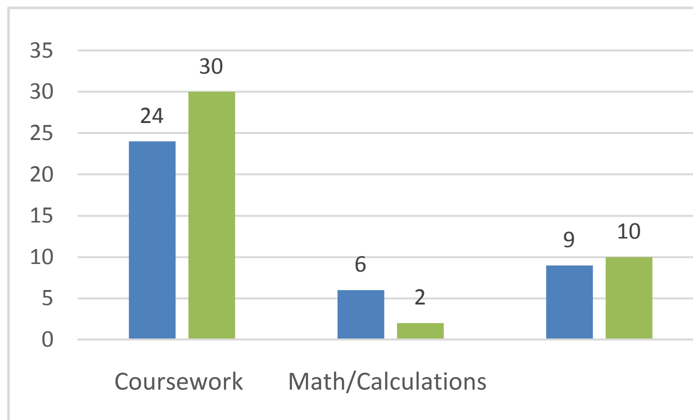

Fig 3. The most intimidating thing about industrial engineering (Q2), pre- and post-activity

When asked to consider their own sets of abilities, students were most confident in their abilities to solve problems and work with others (Figure 4). Student responses regarding what they were least confident in were varied, including responses such as recalling information and managing others (Figure 5). There were not many changes in these responses based on the activity.

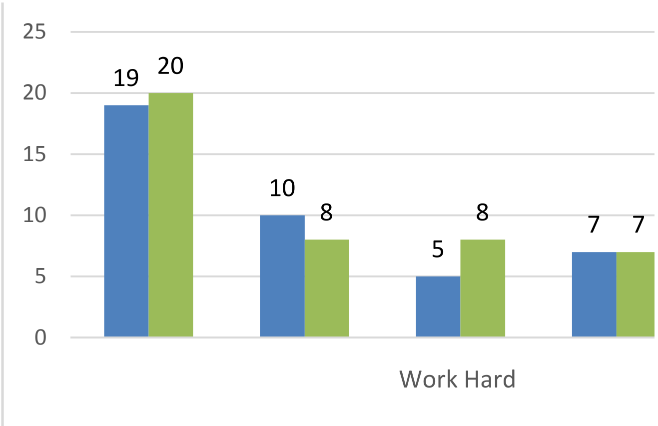

Fig 4. Industrial engineering students were most confidence in these abilities (Q3), pre- and post-activity

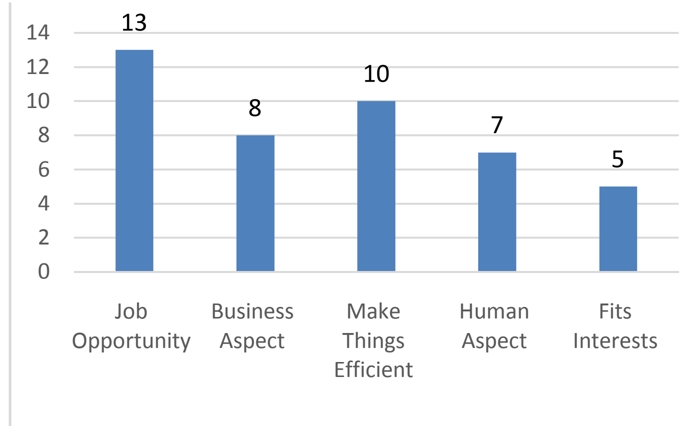

Fig 6. Reasons for choosing industrial engineering (Q6)

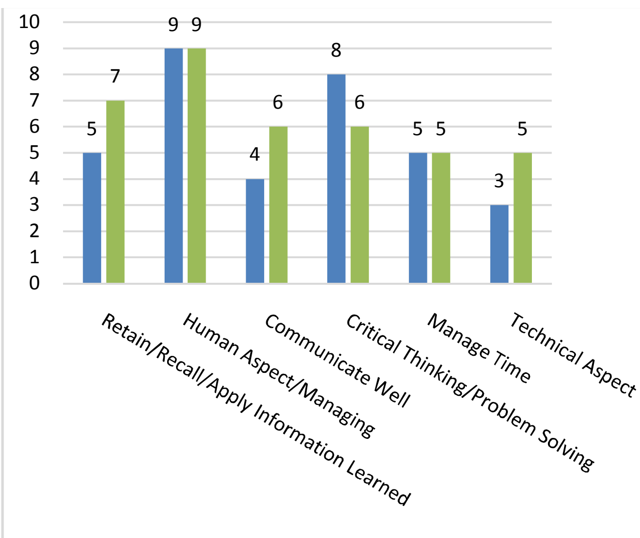

Fig 5. Industrial engineering students were least confident in these abilities (Q4), pre- and post-activity

Students reported a number of reasons for choosing industrial engineering (Figure 6), including job opportunities, the desire to make things efficient, and the ability to incorporate business aspects into an engineering discipline.

IV. DISCUSSION

Although none of the structured efficacy survey questions provided significant data, question 4 did reveal some change in the students' general feelings and attitudes toward industrial engineering as a whole. When further evaluated, this question revealed that student responses were affected by some demographic factors such as their gender, class, prior work experience, and whether or not their parents attended college. It is expected that the efficacy results will show significance in future work with an increased sample size.

We can conclude from the open-ended response data that the module as a whole had an impact on students' feelings and awareness of industrial engineering. Specifically, the students' gained more awareness and interest in a unique field of industrial engineering, human factors engineering. Question 1, which asks about the most appealing aspect of industrial engineering, saw an increase in the categories of "task variety" and "human aspects", and "critical thinking" (Figure 2).

The hands-on aspect of the activity aided the students' confidence in their critical thinking and problem solving. This change is seen in question 4 which asked the students' what ability needed in industrial engineering they were least confident in. Furthermore upon completing the activity students' reported more confidence in their ability to work hard and solve problems.

Although the survey questions provided a surplus amount of data on the introductory students' attitudes toward industrial engineering, there were some limitations. For example, the efficacy data collected via structured questions did not show any significant change in perception post-activity ($\alpha = 0.05$). This could be due to the types or phrasing of the questions used. Furthermore, the consulting phase of this assignment could be improved. For example, the introductory student teams could meet more than once with the advanced level student consultants. Also, it might be useful to consider other sources of consultation other than an advanced level class. For example, one possible alternative could be to involve a few experts from industry to assist in the consultation.

Another limitation of this study is the sample size. Although all students in the introductory class were new to the department, not all were freshmen classification. In future work, the introductory class will be composed entirely of freshmen. This change could provide stronger perception and efficacy results.

To further investigate the influence of integrating cohorts, additional studies are needed. In future semesters, additional combinations of courses will be assessed. Interviews with students will also be conducted to allow for a deeper exploration of the perceptions and efficacy of students, particularly freshmen. Finally, additional engineering disciplines and additional universities will be included to provide a more robust set of participants.

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Assessing Student Information Literacy Skills and the Effectiveness of an Evolving Faculty-Librarian Collaboration in a First Year Design Course

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Abstract—**Engineering students need research skills to effectively complete research and design projects; information literacy education during the first year of college positions future engineers to complete projects both during their college years and when they move into their careers. This study provides evidence that faculty-librarian collaboration is an effective method to train students in these critical skills, and proposes an efficient model that can be adapted to other courses. This work-in-progress, in the third year of a four year analysis, assesses and develops a method of sustainable faculty-librarian collaboration that improves information literacy outcomes in a first-year, project-based engineering design course at Worcester Polytechnic Institute (WPI). To assess the effectiveness of information literacy instruction methods, citation analysis of group project bibliographies, faculty feedback, and student opinion survey data will be used. Preliminary citation data and faculty feedback suggest that increased librarian contact with students, development of resource guides, and design of grading rubrics to incorporate reference list requirements improve student projects and information literacy outcomes. The end result of this four year study will be a recommendation of a sustainable and effective faculty-librarian collaboration that improves information literacy outcomes among students and can be easily adapted to other courses.**

Keywords— Engineering Design, First Year Students, Citation Analysis, Information Literacy

I. Introduction

This paper presents the first three years of a four year faculty-librarian partnership aimed at improving information literacy outcomes in a first-year engineering design course. Information literacy skills are critical during the college years and set the stage for effective information seeking at the professional level. The outcomes assessed in this project are based on standards developed by the Association of College and Research Libraries and include the students' ability to effectively find and use relevant and varied information sources for the completion of a project [1]. Total citations of final group reports for each class are analyzed for diversity of sources, increased use of in-text citations, increased use of scholarship and decreased reliance upon web sources. The total number of citations reviewed over the first three years is 205 across 36 engineering design project reports. The first year of analysis reviews citations and reports from prior to the faculty-librarian collaboration; years two and three review citation data after the librarian and faculty member began to partner. The final year will include review of both citation data and student opinion survey data in order to get a fuller picture of the impact of the faculty-librarian collaboration.

II. Background

The citations analyzed are from ES1020: *Introduction to Engineering Design*, a first-year, project-based design course at Worcester Polytechnic Institute (WPI). Students work together in groups of 4-5 with a total of 12 groups per class. This course has been the subject of innovative teaching for over a decade. For example, in 2003 it was one of the earliest reported first-year engineering design courses built around project-based learning [2]. A 2005 paper describes the use of case studies and reverse engineering activities in the course [3].

One objective of ES 1020 is for students, within seven weeks, to complete an engineering design and prototype, often in the area of rehabilitation engineering. Literature on information seeking in the engineering disciplines makes it clear that to effectively complete such a project, students need a variety of information ranging from scholarly articles and books, to trade publications and patents [4,5]. The instructor had attempted to introduce this concept into the course without much success. In 2011 the faculty instructor and librarian initiated a partnership after the instructor realized that the first-year students enrolled in the course lacked skills to conduct a proper literature search related to their design project and locate appropriate references for constructing prototype devices. Prior to 2011 group project reference lists reflected that student groups lacked the ability to judge the quality of the references cited and were relying almost solely on web based searches. The instructor and librarian had collaborated previously, in an upper level mechanical engineering design course, so adding information literacy instruction to this first-year course was a natural extension of their prior work.

III. Methods of Instruction

Yearly increases in faculty-librarian collaboration over the first three years of the project have included longer librarian face-to-face instruction with students, development of source analysis rubrics to provide formative assessment to students early in the term, and development and promotion of a

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customized online information portal. In the final year the grading rubric will incorporate more clearly defined information literacy requirements for final project reports. Details of each year's evolving collaboration are described in the following paragraphs.

In 2010 all research instruction was facilitated by the faculty instructor. Library inclusion was informal and limited to the faculty instructor encouraging students to visit the library and consult with a librarian as needed. In 2011 instruction was collaborative, with the librarian visiting class for ten minutes of contact time with students. For final grades on project reports, references were mentioned within one portion of the grading rubric as a part of the final project report grade. This section of the rubric, worth 20 points out of a maximum of 85, incorporated other project requirements in addition to references.

In 2012 there was a major shift in instruction methods since the instructor saw beneficial results from the previous year's collaboration. First, librarian contact time with students was increased from 10 minutes early in the term to 45 minutes over two class periods. Second, the librarian created an online resource portal (http://libguides.wpi.edu/es1020) and provided a low-risk source analysis rubric to help students determine whether they were successful in finding and citing sources effectively on an early homework assignment designed by the faculty instructor. Through the rubric students were made aware of the need to 1) collect a minimum number of sources, 2) find diverse sources (scholarly research, news, trade publications, patents, and websites), and 3) cite sources both in text and in a reference list following a specified citation style. After reviewing a sample of the first sets of papers using the rubric, the librarian made specific recommendations to students for ways to improve on final project reports. The comments reinforced the importance of the information seeking concepts taught at the librarian's first visit and included reminding student to avoid heavy reliance on commercial websites, use library resources, and cite sources using a standard citation format. Students were also reminded that if they were unsure of who published or created a source of information that they should avoid citing it in their project report.

In 2013 information literacy instruction will increase in several ways. First, the librarian's in-class instruction will extend from 45 to 75 minutes over two class periods. Second, students will be introduced to a citation management tool. Third, they will be given an opportunity to provide opinions on the librarian-led instruction through a required end of term survey. Finally, the summative assessment rubric for the final project will be more descriptive, and include specific grading criteria for references. These additions are anticipated to yield further improvements in student performance and increased assessment data.

IV. Methodology

Citation analysis has been the primary method used to assess the effectiveness of the faculty-librarian collaboration over the first three years of the project. A total of 205 citations from 36 project reports (12 per year) were analyzed from the 2010-2012 student reports. Information types were simplified or updated based on the methods used in prior research [5,6,7]. The citation analysis consisted of reviewing each group report for number of in-text citations and reference list entries, and types of sources in the reference list. The types of sources fell into the following categories: books, standards, government regulations, reports, scholarly articles, patents, trade news, general news, websites (.com, .org, .edu, etc.), government websites, or indiscernible. Secondary methods of assessment are faculty feedback gathered over the first three years, and a student opinion survey to be administered in the final year.

V. Preliminary Results

Results from the first three years of analysis suggest that librarian-led instruction and faculty collaboration in the development of grading rubrics is effective in improving information literacy outcomes. An increase in librarian contact time with students appears to have a direct relationship with the quality and diversity of sources students use in their papers and the quantity of sources included in reference lists. In each year of the study 12 group project reports were completed and reviewed. Between the first and third years of the study, there was a significant increase in the number of sources cited by teams, both in text and in reference lists (Table 1). Class-wide reliance on web sources decreased from 34 cited in 2010 to 21 in 2012. The number of scholarly sources increased from 0 to 18 over the same period. Another significant finding is that students in year one (2010) cited only four types of sources. By 2012, the diversity of source types increased by over 100% to 9 types of sources, and included books, scholarly articles, government regulations and standards. The increase in book citations was modest over the first three years growing from 0 used in 2010 to 3 in 2012.

TABLE I.

Year	**Total Citation Counts for Team Projects by Year**	
	Total In-text Citations	***Total Sources in Reference Lists***
2010	43	52
2011	37	72
2012	72	81

VI. Discussion and Future Work

The faculty-librarian collaboration has improved student outcomes regarding the use of information sources throughout the design project. During the fourth year of the project, data from student surveys will be analyzed to learn about what portions of the faculty librarian collaboration were perceived as most helpful for students to successfully complete projects. There is little research that provides this type of citation analysis as a tool to assess a long-term and evolving method of information literacy instruction in a first year engineering design course. At the completion of the four year examination the authors will provide a detailed assessment of citations used, and student and faculty opinion, and will contribute an example of a sustainable, effective model of librarian-faculty collaboration in teaching information literacy outcomes that may be generalized to other engineering design courses.

ACKNOWLEDGMENT

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Teaching with Unfamiliar Pedagogy for Engineering Design Instructors

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Abstract - **In recent years, increasing amount of attention has been paid to the teaching of engineering design. This increase stems from response to calls for reform in the way engineering graduates are trained and many engineering programs reacted by adding more practical courses such as engineering design to their curriculum. Unlike traditional engineering courses, teaching engineering design requires adopting a type of pedagogy that many engineering educators are not familiar with and are often resistant to implement. Thus, it is the need to understand resistance that makes the study of concerns that faculty members may have implementing active teaching strategies relevant. Teachers' concerns have been examined extensively at K-12 level, but few studies have examined the same issue in undergraduate engineering education. The purpose of this study is to investigate the concerns of faculty members teaching a freshman engineering design course using an unfamiliar pedagogy, and map these concerns to a model developed for understanding concerns related to adoption of innovation. Themes that do not map unto this model would be deemed specific to the teaching engineering design.**

Index Terms – engineering design, design thinking; teaching engineering; active learning

INTRODUCTION

Current popularity of engineering design as an undergraduate engineering course is the result of engineering institutions' responding to calls from employers, the industry, Accreditation Board for Engineering and Technology (ABET), and the National Research Council (NRC) for reform in the way engineering graduates are trained [1,2,3]. Initially, engineering schools addressed this call by introducing senior capstone projects where students apply knowledge of the engineering design process to create discipline related artifacts [1]. Consequently, some institutions began to teach freshman design courses with the additional hope that such courses will help promote students' interest and retention in engineering; motivate learning of upper division courses; and promote students performance in senior capstone projects [4, 5].

SENIOR CAPSTONE AND FRESHMEN DESIGN PROJECTS

Engineering design has been defined as "a systematic, intelligent generation and evaluation of specifications for artifacts whose form and function achieve stated objectives and satisfy specified constraints" [6]. This statement alludes to the purpose of engineering design: the development of products that meet pre-defined objectives and criterion. The goal of design education extends to include helping students focus on, understand, and experience the engineering design process [4, 5]. Senior capstone projects allow students to experience the integration of knowledge from various contents areas with the practice of engineering design in a final hands-on project [1]. While senior design courses have been used as a tool for enlightening students about the profession, freshmen design on the other hand, is taught mostly to gives new admits into engineering colleges the opportunity to experience what engineers really do [5].

TEACHING ENGINEERING DESIGN

The predominant pedagogy in engineering is lecturing with the instructor seen as the ultimate authority and dispenser of factual truth [8]. However research has shown that engineering educators are beginning to realize that in order to meet the demands of the new mandates and help students develop the non-technical communications and socials skills required in the workplace, they would have to learn and adopt new teaching strategies [3, 2].

Teaching in engineering has always being a private affair, whereby faculty members adopt the approach that is most convenient [10]. This approach to teaching has been claimed to have originated from the fact that only a small percent of engineering faculty receive training regarding their teaching practices during their graduate education or at the onset of an academic appointment [11]. Thus, it is expected that having to change from lecturing to pedagogy of engagement will not be an easy transition for many engineering educators. Research already shows that when asked to use other teaching strategies, engineering educators tend to be reluctant [12].

The types of strategies that are better suited for teaching design are those associated with active learning. Brawner, et al [13] and Felder et al [14] defined active learning as "getting students to do anything course related other than watching, listening to instruction and taking notes". Design courses are fashioned to allow students work in teams while solving ill-structured problems that may have multiple "correct" solutions and undefined constraints that influence the choice of solution. Such learning environments are ripped with ambiguity, lack of procedural and declarative rules than the type of learning environments normally encountered in traditional engineering classrooms [8, 15, 16]. Yet, research tells us that such teaching pedagogies are beginning to gain attention within the engineering community [3, 17].

TEACHING CONCERNS

Teaching design education requires implementing strategies that are unfamiliar to many engineering educators. Therefore, it is expected that faculty members asked to teach design courses would exhibit some concerns about their assignment. Bright et al [18] in their article about the inception of Harvey Mudd College's engineering clinic stated that faculty members received the idea with mixed feelings. They noted that some faculty members expressed preference for teaching what they believe students need to know as opposed to skills that would be learned within the first few months on the job. In their review of how engineering design is taught via capstone projects, Duston et al. [1] reported that engineering faculty members were concerned about teaching design because (1) they believed it will take more time and man power than a traditional course, (2) many of them do not know how design is done in practice, and (3) they perceived that they may not be supported in their endeavor to teach the course. In addition, Turns et al [10] added that engineering educators are also concerned that the time spent teaching design may hinder their chances for tenure and promotion.

Extensive studies have been done to examine educators concerns regarding their teaching at the K-12 levels, but teaching concerns of engineering educators have not been widely studied [10]. Teachers' concerns have been studied using Frances Fullers model for understanding the stages of skills development of teachers and Hall's Concerns-Based Adoption Model (CBAM) for studying teachers concerns during the process of adopting innovative teaching strategies [19& 20]. Fuller's model consists of three stages namely: Self, Impact, and Task, while Hall's model consists of six stages namely: Informational, Personal, Management, Consequences, Collaboration and Refocusing. It is important to note that Hall's model was developed from Fuller model as an instrument for understanding how concerns evolve during the process of adoption of new teaching strategy. These two models have been used to study concerns of engineering educator about their teaching in general. However, no data was found that showed that teaching concerns with regards to a particular course in engineering has been studied.

PURPOSE

The purpose of this work is to investigate the concerns of engineering faculty members selected to teach a first-year engineering design course using a pedagogy with which many of them may not be familiar. These faculty members were pre-selected by the administrative team based on the perception that they were best suited to teach a project-based course. By studying instructors' concerns, this study aims to answer the questions:

- What concerns do educators have teaching design using an unfamiliar pedagogy?
- How do these concerns align with CBAM adoption-based model?
- What concerns are emergent to the context of the study?

CONTEXT

The design course understudy was taught in five separate sessions, with a different instructor assigned to each session, to all incoming engineering students in their first semester. The goal of the course was to introduce the students to the engineering design process in a context free, project-based learning environment. The course was designed such that students of all abilities can be successful, and enrollees were assigned to teams to work on given projects. The course instructors and member(s) of the administration jointly designed the course contents and assessments. The five projects used in the course were designed by each instructor and made available for others to teach. Most of the instructors made slight changes to the materials, especially the presentation slides, before using them. Students were evaluated based on ability to demonstrate the competencies listed in the course objectives.

METHOD

The concern theory framework was used for this study because it offers a lens for understanding the growth and developmental process teachers [21] go through as they develop their teaching expertise overtime. The concern-based model that was considered most suitable for the study was Hall's Concern based adoption model specifically developed for evaluating instructors concerns when adopting new teaching practice. This model was deemed appropriate because the researchers believed that the instructors may not be familiar with students' engagement strategies and implementing such strategies in a design class could be considered adoption of innovative teaching strategy.

Faculty members selected to teach sessions of this course were interviewed about their concerns when they were first assigned to teach the course as well as those that emerged during the course of teaching. The semi-structured interview sessions allowed the instructors to express the issues that were most important to them. Interview transcripts were "searched" for issues that represent concerns, and identical 'concerns" were categorized into themes. Observed themes were mapped unto stages in the Hall's CBAM Model for adoption of innovation.

INITIAL FINDINGS

Our initial analysis showed that the instructors had the following concerns:

- *Engagement*: ensuring that all students are actively participating in team as well as individual assignments.
- *Ambiguity*: dealing with, and managing the ambiguous nature engineering design and students' behaviors in a student-centered learning environment.
- *Class management:* managing students' behavior while still allowing for flexibility required in engineering design and a project-base course.
- *Confidence:* being confidence of one's effectiveness at implementing active teaching strategies.
- *Others Project*: Implementing and managing issues that arise from facilitation projects developed by others.
- *Attitude*: Managing students' attitude while allowing for freedom of expression in demonstrating competency.
- *Assessment*: managing competency based assessment process and ensuring that assignments accurately measure the learning objectives.

Observed concerns were found to map unto most of Hall's CBAM theory with the exception of information and refocusing. The researchers believed that the results mapped as such because of the closed nature of the pilot. It was also observed that all the instructors have had prior experience teaching project-based course and thus are familiar with students' engagement teaching strategies.

Future plans include extending participation to teachers of other project based courses, k- 12 teachers learning to teach design, and further interview of the initial cohort of instructors to examine how their concerns may have evolved over time.

CONCLUSIONS

Studying engineering educators concerns with regards to teaching design mapped well unto Hall's CBA Model for adoption of innovation. Results showed that all the instructors have had some experience with using students' engagement strategies in their classroom. However, despite their experience, the instructors still have concerns about teaching design, especially regarding their ability to interpret the effectiveness of the active teaching strategies adopted.

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Developing Experimental Platforms Using Common Software Tools For Enhancing Technical Skills of Electronics Engineering Students in Microcontrollers

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***Abstract*—An innovative laboratory methodology for simulation of microcontroller based virtual kits is presented. Microcontrollers are widely applied in the field of industry to solve engineering control problems. Today's embedded world uses variety of microcontrollers as heart of processing. These simulation softwares are used to study the functionality of circuit. Students have blindness when they first contact the experiments because of the complexity of the circuit, so this usually leads to the damage to the experiment device. Therefore, it is necessary to make the students to know the theory, models and adjustable parameters of the experiments before the practical experiments. The mixed software stimulation platform based on Proteus, LabVIEW, MATLAB and Arduino was designed for this purpose.**

Keywords—Education; Teaching; Laboratories; Virtual Experiments; Mixed Simulation; Microcontroller; VSM Proteus; LabVIEW; Matlab; Arduino

I. INTRODUCTION

Experiment teaching is an important link in teaching activity[1]. It is playing an important role in the ability and the quality of training student's scientific ideological mode, solid professional knowledge and experimental techniques. Laboratory at colleges and universities is bearing the weight as an important link to foster students to get to work carrying out. With the fast development of electronic technology, circuits, components and equipments have been updated. The existing laboratories are unable to meet the conditions of the various circuit designs and debug requests which affect the results of the circuit experiment teaching to a certain extent.

Specialized basic courses are very important during the electron information specialty teaching, they play the role connecting link of the specialized courses teaching in the whole course system. Simulation tools are used to assist teaching, utilizing intuitionist graph, picture, animation to help students understand abstract theory. Microcontrollers are widely applied in the field of industrial control such as process control, intelligent instruments, electromechanical integration and intelligent interface for features of small size, low power consumption, control functions, expansion flexibility[3].

II. MIXED SIMULATION PLATFORM BASED ON PROTEUS, LABVIEW, MATLAB AND ARDUINO

Students design the corresponding theoretical models based on the learned content. These models were allowed to be designed in corresponding simulation environment. Students also can understand each part in the models by changing the parameters and observe the waveform of the various nodes to see the change in the result. The simulation model is obtained untill the satisfactory response and its corresponding parameters are found in the MATLAB or LabVIEW. Then the students devise the proper circuits according to the optimized model in the Proteus. They are able to observe the response by setting the appropriate parameters of the circuit in the simulation environment. Comparing the results between the theoretical simulation model in MATLAB or LabVIEW and the circuit-level simulation model in Proteus, they identify differences and find a solution by analysis. Finally the practical circuit system which could meet requirements is finished. Then the students realize this system in the actual experiment platform and observe whether the actual response can achieve the requirements or not. These platforms can help students understand not only the basic theory but also the differences between the theoretical model and the actual system. The students are trained to acquire the basic skills and posses quality as engineer. In addition, the damage caused by the wrong operation to the experiment equipments is avoided. This is applied to Analog signal processing and digital signal processing.

III. OVERVIEW OF SIMULATION PLATFORM

The platform is mainly used in courses teaching and experiments, the courses include circuit analysis, analog circuit, digital circuit, high - frequency circuit, automatic control theory, embedded system and so on. Proteus is mainly used to make circuit-level simulation. LabVIEW and MATLAB are to complete the algorithm-level and modeling simulation. Arduino software is mainly used to make programs.

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Microcontroller is a technical course with very strong practicality, undoubtedly the experiment is one of most important practice links of teaching. Due to limited fund and hardware experiment resource, the students can not have enough chances to exercise. If we full use the simulation emulation of the software as the auxiliary experiment means, it will greatly promote the teaching of the microcontroller.

Proteus VSM can facilitate co-simulation of complete microcontroller-based designs. VSM is uniquely suited to buliding virtual lab for microcontroller for its full virtual debugging interface. With the aid of Proteus VSM, teachers and students can develop and test application systems before physical prototyping. The virtual lab obviates the need for expensive hardware and allows the students the freedom and flexibility to design and develop microcontroller solutions without the need for a physical prototype.

V. EXPERIMENT

For experiments, we have selected Arduino hardware platform which is simulated in Proteus.

A. Project 1: Temperature sensor Interfacing of Proteus with LabVIEW

Virtual interfacing of Proteus(Arduino) with LabVIEW. This module comprises of temperature sensing implemented using Arduino simulated in Proteus. The changes in the temperature are communicated to LabVIEW through virtual serial port. The results are displayed in LabVIEW.

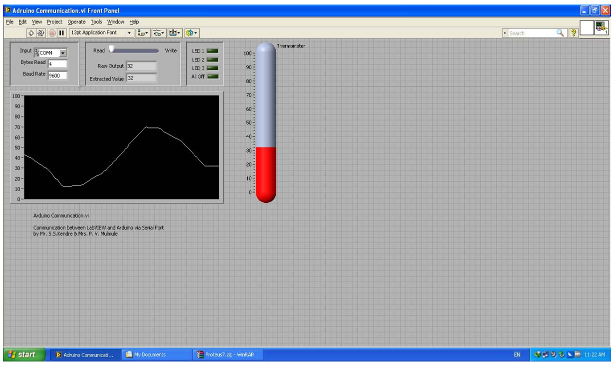

Fig.1. Front panel of LabVIEW for measuring temperature

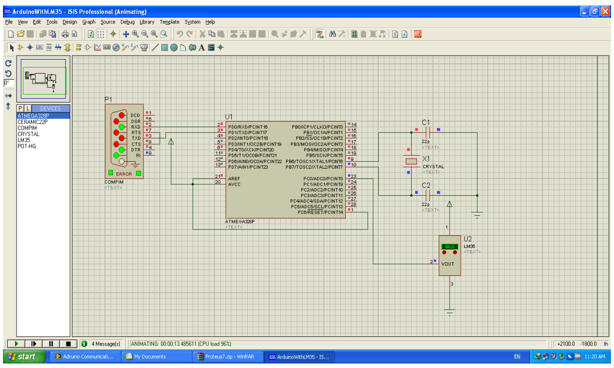

Fig.2. Simulation of LM35 Temperature Sensor interfacing with Arduino in Proteus

B. Project 2: Interfacing and controlling of LEDs in Proteus with LabVIEW

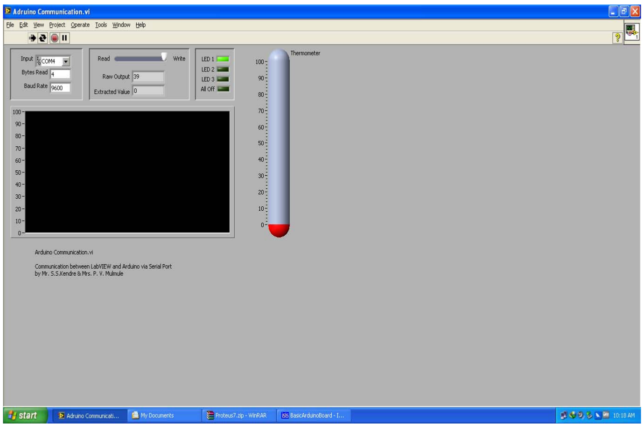

Fig.3. LED control Panel in LabVIEW

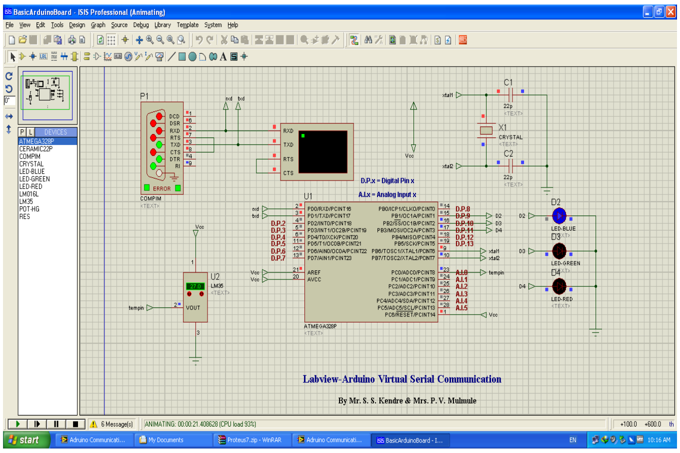

Fig.4. Simulation of LEDs interfacing with Arduino in Proteus

C. Project 3: LCD Interfacing of Proteus with Matlab

It shows Interfacing of LCD with Arduino is simulated in Proteus. Message to be displayed on LCD is transferred through Matlab and virtual serial port.

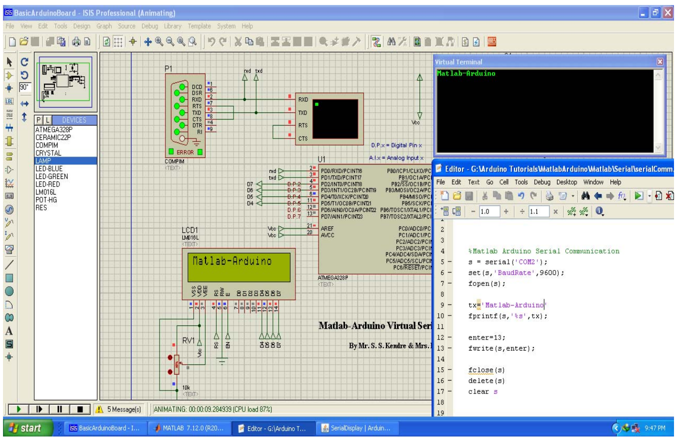

Fig.5. LCD interfacing with Arduino in Proteus VSM and Matlab code

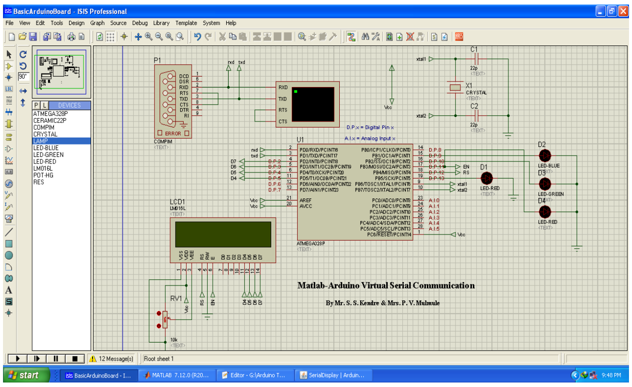

Fig.6. Arduino in Proteus

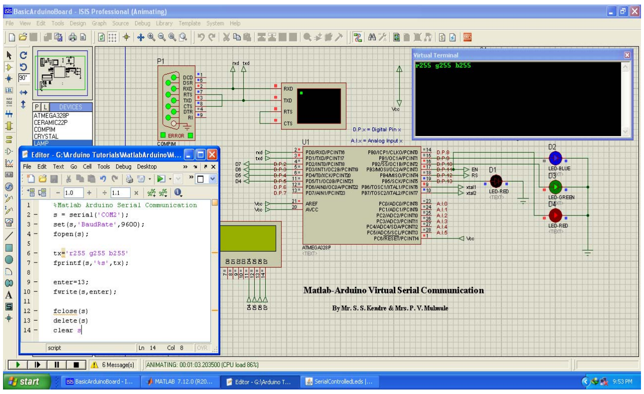

Fig.7. LEDs interfacing with Arduino in Proteus and Matlab code

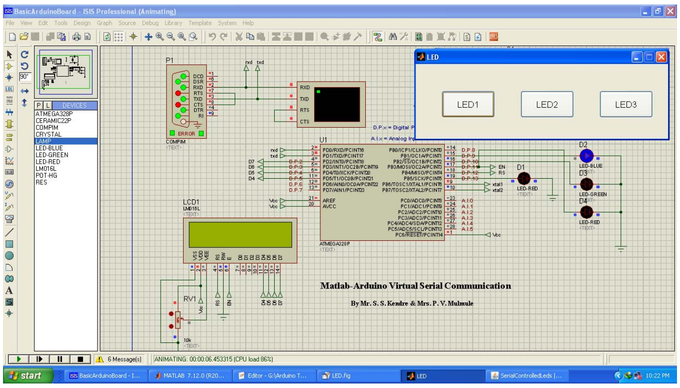

Fig.8. Simulation of LEDs interfacing with Arduino and Matlab GUI

Fig. 9. Complete Setup for Evaluation

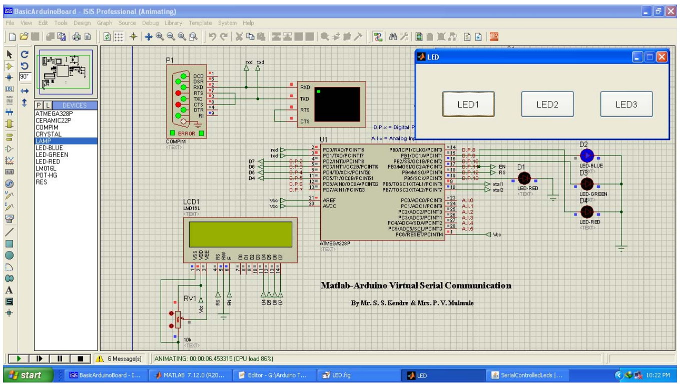

Fig.10. Simulation of LEDs interfacing with Arduino and Matlab GUI

All above experiments are verified by executing on hardware platform Freeduino RichBoard in lab[12].

VI. CONCLUSION

From the above examples, the conclusions could be drawn that establishing a mixed simulation platform by Proteus, LabVIEW, MATLAB and Arduino on a computer can easily build all kinds of experiment models, in addition to carry the simulation and the test to the system. The mode of virtual experiment combined with practical experiment may not only enable students to master basic theory and skills of electronic technology curriculum, but also give full play to the initiative, and ultimately enhance the students' practical ability and scientific innovation consciousness. It plays a very important role in updating experiment teaching method, improving teaching quality of circuit courses, and optimizing the effect of teaching.

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Abstract—***This work-in-progress paper briefly describes the uLab, a new method and framework for remote hardware design laboratories, which uses Linux and FOSS to provide real-time design and debug services to students over standard RDP channels. A secure, encrypted, plugin-based remote laboratory framework allows customization of programming and debug/test services to match physical laboratory resources. Industry standard technologies such as LDAP and Kerberos are utilized to ensure scalability, security, and ease of management. Emphasis is placed on direct access to real hardware, with the normal array of simulation tools and design software also being provided. In contrast with many of the remote laboratories currently in existence, this system places strong emphasis on direct, long-duration access to real, physical hardware for non-trivial design and evaluation tasks. In order to achieve this goal, secure, network-enabled hardware "pods" were created from inexpensive COTS components, and a blend of new and existing open-source software was used to connect with the overall laboratory framework. Hardware-design software and tools, including the software for physical hardware access, are preloaded and made available within the desktop session, allowing students to log in and start working almost immediately.***

Index Terms—**Client-server system, cost effective, engineering education, hardware-access pods, hardware design, Internet access, Kerberos realm, remote laboratory access, TDE, uLab, Universal Laboratory**

I. Introduction

A typical hardware design laboratory consists of several workstations and associated hardware in an access-controlled room with rigidly scheduled laboratory dates and times. This laboratory model inherently presents several drawbacks. One of the largest issues with this type of laboratory is the low average utilization ratio; there normally are large portions of each day when the laboratory is nearly or completely idle with no student access permitted. Another drawback is a relatively short window for laboratory sessions, during which the students are more focused on completing particular assignments within the allotted time frame than they are on learning vital concepts via semi-structured, hands-on interaction with design tools and hardware. Additionally, in many institutions, there are insufficient resources available to handle simultaneous usage by all students within a particular laboratory period; this forces multiple students to be assigned to a given workstation and further removes each student from hands-on interaction with the design software and physical hardware. Remote laboratories, such as the uLab system described in this paper, not only alleviate many of the drawbacks listed above, but also provide exciting new opportunities for students to interact with the laboratory hardware in a non-traditional manner.

In contrast to many of the remote laboratories currently in existence, the uLab places strong emphasis on direct, long-duration access to real, physical hardware for non-trivial design and evaluation tasks. In addition, most of the existing laboratories offering access to real, physical hardware, such as MIT's iLab[1], [2] or the VISIR system[3], require expensive, proprietary software packages, such as LabView, in order to function. By contrast, the new uLab laboratory system, which derives its name from the goal of providing a "Universal Laboratory," is not only open-source itself, but also is built entirely upon open-source software and, where possible, open hardware. This frees institutions from the requirement of purchasing expensive software licenses for each new hardware workspace, and allows them to, instead, focus on providing the best possible experience for their students. This characteristic also enables institutions to modify the uLab system to meet their particular needs rather than adjusting their curriculum to work around any limitations present in existing, closed-source software. A comparison of features between the new uLab system and selected existing laboratories is given in Table 1.

II. Design

The uLab system is comprised of three main components: infrastructure, terminal services, and hardware-access workspaces. The infrastructure component provides relatively mundane but essential services, such as Kerberos authentication, to the other two main components; the infrastructure component, therefore, plays a critical role in the provision of a unified laboratory experience. The terminal services component provides a full-featured remote desktop environment, complete with hardware design and simulation tools, to the end user over a standard Remote Desktop Protocol

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TABLE I. COMPARISON OF REMOTE LABORATORY FEATURES

	uLab	RemoteFPGA [4]	SolarLab [5]	MIT iLab [1], [2]	TCAD [6]	VISIR [3]	TINI-based [7]
User access control	X	X	X	X	X	X	
Pluggable backend server access control	X			X		X	
Encrypted, authenticated client-server communication	X						
Encrypted, authenticated inter-server communication	X						
Single sign-on (SSO)	X						
Terminal services	X	X			X		
Integration with existing course management systems							
Access from new forms of computing devices	X		X	X	X	X	X
Web-based interaction			X	X	X	X	X
Rich GUI widget I/O (not camera based)	X	X	X	X	X		X
Modular design	X			X			
Reconfigurable hardware connections					X	X	
Integral surveys and/or learning assessment	/		X	X			
HCI method	WIMP	WIMP	WIMP	WIMP	WIMP	WIMP	WIMP
Primary client/server programming language(s)	C C++	Visual Basic	LabView PHP	Java LabView	LabView	LabView	Java MATLAB
Remote development tools	X	X		X			
Remote simulation tools	X	X		X	X		X
Access to physical hardware	X	X	X	X	X	X	X
Exclusive, full access to physical hardware	X	X	X	X	X	X	X
Inexpensive, low-power network to hardware interface	X						X
Unscripted experimentation environment	X	X		X		X	
Laboratory software available as open-source	X	X	X	X		X	X
Storage for user design files	X	X					
Integral capture and storage of experimental results	X						

Legend:
X Supported
/ Technically possible with minor changes but not yet implemented
An empty box indicates that the feature is unsupported without major changes to software, hardware, or both.
Please note that only those features mentioned in the referenced sources are included in this table.
The contents of this table are based on the author's analysis of the referenced sources.

(RDP) link. These terminal services leverage the provided Kerberos infrastructure to enable single sign-on functionality across all uLab components, presenting a more unified environment to the end user. Finally, the hardware-access workspaces component provides the end user with access to real, physical hardware. This component also leverages the Kerberos infrastructure for authentication and encryption of both client-server and server-server connections, thereby

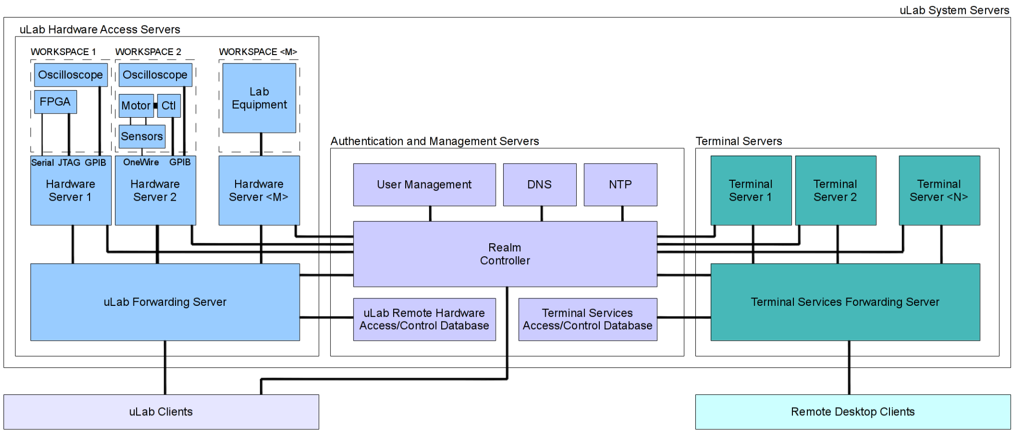

Fig. 1. Major components of a generic uLab system

maintaining the security of all hardware-access components. A diagram illustrating the relationships between major components in a typical uLab system is shown in Fig. 1.

A significant innovation within the uLab system is the use of self-contained hardware-access "pods." In the current uLab implementation, each pod consists of a Raspberry Pi ARM Single Board Computer (SBC) to which various hardware devices are connected. The Raspberry Pi runs one or more hardware-access daemons which interface with the attached hardware devices. These daemons make the attached hardware devices available to the main uLab system, and thus available to remote users via the uLab client software. Each hardware-access pod needs only 5V power and an Ethernet connection with access to the uLab arbiter in order to function, simplifying installation in most laboratory environments.

III. Future Work

Although the uLab system is currently installed and verified as fully operational, it has yet to be used by students within the framework of a standard academic course. This usage is expected by the fall semester of 2013, when the uLab at Northern Illinois University will be used in an undergraduate FPGA-based hardware design course. Because the laboratory does not currently provide signal generation or waveform capture equipment, future work may also include the addition of fully open-source and open-hardware waveform capture and signal generation equipment. This equipment is not essential for the original intended use of the uLab, but its addition would allow additional courses to take advantage of the uLab for distance education. This new hardware would become part of the existing FPGA-design hardware-access pods, maintaining the ease of pod installation described above.

IV. Conclusion

In this paper, a new method and framework for remote laboratory access has been introduced. Several current remote access laboratories were identified, along with their major features and limitations. The three main components of the new uLab system were discussed, and the concept of self-contained, network-attached hardware-access "pods" was introduced. Future work was discussed, along with intended usage of the new uLab system at Northern Illinois University.

Because a major goal of this research not only was to prove that a fully open-source remote laboratory can be built, but also to ensure the sustainability of such an environment for multiple institutions to use, all source code written for the uLab system has been released in a set of Git trees. As of this writing, project code repositories and detailed design documentation are available at http://ulab.trinitydesktop.org. In addition, a highly condensed set of installation instructions for a lab using the design detailed herein is available at the same location.

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Power Electronics Education Using the Integrated Circuit Consistent Education System and TCAD

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***Abstract*—In this study, we perform a device evaluation from trial device production (a computer simulation) using technology CAD (TCAD) in an integrated circuit consistent education system, which consists of a series of processes: system design, semiconductor process, trial device production, and device evaluation. By changing the device parameters (kinds of material, film thickness, impurities density) of the semiconductor process, the simulation can more closely approximate the electrical property of the desired target performance. By integrating the simulation technology using TCAD with each piece of knowledge mastered by the integrated circuit consistent education system, which is currently under development, we are able to construct an education system that can be mastered not only for an integrated circuit for information processing but also for the semiconductor process and the global perspective of the device structure in a power device. Furthermore, the possibility of applicability to a new device structure and process development is shown by means of a simulation using TCAD in virtual processing conditions.**

Keywords—education system; integrated circuit (IC); technology CAD (TCAD); power electronics; power device; SiC;

I. Introduction

As a result of the remarkable progress made in integrated circuit technology in recent years, integrated circuits have improved in terms of high speed, high performance and high integration. As a result of these advances, the importance of integrated circuit education is seen as an issue in electronic technical education. It is necessary to implement education through which one can learn about the technologies involved in the field, such as the circuit design of electronic devices, the semiconductor process, device structure, and the evaluations of electrical properties in the integrated circuits. It takes a lot of time and a great deal of money to learn the above, and the engineers and students studying integrated circuits face many difficulties. Furthermore, because the application domains of electronic devices are increased, it is becoming ever more difficult to respond to the research and technological development solely by possessing knowledge of individual electronic devices. In light of this, we are developing a consistent integrated circuit education system to solve the above difficulties, and to support the understanding of a global perspective on electronic devices. We believe this system will prove useful in raising the abilities of technical developers by providing an overview of integrated circuits as a whole, because this education system can be implemented as part of consistent education in the design, creation, and evaluation of an electronic device using a basic circuit.

Power electronic systems such as the smart city and the smart grid are being introduced into society, and an environment-friendly society is being constructed. In such a system, power devices play an important role, thus research on power devices and the education relevant to power devices are vital. However, because detailed information of the process, device structure, and circuits in general power devices is not disclosed, this presents a problem in education on how we deal with these matters.

II. Integrated Circuit Consistent Education System

A. *System Structure*

The overall design flow of our trial IC fabrication is illustrated in Fig. 1. On the first occasion, the training is exploratory in nature, but starting with the second session, training operations are documented. As a result, a manual is compiled and updated on every subsequent occasion. The trainees do not merely record their operations, but analyze them so as to improve the manual, which has a great educational effect.

In this study, AND circuits are considered, and a CMOS layout is designed aiming at a basic familiarization with practical modern information and technologies related to system LSI. Examples of layout design and fabricated MOSFET are given in Figs. 2 and3.

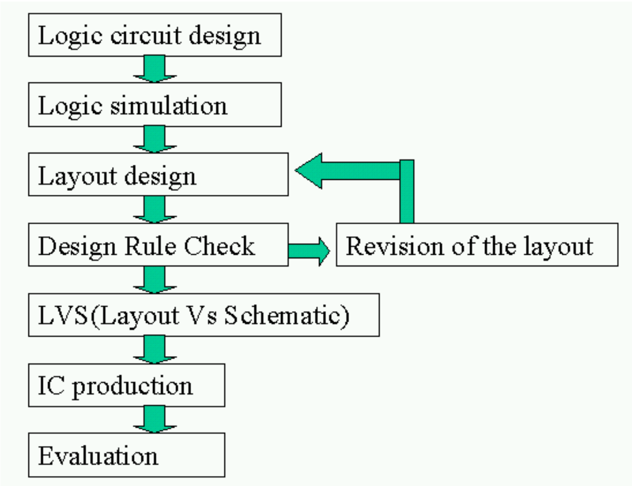

Figure 1. Design flow of integrated circuit production.

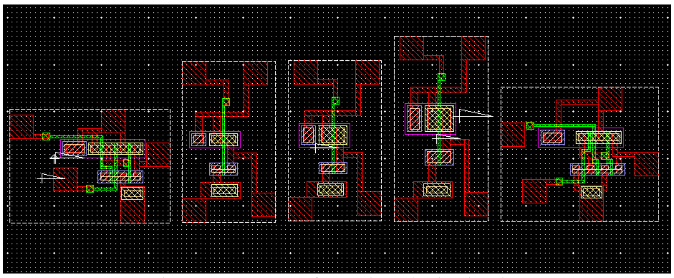

Figure 2. Layouts for various logic circuits.

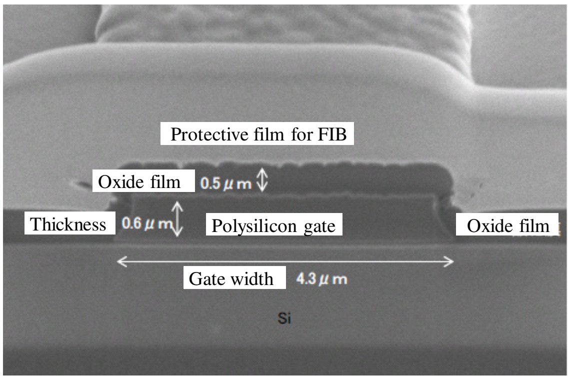

Figure 3. SEM photograph of cross-sectional view of the gate in a MOSFET.

III. Power device

The key device in power electronics technology is the power device. In power devices, the function (switching) that turns on and turns off the electric power, and the function (rectification) to cause current to flow in one direction are important. Therefore, power devices need a low-loss conduction capability, a low-loss switching capability, and good current interruption capability [1]. The electrical connection resistance leading to a power loss is proportional to the square of blocking voltage, and in inverse proportion to the third power of the dielectric breakdown strength. Therefore, materials with a high breakdown strength are required for power devices.

A. PowerMOSFET

A power MOSFET is MOSFET that can handle the comparatively high electric power used for a power converter. Because fast switching is possible, MOSFETs are used as the main parts, such as a DC-DC converter.

A power MOSFET has the source electrode on the substrate face side, and the drain electrode on the substrate back side, and the electrons serve as a carrier from the source and the drain, that is the electrons flow through the back surface from the substrate surface, therefore a current flow through the substrate surface from the substrate back surface (Fig. 4).

B. Necessity of Compound Semiconductors

There is demand for Si semiconductor devices with a higher performance. However, the current technology is beginning to approach the limit of the physical properties of Si, which is the material from Si semiconductor devices are made, and it is difficult to further increase performance. In order to overcome this limit, the development of semiconductor devices using SiC (silicon carbide) and GaN (gallium nitride) with physical property values that are different from Si is expected.

With wide-band-gap semiconductors such as SiC and GaN, low loss, high-speed switching, and high-temperature operation exceeding the limit of the physical property values of Si is expected. SiC is excellent with respect to the stability of the material at high temperature compared with GaN. Because their ability to be miniaturized, their low loss, their high efficiency, and because their nature allows for a simplification of cooling design, much is expected of SiC devices. If SiC devices are used in power devices, a more effective use of electrical energy can be expected.

C. Compound Semiconductor Properties

Table 1 shows the physical properties for 4H-SiC, GaN, and Si. 4H-SiC has a large band gap compared with other crystal structures (such as 6H and 3C) especially among SiC, and has a high heat resistance and high electron mobility (index of the electronic ease of moving), so its use reduces the resistance of devices, and is expected due to its physical, mechanical, and electrical properties to be used for semiconductors for next-generation electronic devices. Research and development are is being conducted from substrate growth through to device application by many research institutions and companies [1].

Because SiC has a high breakdown strength—about ten times than Si—it can lead to a reduction in the electrical connection resistance at the time of ON operation, and can lead to a reduction in power loss from devices. For this reason, the thickness of the drift layer holding the blocking voltage can be made thin—about one-tenth that of with Si power devices of the same element blocking voltage, and the impurity density can be designed to be high, as in unipolar devices, so ON resistance can be reduced by more than a one three-hundredth in theory (Fig. 4). Furthermore, when the thickness of the drift layer is the same in SiC and Si power device, this can realize a blocking voltage more than ten times that of Si devices.

Table 1 List of physical properties.

	4H-SiC	GaN	Si
Band Gap	3.26	3.39	1.12
Electron Mobility	1020	900	1400
Hole Mobility	115	150	600
Breakdown Strength	2.2×10^6	5.0×10^6	3.0×10^5
Thermal Conductivity	4.9	1.3	1.5
Dielectric Constant	9.7	9	11.8

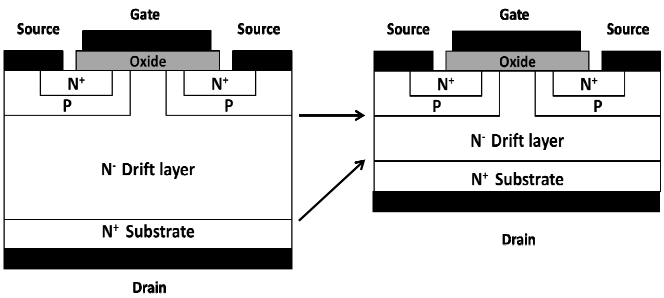

Figure 4. Comparison of structure of a power MOSFET in Si and SiC.

IV. Simulations of power device using TCAD

TCAD is a framework that integrates tools for the semiconductor process, device structures and the circuit simulators. It also can save time and costs because it can optimize a device design and a semiconductor process without actually producing a trial device. Moreover, by using TCAD, we can solve the partial differential equation of fundamental physics such as diffusion and transport equation, and can simulate the structural characteristic and electric operation of a device. Therefore, the semiconductor process and device simulation tools of TCAD can be applied to broad applications such as CMOS integrated circuits, memories, and power devices. In order to perform a simulation, it is necessary to consider the resistivity and the breakdown voltage that are related to the impurity concentration and the band gap.

Thus, we performed a device simulation of an SiC-MOSFET (power MOSFET), which a power device that uses TCAD. We verified that an SiC-MOSFET can handle a large current at high voltage from the simulation results of electrical characteristics results in Fig. 5. Furthermore, by optimizing device parameters with simulations, we were able to deepen the understanding of power devices.

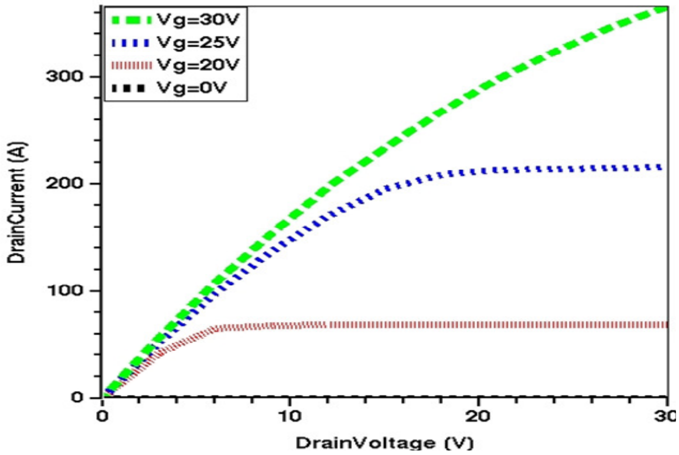

Figure 5. I-V characteristics of SiC-MOSFET (simulation).

After designing a device structure for power electronics, we verified it by using basic knowledge such as that on solid state electronics and the properties of materials. We then described the parameters of the device structure and performed a TCAD simulation, which enabled us to obtain basic data such as the electrical properties of the device. We were able to construct these consistent systems as an education system aimed at elementary engineering education.

This educational system makes it possible to provide education on making a comparison of the width of the depletion layer, resistivity and breakdown voltage that simulated a rudimentary device structure. We consider that the developed system will prove to be useful in the general education of students and engineers in the future.

V. Conclusion

In this research, we performed a device evaluation from trial device production using TCAD in an integrated circuit consistent education system. By integrating the simulation technologies using TCAD, we were able to construct an educational system to learn the whole picture of the structure and the semiconductor processes of power devices as well as integrated circuit devices for information processing. Furthermore, the possibility of applicability to a new device structure and process development was shown by conducting a simulation using TCAD in non-actual process conditions.

Acknowledgement

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Java Tools for Teaching OFDM Principles in Undergraduate Courses

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***Abstract*—In this paper, we describe a new set of software functions and associated exercises that can be used for teaching orthogonal frequency division multiplexing (OFDM) concepts in undergraduate DSP and communications courses. These tools can be used to simulate, visualize, and analyze the performance and behavior of OFDM systems by considering different input signals and communication channels. OFDM is a compelling paradigm because of its utility in WiFi and LTE. It is also a good demonstration of the use of the FFT in a communication system. We have developed the proposed set of functions as a part of the Java-DSP (J-DSP) visual programming environment. The functions can be used in undergraduate DSP and communications courses, in order to demonstrate to students, the application of DSP concepts in a communication system, as well as concepts such as FIR filter design, properties of the DFT matrix, random signals, and circular effects.**

Keywords—orthogonal frequency division multiplexing (OFDM); modulation; FFT; channel; noise

I. Introduction

There is a need to present real-life scenarios and applications for several physical and mathematical principles taught in STEM courses. In particular, the undergraduate courses on signal processing and communications are mathematically rigorous, and students are often unable to relate those concepts to practical engineering systems. Teaching the design of an OFDM system for communications can be an ideal methodology to bridge this gap. In addition to being an interesting paradigm for teaching DSP concepts, OFDM systems find widespread use in several standards for technologies such as 4G communications, digital audio/video broadcasting, ADSL, WLAN, and WiFi.

In order to teach principles of DSP and communications in undergraduate courses, the freely accessible online simulation software Java-DSP (J-DSP) (Fig. 1) was selected as the host environment. J-DSP is being used for education and research in different areas of signal processing and communications [1-4]. Simulations in J-DSP can be performed by simply placing and connecting blocks that correspond to different signal processing functions. As a result, using J-DSP requires little programming or coding experience. The intuitive interface allows for visualization of DSP concepts and students can focus more on understanding the system.

In this paper, we describe the orthogonal frequency division multiplexing (OFDM) system [5], and related function modules.

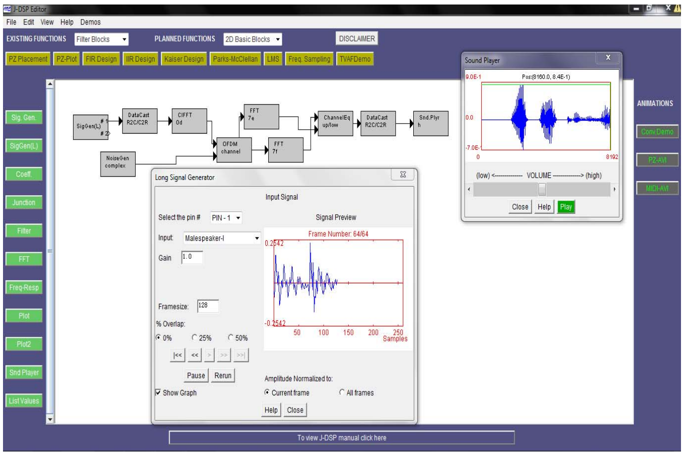

Fig. 1. Example of an OFDM simulation in J-DSP.

We will describe laboratory exercises, which are comprised of basic simulations for understanding frequency domain processing. By simulating an OFDM system using the proposed functions, students will have a better understanding of basic DSP concepts such as FIR filter design, FFT/IFFT, properties of the DFT matrix, convolution, circular effects, and random signals.

The rest of this paper is organized as follows. First, a brief description of the OFDM system is given in Section II. In Section III, we present the modules designed for the OFDM system in J-DSP. In Section IV, an exercise of the OFDM system and the analysis of the system with different parameters are shown. Assessment results are summarized in Section V, and concluding remarks are presented in Section VI.

II. OFDM Principles

We choose OFDM because of its utility as a modulation/multiplexing system in modern communication systems, including compelling LTE and WiFi applications. OFDM shows students how the IFFT is used as a modulator. It also exposes students to channel modeling, fast deconvolution, DFT matrix properties, channel noise and circular effects.

Mobile radio communications are generally subject to multipath propagation [5, 6]. The received signal will therefore be a combination of several distinguishable signals and the channel can be modeled as a finite-length impulse response (FIR) filter, and the process of data transmission over the channel can be represented as a convolution sum of the

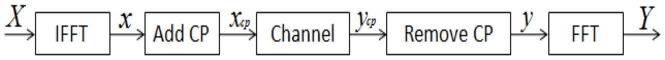

Fig. 2. Signal flow diagram for the OFDM system.

transmitted signal and the filter coefficients. OFDM is one method that can be used to mitigate the effect of such multipath channels. In an OFDM system, an IFFT of the input frequency domain signal is first performed as subcarrier modulation. Then, the process of adding the cyclic prefix, filtering by the channel (linear convolution) and finally removing the cyclic prefix simulates circular convolution. By taking the FFT of the received signal, the data is transformed into frequency domain. The basic model of the OFDM system is shown in Fig. 2, and basic principles of the corresponding process can be found in [6-8].

III. OFDM Modules In J-DSP

As shown in Fig. 3, we have developed several functions that are designed for the simulation for OFDM systems. By using this Java tool, we will be able to introduce students to the basics of OFDM and enhance their understanding of the basic principles of signal processing and communications [9].

In Fig. 3(a), the process of OFDM is captured in the OFDM simulation shown in J-DSP. Using the *SigGen(L)* block, an audio signal is generated and segmented into frames for further processing. The signal is first passed though the *IFFT* block. The *OFDM* block (Fig. 3(f)), which is next, adds a cyclic prefix, simulates the channel, and then removes the cyclic prefix. The length of the cyclic prefix, as well as the length of the channel can be provided by the users. Additionally, the users can also select between randomly generated channel coefficients (Fig. 3(f)), or set their own values for the filter coefficients. The users also have the option of adding noise to the system using the *Complex Noise Generator* block (Fig. 3(e)).The *OFDM* block is followed by the *FFT* block to transform the signal back into the frequency domain. Finally channel equalization or channel deconvolution is achieved by dividing the FFT output by the frequency response of the channel. The *Channel Equalization* block is shown in (Fig. 3(c)).

In the following subsections, we will present an overview of the modules and functions developed for simulating OFDM in J-DSP.

A. The OFDM Module

The *OFDM* block (Fig. 3(f)) performs the processes of adding the cyclic prefix, filtering using a FIR filter, adding the transmission noise, and removing the cyclic prefix.

The channels are modeled as FIR filters of a given length. The filter coefficients can be Gaussian distributed or user defined. The block also has a second input pin for the channel noise that users can feed into the system.

In this block, users can define parameters for the FIR filter, the length of the cyclic prefix, frame size, and channel filter coefficients.

B. Complex Noise Module

Using the *Complex Noise* block (Fig. 3(e)), complex-valued random signals (Gaussian, Uniform or Rayleigh) can be generated, and added to the signal as noise, as an input to the *OFDM* block.

In the *Complex Noise* block, users need to set the noise type, signal length, and the mean and variance of the noise.

C. Channel Equalizer

In the *Channel Equalizer* block (Fig. 3(c)), the output of the FFT is fed into the upper pin and the FFT of the FIR filter coefficients (frequency response) is fed into the lower pin of the block. The block performs element-by-element division of the FFT of the signal by the channel frequency response to achieve deconvolution in time.

D. Other Modules

Other modules that are used in the simulation of the OFDM system include the *FFT* block and the *IFFT* block, which have been previously developed in JDSP [4].

IV. Sample Exercises

In this section, some parts of an exercise developed for the OFDM system using the modules described in the previous section are described. The exercise can be used to introduce the OFDM system to the undergraduate students in signal processing and communication courses. In the exercise, by building an OFDM system, students will be able to relate the concepts learned in undergraduate courses to the real applications. The exercise helps students relate the concepts learned in STEM courses including the FFT/IFFT operations, properties of the DFT matrix, random signals, FIR filters, circular effects, convolution, and random processes. In what follows, a brief description of the exercise will be given.

In the first part of the exercise, a simulation model for the OFDM system is introduced to the students. System parameters including cyclic prefix length, channel coefficients, input signal, and noise type can be modified in the simulation. By comparing the output signal with the input signal, the OFDM system is analyzed. The simulation introduces the concept of cyclic prefix and transmissions over a wireless multipath channel to the students. In the second part of the exercise, students modify the cyclic prefix length and the order of the FIR filter to study the effects of the cyclic prefix on the performance of the system. In this way, students can learn that in OFDM, the cyclic prefix should be at least as long as the order of the filter. In the third part of the exercise, students build an audio processing model using the OFDM system. In the simulation, an 8192-sample speech signal is generated in the *SigGen(L)* block. The signal is processed frame-by-frame with 128 samples in each frame and a total of 64 frames, with no overlap between frames. Noise is introduced into the system to simulate a noisy channel. The *Sound Player* block provides students with a graphical view of the audio signal and students can also listen to the output audio signal and draw conclusions about the performance of the system.

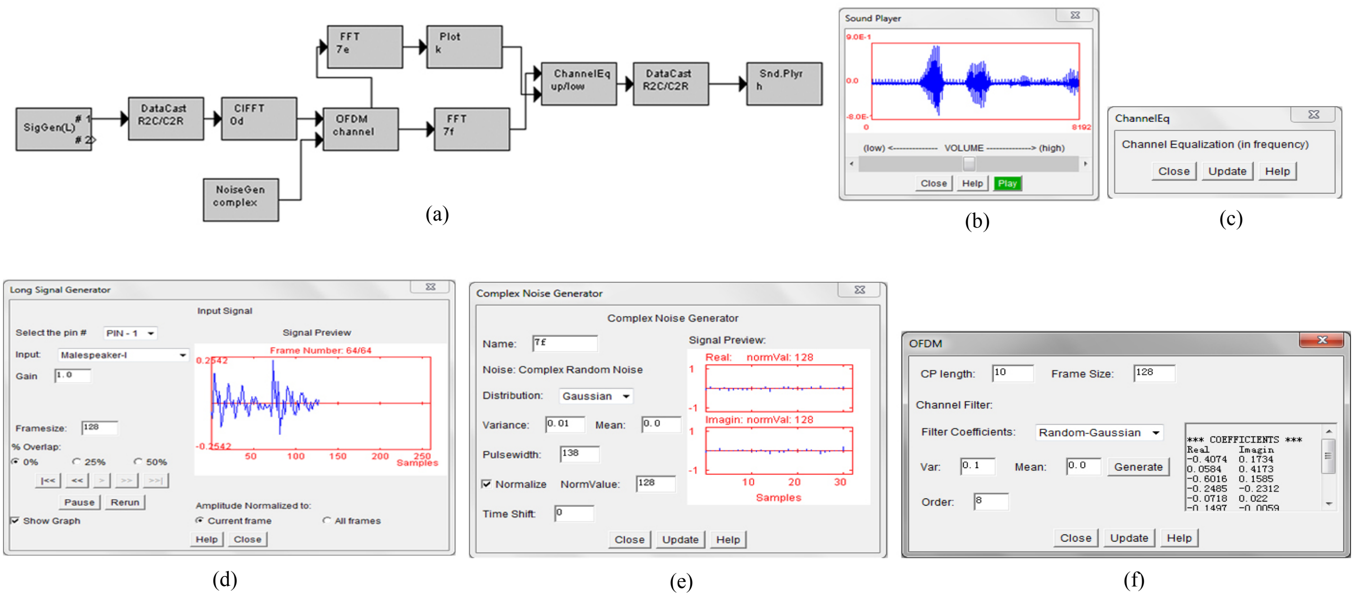

Fig. 3. OFDM simulation in J-DSP, and related blocks.

V. ASSESSMENT RESULTS

Preliminary assessments for the effectiveness of JDSP in DSP and communications education have been conducted [4, 9]. The results show the effectiveness of using JDSP in the classroom environment and the benefits of using JDSP in undergraduate DSP and communications classes. A workshop for signal processing and communications graduate and undergraduate students will be conducted for testing the OFDM system simulation in J-DSP and assessment results will be collected. The assessment questions are based on the OFDM exercise described in Section IV. Questions that are related to the performance of the system due to different noise parameters, channel coefficients, and effects of the cyclic prefix are asked. Some questions about the general design of the modules and suggestions for improvement of the software will also be solicited. Detailed assessment results will be presented at the conference.

VI. CONCLUSIONS

In this paper, we described the OFDM system simulation using the free web-based online Java tool J-DSP. The blocks developed can be combined to create a complete OFDM system. The system will perform the functions of IFFT, addition of a cyclic prefix, channel filtering, removal of the cyclic prefix, and an FFT, all components of an OFDM system. The simulation can also include features for adding channel noise, and for channel deconvolution. Using these blocks, students can learn the concepts of IFFT-based modulation, properties of the DFT matrix, convolution and circular effects, and noise processes and statistics.

Education for STEM courses can greatly benefit from the J-DSP OFDM modules. Students can relate the basic concepts with real applications, using the JDSP-based simulations. Since using J-DSP requires no coding background, students with limited programming ability or students from areas outside engineering can also perform the OFDM simulations.

ACKNOWLEDGMENTS

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Developing a New Advanced Microcontrollers Course as a part of Embedded Systems Curriculum

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***Abstract*— This paper presents our experiences in developing a new advanced microcontrollers course within the Department of Electrical Engineering and Computing Systems at the University of Cincinnati (UC). This course was developed and offered for the first time in Spring 2013 to undergraduate seniors and first-year graduate students in electrical and computer engineering. It is also open to interested students in other relevant science and engineering programs. The course aims at providing advanced skills in designing and developing microcontroller-based embedded systems. It adopts an instruction model that integrates active learning techniques with in-class lectures and laboratory projects. The paper elaborates on the course structure and schedule, pedagogical techniques used in the course, and student feedback results. It also explains how this course fits in to the existing embedded systems curriculum at UC.**

Keywords— course development; embedded systems; interdisciplinary education; microcontrollers

I. INTRODUCTION

Instruction in embedded systems is multifaceted and multidisciplinary. First, embedded computing systems are designed and built through different levels of abstraction (hardware, system software and application). Second, it involves concepts from multiple disciplines that include, but not limited to electronics, computer science, software engineering, and control theory [1]. Most importantly, the field has pervaded into a myriad of application domains, and the design approaches are different in each domain. Hence, from a pedagogical point of view, there are a number of considerations that influence instructional design in advanced embedded systems namely, abstraction layers, application domains, and breadth of concepts.

The objective of this paper is to present experiences from developing and teaching a new advanced microcontrollers course, *EECE 6038C – Advanced Microsystem Design*, that primarily focuses on hardware peripherals and interfacing, and developing microcontroller-based solutions to application-specific requirements. This class is intended to supplement introductory embedded system design courses and provide specific expertise in high-level programming (rather than assembly language programming) to integrate standard input/output hardware using low-cost and high performance microcontrollers.

II. ADVANCED EMBEDDED SYSTEMS CURRICULUM

In addition to an introductory microcontrollers course, there are three courses that form an integral part of the advanced embedded systems curriculum at UC. Table I shows an overview of those core courses.

- *EECE 6017C - Embedded Systems* is a comprehensive embedded/real-time system design and development course that is open to seniors and graduate students in applied sciences and engineering programs. This course was recently redesigned and expanded to facilitate interdisciplinary instruction in advanced embedded and real-time systems [2]. This course introduces several hardware/software concepts with major emphasis to software modeling for embedded systems, prototyping using FPGAs, and real-time operating systems.
- *EECE 6015C – Instrumentation and Industrial Control* focuses specifically on designing systems for industrial automation and control. It covers topics related to selection and utilization of analog, digital and piezoelectric sensors in electric energy, power system, manufacturing and other industrial plants. Students learn how to connect these sensors to digital controllers and program the controllers for electrometrical device monitoring and protection.
- *EECE 6038C – Advanced Microsystem Design* (See Section III).

TABLE I. CORE COURSES IN EMBEDDED SYSTEMS CURRICULUM

Course #[a]	Course Name	Level*
EECE 4038C	Embedded System Design	U
EECE 6015C	Instrumentation and Industrial Control	G/U
EECE 6017C	Embedded Systems	G/U
EECE 6038C	Advanced Microsystem Design**	G/U
EECE 7XXX	Trustworthy Embedded Systems***	G

* U – Undergraduate, G – Graduate; ** New; *** under development; [a] 'C' denotes Integrated lab component

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III. EECE 6038C Course Design

This section explains the course design and structure of *EECE 6038C – Advanced Microsystem Design*, in detail. This course was offered for the first time in Spring 2013 at UC.

A. Learning Objectives

The ABET learning outcomes for this course are as follows:

- Identify major architectural components of a PIC® microcontroller and understand their purpose (a, k).
- Construct and demonstrate microcontroller-based systems that integrate standard input/output hardware and custom software to address common embedded systems tasks (a, b, c, e, g, k).
- Demonstrate using a commonly available CAD environment the ability to write, debug, simulate, and test programs for the PIC® microprocessor family (a, c, e, g, k)
- Design, verify and document a microcontroller-based solution to a general problem statement that utilizes common architectural features of the PIC microcontroller that may include digital/analog inputs, digital outputs, counter/timers, and interrupt driven program flow (a, b, c, e, g, k).

B. Hardware and Development Tools

The course is based on low-cost16-bit PIC microcontrollers (PIC24F family of microcontrollers or dsPIC33 family of digital signal controllers) available from Microchip Inc. Students may use a development or demonstration board such as the Explorer 16 development board but are not required. Some laboratory assignments use a PICtail™ Plus daughter boards for audio/video interfacing and I/O. MPLAB® X Integrated Development Environment (IDE) and MPLAB-XC C compiler are used to develop and debug applications. Both the IDE and the compiler are freely available for all commonly available operating systems.

C. Topics

The course starts with a review of basic microcontroller concepts, programming with embedded C, overview of microcontroller architecture (16-bit PIC® microcontroller family), interrupts and memory model. Next, we explore concepts related to interacting with external devices including synchronous and asynchronous serial interface, LCD displays, and devices that produce analog signals. Finally, from these basic interfacing concepts, we then explore concepts related to connecting with standard interfaces such as PS/2 and USB, producing composite video, and managing larger storage devices such as SD and MMC storage cards [3].

D. Laboratory Projects

Eight laboratory projects were assigned to provide hands-on experience in microcontroller-based development, peripheral interfacing, and embedded-C programming. Table II gives a summary of laboratory assignments and their objectives. It also lists the cognitive level of learning based on Bloom's Taxonomy.

TABLE II. Summary of Laboratory Assignments and Objectives

Lab #	Lab Objective	*BT Level
1	a) To get the development environment set-up and then, use it to acclimatize to the PIC24F microcontroller and relevant CAD tools. b) To review interrupt mechanism and memory allocation techniques.	K
2	- To demonstrate knowledge of using the Serial Peripheral Interface (SPI) that enables synchronous serial communication with an EEPROM device.	A
3	- To understand the UART interface that enables asynchronous communication with a serial port.	A
4	- To use the Parallel Master Port (PMP) to communicate with an LCD display module.	A
5	a) To learn how to use a 10-bit ADC module to read and process analog signals. b) To combine techniques from lab #1 and lab #4 to create a temperature sensing system.	S
6	a) To implement interfacing methods that can support connection of a PS/2 keyboard to the microcontroller. b) To test the PS/2 connection by allowing UART communication to a terminal emulator.	L
7	- To understand how a video card works and implement a simplified version of a video card that produces a standard composite video signal for a monochrome video display	L
8	a) To develop an understanding of i) how to interface the PIC demonstration board to an SD card, ii) how to interact with a FAT16 file structure, and iii) how to use the PWM functionality of PIC24 to create analog waveforms. b) To create and test a simple music player by integrating the concepts and techniques in 8a.	S
9	Final Project (See Section III E)	A, S, E

* *Bloom's Taxonomy of Cognitive Domain:* K-Knowledge, C-Comprehension, A-Application, L-Analysis, S-Synthesis, E-Evaluation.

E. Final Projects

The goal of the final project is two-fold. First, the project gives an opportunity to demonstrate the ability of students to utilize the skills and concepts learned in this course. Second, it also gives an opportunity to explore technologies related to the core content of advanced microcontrollers. Students define their own design project that must use a 16-bit microcontroller from the PIC24F family of microcontrollers or the dsPIC33 family of digital signal controllers. Students may use custom design printed circuit boards for either daughter boards or full implementation.

F. Instructional Methods

The course is designed to include several methods of instruction: 1) Traditional lectures, 2) Collaborative learning through in-class discussions, and 3) Participatory learning. The class meets thrice every week. The majority of learning in this course is through weekly laboratory assignments. Hence, at least one lecture is presented at the beginning of every week to cover concepts related to that week's laboratory assignment. The remaining class sessions in the week are used to facilitate discussions on concepts and problems related to the lab assignment.

A participatory session called *Unlecture* was held towards to end of the term. This is an informal discussion session that is primarily driven by participants (students). The goals of this session are: 1) To enable an open-ended discussion on the discipline of embedded systems, and gain insights on gaps between education and industry trends in the field of embedded/real-time systems, 2) To examine the potential of such participatory sessions as a pedagogical technique for future offerings of this course. The theme of the session was "Current Trends in Embedded Systems Design". A wide-ranging theme was chosen on purpose to encourage participation among students.

IV. Course Assessment

The first offering of the course received an enrollment of thirty five students from three majors – electrical engineering (24), computer engineering (10) and applied physics (1). Of the 35 students, 24 were undergraduate students and 11 were graduate students. Data and feedback presented in this section were collected through three surveys at periodic intervals during the semester (pre-class, mid-term, and final).

A. Project Proposals

A wide range of projects were proposed by students as a part of the course requirement. Fig.1. shows a categorical chart of various projects. Uncategorized projects include network-based designs, research projects, and custom circuit designs.

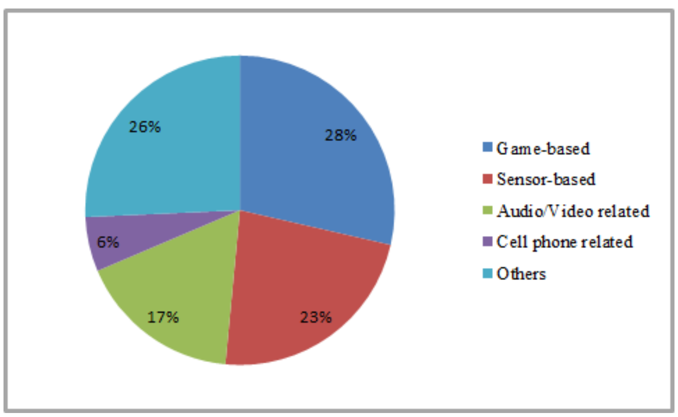

Fig. 1. Categorical chart of project proposals

B. Student Assessment

Students are assessed based on the following grade distribution: Weekly laboratory assignments (40%), Laboratory demonstrations (30%), Final project (25%), and In-class activities and participation (5%).

C. Student Feedback

Responses to course-specific questions are shown in Table III. The majority of students thought that the course was well-structured and informative. Most students found the laboratory assignments to be involved and challenging. However, there were some comments about lab assignments being less rigorous at the beginning of the term. The course was intentionally organized to be less intense at the beginning to allow students from different backgrounds familiarize with the design tools and course content.

The collaborative sessions received mostly positive reviews. Students felt that in-class discussions were a great way to collaborate on common problems related to the design environment. Also, there were specific comments about teaching methods being unique and different.

TABLE III. Responses to Course-Specific Questions

Course-specific question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Increased my interest in microcontrollers	3%	7%	3%	56%	31%
Developed skills that will help in seeking employment	3%	3%	14%	60%	20%
Final project increased my understanding of several concepts that were covered in the class	0%	0%	3%	50%	47%
Rate your expertise in microcontroller-based design and programming*	5.93 (Pre-class) →7.07(Mid-term) →7.83 (Final)				

* Rating Scale: 1 to 10 (1 being least, 10 being highest); Values are average of rating responses.

V. Discussion and Ongoing Work

It can be seen from Table III that the average expertise level in microcontroller-based design and programming has significantly increased during the course. It can also be observed that the course project has improved students' confidence levels in their ability to demonstrate such skills after the completion of the final project and the course itself.

The first trial run of the *Unlecture* session gave a better understanding of how this technique can actually be used to deliver technical content. Based on the session outcomes, the technique was formally modeled, and is currently being deployed in an upper-level computer engineering course. Overall, the advanced microcontrollers course (*EECE-6038C*) was successful in integrating and formulating active learning techniques with traditional lectures and laboratory projects. Also, the first offering has helped in streamlining and creating a feasible set of laboratory assignments and other course content. As a part of next steps, the following topics are being expanded or added to the course catalog: PCB design, digital signal processing using dsPIC, bluetooth and ethernet interfacing, and advanced file management.

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Engaging Students for Success in Calculus with Online Learning Forums

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***Abstract*— It is said that we face an engineering "talent crisis" [1]; the United States is failing to keep pace in educating a highly skilled and diverse engineering workforce. Emphasis is currently placed on recruitment and retention of underrepresented minorities. Newer distance-delivered programs seek participation of non-traditional and geographically underrepresented students.**

With expansion of educational offerings in engineering, one issue that emerges is student attrition during the first two years. It is suggested [2-4] that success in first year calculus reliably predicts persistence in engineering. To increase retention, new strategies are needed. Effective interventions may have the most impact if employed within the first year calculus sequence. Pedagogies that support traditional classroom learning as well as hybrid instruction and distance education offer the greatest transformative potential.

This work-in-progress paper describes research underway to evaluate the use of online learning forums during first year calculus. A freely available, wiki-based online learning forum is employed during a mixed-methods study. The study is conducted within sequential calculus courses distance-delivered across two academic years. Qualitative and quantitative data are used to evaluate the effect of forum use on student achievement, engagement and attitudes. A usage model is developed to disseminate within the STEM education community.

Keywords—distance education, engineering retention, social learning theory, mixed methods research

I. INTRODUCTION

A heightened focus on retention in engineering is evidenced in a number of research studies conducted to evaluate innovations in engineering mathematics instruction. These studies investigated the use of structured experiences [5], new curricula [6] and targeted interventions [7, 8] to improve retention. Other studies [2-4] have reported strong correlations between academic performance in first year calculus and attainment of an undergraduate engineering degree. A recent longitudinal study [2] indicated that success, measured solely by the grade achieved in *first semester* college mathematics and independent of secondary mathematics preparation or achievement, is itself a reliable predictor of retention among engineering undergraduates.

Recent data for the 2009-2011 academic years, gathered locally in conjunction with the Utah State University (USU) Advising Center, show that an average of 28% of USU engineering students enrolled in traditional (face-to-face) sections of Calculus I either withdrew from or failed the course (final course grade of W, D or F). This rate was nearly double - *an attrition rate of 52%* - during the same time frame for the engineering students enrolled in distance delivered (synchronous broadcast) sections of Calculus I.

Additional data, gathered in conjunction with the USU Office of Analysis, Assessment, and Accreditation from the same time period, indicate student satisfaction in the calculus sequence is lower for distance delivered than for traditional sections. During the 2009-2011 academic years, data from end of course student evaluations show that distance sections scored almost one full point lower (on a scale of 1-poor to 6-excellent) than traditional sections of Calculus I in ratings of instructor effectiveness (4.10 distance | 4.91 traditional) and overall quality of the course (3.96 distance | 4.90 traditional).

These data suggest that intervention strategies that target retention in calculus should not only focus on improving student academic achievement (knowledge and skills), but should also address affective outcomes such as student engagement and attitudes towards learning, the learning environment, available support, and the overall sense of learning community within the course. Researchers [9] have discussed that these are typical areas where students experience isolation, disconnectedness and dissatisfaction with the distance instruction. Thus, these are important areas to consider in designing interventions with a goal of improving retention.

II. ONLINE LEARNING FORUMS AS INTERVENTION

A. What are Online Learning Forums?

Online learning forums are discussion sites accessed via the internet by participants in a course. Online discussion sites allow individual learners to hold conversations with other individual learners, groups of learners, teaching assistants and instructors by posting text-based messages to the forum. Student access to a forum occurs asynchronously and apart from other synchronous learning sessions, meetings, or activities. Thus, despite their online nature, online learning forums are useful across the spectrum of educational delivery platforms (e.g. traditional, web-enhanced, online, etc.).

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B. Theoretical Framework: Social Learning Theory

Social learning theory, as pioneered by Vygotsky, claims that learning is not simply "...an unfolding or maturation of pre-existing 'ideas'; on the contrary, it is the formation of such ideas-out of what originally was not an idea- in the course of socially meaningful activity" [10]. Online forums support important social influences on learning namely "competence" and "social" motivation to learn, "learner-friendly" formative assessment, and a community approach to learning [11].

1) Motivation: Student motivation is linked to learning achievement because the amount of time a student is willing to put into a subject is directly related to their motivation for learning the subject material. Competence motivation to learn decreases when learning "challenges" are either too easy or too difficult [11]. The goal of a learning forum is to provide enough timely feedback, whether from instructors, teaching assistants, or fellow students, so that students do not become frustrated and lose motivation for learning calculus and/or for pursuing engineering altogether.

Social motivation to learn increases when students perceive themselves to be helping others [11]. The online learning forum creates a virtual meeting place where students can meet online to share ideas and offer solutions that directly lead to learning. Thus, the benefits of the student as teacher paradigm can be realized even as students are geographically dispersed, studying alone during late night hours, or otherwise participating in distance education out of convenience. Moreover, use of the online forum can not only be adapted to differences in time and place between students and instructor, but also to differences in student learning styles and pace that are particularly prevalent among adult learners [12].

2) Formative Assessment: A system for continuous formative assessment is vital to promoting student learning and informing day-to-day instruction [11]. For pre-calculus high school seniors, researchers [13] found that frequent instructor interaction helped students to express and refine their level of mathematical understanding. The optimal occasion for formative assessment is during time of deep student engagement, usually during problem solving and homework preparation. Traditionally, instructor office hours have provided opportunity for this critical discourse to develop. With increasing numbers of non-traditional and working students and rising enrollment in distance education classes, physical attendance at instructor office hours is no longer feasible for many students. Thus, the availability of a 24/7 online forum that allows for more flexible instructor-student or student-student interaction could be transformative.

3) Community Approach to Learning: Learning is most effective *and* lasting when the environment is communal rather than punitive. In a true learning community, students are encouraged to attempt understanding, make mistakes, seek feedback, and revise their knowledge [11]. Creating a sociable learning community, however, can be difficult in classrooms when the subject matter is quantitative and presents "right" and "wrong" answers. Creating a true community for open discussion and problem solving may be easier to accomplish virtually, as students may sense some degree of anonymity and be more willing to ask questions or offer solutions online.

The growing popularity and common use of online social networking tools imply that students today may be more apt to converse in an online environments than in traditional classrooms. As evidence, researchers [14] have documented the growing use of "free, open, online, internet help forums" to learn mathematics. In these online mathematics forums, students voluntarily access help and communicate online anonymously with volunteers located throughout the world to get help on their homework and assignments.

III. Research Project

A. Description of the Research Project

1) Pilot Study: The researchers piloted Piazza in seven sophomore level engineering courses between Fall 2011 and Spring 2013. Six courses were small (5-14 students) and taught via synchronous video broadcast and one was large (>150 students) and taught traditionally (face-to-face). Students were surveyed to judge their use of and satisfaction with the forum. The results were overwhelmingly positive. Student responses in Fall 2011 and Spring 2012, 19/20 students reported that Piazza was at least somewhat effective in improving their learning and attitudes towards the course. Therefore, we hypothesize that use of the forum will improve both cogntive and affective student outcomes in calculus.

2) Quasi-experimental Study: In Fall 2013, we will implement the online learning forum as the treatment condition of a quasi experimental study conducted in distance delivered (via synchronous broadcast) sections of first year calculus across two academic years. Because random assignment of students is not feasible, a quasi-experimental nonequivalent control group design will be employed [15]. Assessment will measure the extent to which the online learning forum improves engineering student cognitive (academic achievement) outcomes as measured by quantitative data (student exam scores, post test results).

3) Student Surveys, Observation and Interviews: Student affective (engagement, attitudes, motivation) outcomes will be assessed and compared across both treatment and control groups of the quasi-experimental study using quantitative (end of course surveys) and qualitative (classroom observation, forum posts, artifact analysis, and targeted student interviews) data. Interviews will focus on students that fail or withdraw from the course. Quantitative and qualitative data will be used to develop a usage model to aid implementation of online learning forums througout the STEM education community.

4) Research Questions: Our research questions and associated assessment measures are:

1. How does student academic achievement vary with respect to participation in the forum?
(exam scores, artifact analysis)
2. How does student interest in and attitudes toward learning calculus vary with respect to participation in the forum?
(survey, observation, interviews)
3. How do students involve themselves in social interaction within the online forum?
(survey, observation, interviews)
4. What motivations increase participation by high achieving vs. low achieving students?
(survey, observation, interviews)
5. How can on-demand support be sustained over time?
(survey, observation, interviews)

B. Contribution of the Research Project

Researchers report a gap in the literature, particularly within undergraduate engineering education and the sciences, concerning “networked learning” [16], and the implementation of online forums [14]. The term “networked learning” is defined by the authors [16] as the use of information computer technology (e.g. asynchronous email and text messaging) to promote learning connections and directly fits the purpose and function of online learning forums described in this study. Therefore, there is potential for this project to break new ground in assessing the effects of online learning forums and in developing usage guidelines for dissemination throughout the STEM education community.

C. Choice of Online Learning Forum

We choose to implement Piazza [17], a freely available, wiki-based online learning forum. Wikis are collaborative “groupware” that enable geographically dispersed, “virtual” teams to write “peer-produced” documents using a only text editor and a web browser [18]. The wiki nature of Piazza is one of its most unique and compelling educational features. Wiki based forums stand in contrast to traditional online forums using threaded discussions because wikis allow participants to edit for both organization and content [18]. It has been suggested [19] that threaded discussions are problematic for education because they exhibit incoherence and a lack of convergence that prevents learners from seeing the main ideas of the discussion or interchange. Since topics in threaded discussions are organized historically rather than conceptually, threaded discussions make it difficult for learners to place information into the correct context or conceptual framework, a skill that is needed for deep understanding. Additionally, Piazza’s built-in equation editor and symbolic editing features make it an advantageous choice for STEM applications.

IV. SUMMARY

Results of this mixed-methods study will be useful in formally assessing the effects of online learning forums on student cognitive and affective outcomes in STEM education settings. Quantitative and qualitative data will guide the development of a usage model to facilitate the use of online forums throughout the STEM community. Data gathered will provide deep insights into the role(s) that virtual learning communities and the social aspects of learning play in STEM education, pointing toward new avenues for investigation.

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Computer Self-Efficacy, Cognitive, and Metacognitive Strategies of High School Students While Engaged in Interactive Learning Modules

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***Abstract*—Along with the rapid development of computer and Internet technologies, efforts have been conducted to include design, development, and evaluation of computer applications for learning activities. Although extensive research has defined the use of computer applications in various disciplines, few studies have systematically investigated students' self-regulated learning skills while learning with an interactive learning module specifically in computer science education. The purposes of this study are to investigate high school students' computer self-efficacy, cognitive, and metacognitive strategies while students learn with the interactive learning modules and performing a mixed-methods study. Data collection included students' self-reports and traces of student activity. The quantitative analyses applicable to this study included descriptive and non-parametric statistics. Qualitative data were gathered from interactive learning module screen-captured videos and interview transcripts to support findings from quantitative data. The outcome of this study will inform policy makers, educators, researchers, developers, and others of the importance of a self-regulated learning perspective when designing instruction using an interactive learning module.**

Keywords—computer self-efficacy; interactive learning module; mixed-methods study; metacognitive strategies

I. Introduction

A common goal has been made between educators and policy makers to improve teaching of science, technology, engineering, and mathematics (STEM) subjects in the U.S. The calling for the improvement comes from the Committee on Highly Successful Schools or Programs in K-12 STEM Education, Board on Science Education, Board on Testing and Assessment, Division of Behavioral and Social Sciences and Education, National Research Council, and many others [e.g., 1, 2]. The concerns on STEM education are related to the U.S. competitiveness in the global economy. The National Academy of Sciences, National Academy of Engineering, and Institute of Medicine published *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* [3]. One of key recommendations suggested in this report is improving mathematics and science education in K-12 level in order to maintain the U.S. competitiveness.

Along with the rapid development of computer and Internet technologies, many studies have been conducted which include computer applications for learning activities. Tremendous effort has been made to design, develop, and evaluate computer-based learning environments for different purposes and areas, for example in chemistry, mathematics, and reading achievement [4-6]. Thus, there are many available definitions related to computer-based learning environment. Previous research suggests that an interactive learning module as part of computer-based learning environment can be used as a tool to provide responsive feedback and flexibility in accessing materials [7].

This study will focus on computer self-efficacy, cognitive, and metacognitive strategies while students learn with the Interactive Learning Modules (ILMs). The researchers use computer self-efficacy to understand students' background knowledge and perception of computer usage. Computer self-efficacy can be defined as personal judgment of capabilities to use computers in different situations [8, 9]. While cognitive strategies represent actions on a specific context (e.g., reading, working with computer, etc), metacognitive strategies are

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represented by planning, monitoring, and regulating strategies related to the actions.

Previous research has suggested that college students' self-efficacy beliefs are strongly related to the use of cognitive and metacognitive strategies [10, 11]. In addition, at the junior high school level, the use of cognitive and metacognitive strategies was positively correlated with self-efficacy judgment [12]. Also, Compeau, Higgins, and Huff [8] found that computer self-efficacy increased computer usage in general. However, it is not yet clear how students' beliefs about their performance capabilities when using computers (i.e., computer self-efficacy) is related to cognitive and metacognitive strategies while learning with ILMs specifically at the high school level.

II. Purposes and Objectives

The purposes of this study are to investigate high school students' computer self-efficacy, cognitive, and metacognitive strategies in a self-regulated learning (SRL) framework while utilizing ILMs and performing a mixed-methods study. The researcher hypothesizes that computer self-efficacy is positively correlated with cognitive and metacognitive strategies while the students are engaged with ILMs. The metacognitive strategies in this study include planning, monitoring, and regulating strategies. Butler and Cartier's SRL model [13, 14] will be used as the framework for this study. The following objectives will frame and guide the research: (1) to investigate the relationship between students' computer self-efficacy and cognitive and metacognitive strategies while using ILMs; and (2) to investigate the relationship between students' cognitive and metacognitive strategies while using ILMs.

III. Research Method

A. Participant of the Study

A high school student classroom is ideal for evaluation of the ILMs. In a college classroom, the modules tend to be used differently. Because time is more closely monitored and because most college classrooms do not have individual computers, on a college campus, ILMs are primarily used as teacher demonstration or as part of homework exercises. Students at School X who take the Career and Technical Educational course (i.e., Programming 1A and Math 1) and students at School Y who enrolled in a physics class in spring 2013 were invited in this study. One hundred and thirteen students participated in this study. Student participants were informed of the purpose and methods of the project in which they participated.

B. Instrumentation

1) Demographic questionnaire: The questionnaire includes: gender, age, ethnicity, class, GPA, the highest math class already taken, and whether they are considering majoring in a field of engineering, technology, or computer science in college.

2) CSE questionnaire: The researcher assessed students' computer self-efficacy (CSE) by modifying the work of Durndell, Haag, and Laithwaite [15]; the work was based on Torkzadeh and Koufteros [16] and Murphy, Coover, and Owen [17]. The CSE questionnaire has very high internal reliability scores. The Cronbach's Alpha coefficients of Beginning Skills, Advanced Skills, File and Software Skills, and Mainframe Computer Skills are .93, 88, .90, and 95, respectively. The questionnaire responses range from 1 to 5 (i.e., 1 = *not at all true of me*, and 5 = *very true of me*).

3) SRCBL questionnaire: The development of a SRCBL questionnaire contextualized to the interactive learning module is required. Schunk [18] argued that SRL skills and strategies appear to be "highly context dependent." The researcher modified an instrument developed by Lawanto [19] using Butler and Cartier's SRL framework and focusing on cognitive and metacognitive dimensions of the framework. The 21-item SRCBL questionnaire consists of four components: Planning, Cognitive, Monitoring, and Regulating Strategies. Measurement scales of the SRCBL Questionnaire responses will range from 1 to 4 (i.e., 1 = *almost never*, 2 = *sometimes*, 3 = *often*, and 4 = *almost always*).

C. Material: Interactive Learning Modules

Interactive Learning Module (ILM) is a type of computer-based instruction developed at Department of Computer Science, Utah State University which reinforces computing ideas by utilizing immediate feedback and user manipulation of computer science models [20]. This study focuses on three modules called the Boolean Logic, Minimum Spanning Tree, and Modeling Using Graphs. These ILMs were chosen for this study because of their correlation to the high school curriculum. For example, in the Boolean logic ILM, students perform a variety of activities which include predicting the result of Boolean operations and experimenting with simplifications of expressions.

D. Data Collection and Analysis Procedures

In this paper, the researcher only reported the data collection and analysis procedures without any finding because the analysis could not be completed by the time this paper was submitted. Data collection was conducted in a classroom or lab equipped with Internet ready computers. Students filled in the surveys online and learned with the interactive learning modules that were also available online. The students were not required to use username and password to access the online survey and the modules. Instead, they were given an ID code to protect their privacy. The students were also given an orientation to the research protocol.

As explained earlier, data collection included quantitative and qualitative data. The researcher gathered quantitative data from CSE and SRCBL questionnaires and qualitative data from screen-captured videos and interviews. Participants were expected to complete an online CSE questionnaire preceded by a short demographic survey on the first day of the data collection. After completing the questionnaires on the first day, participants were asked to use the learning modules and then complete the SRCBL on the last day.

Purposive sampling was used to investigate students' cognitive and metacognitive strategies with high and low CSE. The sampling process was conducted by categorizing the participants based on the CSE level. Students' CSE levels among the participants were identified by applying cluster analysis. The results were used in the selection for screen-captured videos and interviews. In this study, the screen-capture tool captured all students' activities while using the ILM. Data regarding ILM navigation were gathered in selected class sessions in which the learning modules were investigated. In addition, the recorded interview sessions assessed students' perception about their learning strategies. The questions asked the students on how they used features of the modules, arrived at solutions in a learning exercise and problem-solve, and what strategies they used. Different questions were asked to selected participants, depending on how the researcher interpreted the findings from questionnaires and ILM screen-captured videos related to specific students.

Descriptive statistics will be applied to analyze quantitative data from the demographic, CSE, and SRCBL questionnaires. Given the likelihood of a relatively small number of students, the researcher will also apply nonparametric statistics in order to conduct correlation and significance tests (i.e., Spearman and Wilcoxon tests). Target students for ILM screen-capture analysis and audio-taped interview sessions were chosen based on the results of the cluster analysis. Two graduate students, who have already taken the cognition class, will code the sequence of events, and categorize the sequence of events into relevant cognitive and metacognitive strategies. Interview transcripts will be segmented, coded, and analyzed.

IV. Expected Outcomes

The outcome of this study will inform policy makers, educators, researchers, developers, and others of the importance of a self-regulated learning perspective when designing instruction using an interactive learning module. The results will also identify the relationships between (1) CSE and cognitive strategies, and (2) CSE and metacognitive strategies while using the ILMs, and benefit researchers who are interested in developing methodologically suite of tools for an interactive learning module specifically in computer science context. The results of this study will be presented at the 2013 FIE conference.

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Student Perceptions of Differences in Visual Communication Mode for an Online Course in Engineering

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***Abstract*—Online courses have the promise of extending the horizons of today's academic landscape with their cost-effective and convenient model compared to traditional learning environments. Despite the promising nature of the learning model, there continue to be several challenges that hinder learning, one of which is lack of instructor presence. This study aims at understanding the effect of instructor presence on student satisfaction in an online setting of a course in engineering.**

We conducted a student-centered pilot experiment to assess engineering students' perceptions of two modes of online mini-lectures: the first, a presentation with the instructor appearing in window, created using an off-the-shelf screen-capture software; the second, a presentation with the instructor overlaid in the slides created using recent visual communication technology that overlays the video of the instructor without any background images or outline boxes. The instructor was the same in both the presentations. Our focus here is on the following factors: 1. Comparing overall student satisfaction after watching the two modes; 2. Comparing the perceived non-verbal immediacy factors of the instructor; and, 3. Comparing the preference of video mode for future online courses.

Preliminary results suggest a preference of the video mode with the instructor overlaid over that with the instructor in a box. The effect sizes of the differences in overall satisfaction between the experimental groups and their perceived levels of non-verbal immediacy factors when viewing the online lecture in the two modes are encouraging enough to pursue more longitudinal studies with the set-up.

I. Introduction

The advent of online learning has extended the horizons of today's academic landscape. The new model is being promoted as being more cost-effective and convenient than traditional learning environments while providing educational opportunities for larger communities of learners regardless of geographic location and independent of time. Despite the promising nature of the learning model, there continue to be several challenges that hinder learning in such environments.

One of the oft-cited disadvantages of the new learning model is its being not as effective as traditional classroom learning owing to the lack of face to face interactions. Several case studies [1], [2] have cited instances where students felt disconnected from others in this type of learning environment, citing lack of facial expressions and other features common to a traditional classroom environment. Unfortunately, until recently there have been very few ways for an instructor to create this sense of instructor presence in the online learning environment aside from a handful of interactions in online discussion environments and in the pre-recorded video lectures. In this study, we explore how different visual modes that incorporate instructor presence in an online lecture are perceived differently by students.

II. Background

Research in psychology, communication and online learning reveal that learners need to have a sense of relatedness to their instructors and that this sense of relatedness is often communicated through information that is superfluous to the learning objectives [3]. A recurring finding of empirical studies on motivational agents in the context of embodied interfaces is that these agents make the user experience more engaging (a phenomenon termed persona effect) - users find that the visual and auditory presence of a virtual person renders these interactions more human-like and more social (e.g. [4], [5]). Moreover, research suggests that pedagogical agents have a supportive role when learners are working with complex tasks [6] and that in multimedia learning environments they increased both learners' retention and transfer scores [7].

Research in nonverbal communication has identified a number of nonverbal cues (nonverbal immediacy), that include bodily behaviors such as proximity, gaze, gestures, posture, facial expressions, and touching as well as vocal behaviors such as vocal tone and expressions, as critical components of human to human communication [8], [9]. That nonverbal immediacy behaviors positively affect student motivation, participation and attendance, affective and cognitive learning in classroom scenarios has been well studied [10], [11]. It has also been found that these positive effects prevail in large classes [12], and under high workload demands [13]. However, only recently is the use of non-verbal modalities being harnessed in virtual communication scenarios (e.g, access to the course instructor teaching in a window at the corner of the presentation screen in a video lecture). It is likely, though, that increased amounts of non-verbal communication in a video lecture can improve an instructor's sense of presence in an *online-only* learning environment and thus improve students' learning and

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their desire to stay engaged in their learning. Unfortunately, research is still inconclusive regarding which elements of a pedagogical agent's non-verbal communication is critical to learning. Moreover, studies on the effects of instructor non-verbal behavior on student satisfaction and performance in online learning scenarios are only in their incipient stages creating an immediate need to address this heretofore unexplored aspect of online learning.

III. Objectives of the Study

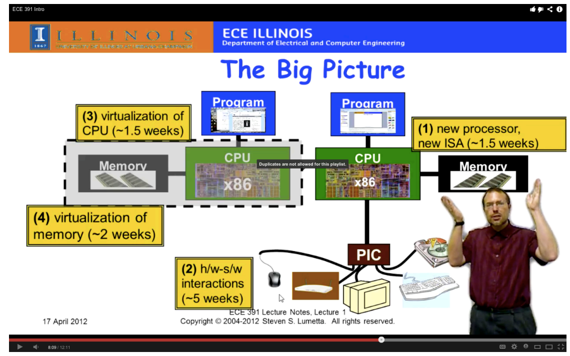
This study aims at understanding the effects of instructor presence on student satisfaction and choice of preferred visual mode in an online course setting. A fundamental question that arises towards this end is - how can we make the essential modalities of human communication accessible to students in an online setting?

A number of previous research studies suggested that an interactive teaching style and high levels of learner-to-instructor interaction are strongly associated with high levels of user satisfaction and learning outcomes [14], [15]. Until very recently, most instructor to student communication in online courses was textual. However, with the recent use of streaming media, online course materials now make instructor voice and video accessible to students, making instructor non-verbal immediacy behaviors more accessible to learners.

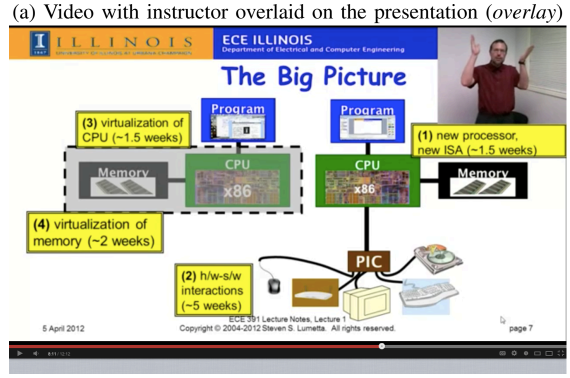
Recent advances in video capture technology allow the creation of video lectures that increase instructor's presence in the online classroom. While previous technologies such as Camtasia can embed a video of an instructor inside a recording of a video lecture, the instructor appears inside a small window that includes extraneous background information from the room that the instructor was in. New screen capture tools from Personify[1], are able to capture only the instructor sans background and overlay video of the instructor into a presentation such as PowerPoint Slides. Thus, a human avatar can be overlaid into any video lecture with a minimal level of effort and without adding the extraneous information present in older technologies such as Camtasia. We thus have two modes of visual communication that make instructor non-verbal behaviors available to the students and the question then, is whether one mode is better than the other for online learning.

As a first step towards answering the research question, we conducted a student-centered pilot study to assess engineering students' perceptions of an online mini-lecture created in the two modes (mentioned above) with increased presence of the instructor. The two modes differ fundamentally in how they make instructor non-verbal immediacy factors accessible to the students 1. One mode (termed henceforth *window*) is a presentation with the instructor appearing in a window of the screen, created using an off-the-shelf screen-capture software Camtasia; the second, a presentation with the instructor overlaid in the slides created using Microsoft's Kinect camera and Personify Live technology that overlays the video of the instructor without any background images or outline boxes (henceforth termed *overlay*). The same instructor appeared in

[1]Personify Inc., a start-up spun off from the University of Illinois is the maker of Personify Live, a tool that uses state-of-the-art machine vision techniques to include an embedded video of the presenter alongside the central material being presented



(a) Video with instructor overlaid on the presentation (*overlay*)



(b) Video with instructor appearing as picture in picture (*window*)

Fig. 1: Screenshots of the two video modes, *overlay* and *window*. The instructor without any distracting background is embedded in the *overlay* mode and dynamically points to material on the slides; the *window* mode has the instructor relegated to a corner in the screen.

both the modes and the recording was done simultaneously. In particular, our focus in this study is to answer the following questions: a) How do the two video modes affect overall student satisfaction? b) Is a video mode better at making non-verbal immediacy factors, such as that of instructor's gestures and eye gaze, available to the student? c) Among the two video modes, do students have a preference for future online courses?

IV. Methods and Data Source

Our experiment involves 60 students from the department of electrical and computer engineering at the University of Illinois, Urbana-Champaign. In the study, the students watched an introductory online lecture summarizing the course objectives and tasks of an optional course (Computer Systems Engineering). The course would be offered by an instructor who was rated high for teaching quality and had not taught the students before. Students were randomly assigned to two groups (A and B) to watch a video mode online and then asked to answer a questionnaire. The questionnaire solicited participants' demographic information and asked them to rate their level of satisfaction and perceptions of non-verbal immediacy behaviors of the instructor. Overall satisfaction was sought on a scale of 1-5 (1=Poor, 5=Excellent). The ratings of the non-verbal immediacy behavior of the instructor were obtained via questions based on the non-verbal immediacy behavior (NIB) scale originally constructed in [16] adapted to an online learning scenario. In the end, the subjects were asked to watch the video in the other mode and indicate their preferred mode for an online course upon having watched the two visual modes. The variables obtained from this section of the survey are students' overall satisfaction score and students' perceived level of non-verbal immediacy behaviors of the instructor (derived from students' response to the NIB scale).

There were 28 students in Group A (that watched *window* followed by *overlay*) and 32 in Group B that watched the videos in reverse order from that of Group A. The majority of participants in both the groups were sophomores (A: 36%, B: 53%) but there were freshmen, juniors and seniors as well. 82% of Group A and 91% of Group B were male. A majority of the participants (A: 61%, B: 56%) reported that they had no prior online course experience.

V. RESULTS

	Group A ($n = 28$)		Group B ($n = 32$)		
Factor	Mean	SD	Mean	SD	Cohen's d
Satisfaction	3.67	0.98	4.03	0.74	0.40
NIB	19.46	3.45	21.34	4.30	0.49

TABLE I: Descriptive statistics of the two groups with Cohen's effect sizes for mean ratings of satisfaction and perceived non-verbal immediacy.

Our analysis seeks whether overall student satisfaction, perceived level of instructor non-verbal immediacy, and preferred mode for an online course differed between the two groups. The results are summarized in Table I. Two-sample t-tests for difference between mean satisfaction scores, ratings of the instructor's nonverbal immediacy between the two groups, suggest that based on this sample of subjects there is no difference between the means between of the two groups at the 0.05 level (p-values 0.13 and 0.06 respectively). However, given that measures of statistical significance are critically dependent of sample sizes, we consider Cohen's effect sizes of the mean scores to see whether the differences are meaningful. We find medium effect sizes in the differences in mean scores between the two groups (0.40 and 0.49 respectively), suggesting that the means of Group B are bigger than that of Group A. Further, in choosing their preferred video mode for future online courses, 82% of subjects in Group A and 88% of subjects in Group B preferred the overlay mode to the window mode. This indicates that the overlay mode was preferred by a majority of the subjects in both the groups.

VI. SIGNIFICANCE OF RESULTS

Results suggest a student preference of the overlay video mode over the window mode. The medium effects in differences in overall satisfaction between the experimental groups and their perceived levels of non-verbal immediacy factors when viewing the online lecture in the two modes are encouraging enough to pursue more longitudinal studies with a larger set of subjects and in other online learning scenarios. Assuming that the overlay mode permits better access to gestures and eye-gaze of the presenter, the preliminary results obtained are in-line with the background literature on the positive effects of access to instructor non-verbal immediacy.

Our planned extensions to the study include conducting experiments over the duration of an entire course (including a massively open online course) and augmenting the factors studied to include aspects of performance by including pre- and post-tests to assess the influence of the visual mode on learning and transfer.

The emerging virtual environment for engineering education presents a great opportunity for learners and educators. New research in pedagogy informed by psychology and cognitive science combined with the technological enhancements in the area of visual communication can make online classes more engaging and an active learning environment.

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Assessment of Online Participation through Social Network Measures: A HLM Approach

Abstract— **In this research, we bring attention to one of the largest electrical and computer engineering (ECE) online discussion forums AllAboutCircuits.com. There are close to two hundred thousand learners contributing more than a million messages to this forum for over more than a decade. The massive archives of educational data raise an important question for engineering educators: How do we assess online participation? In this work-in-progress, we propose a multilevel approach to assess online participation based on social network measures and Hierarchical Linear Modeling (HLM) techniques. Specifically, we consider the employment of HLM to model the association between online participation and measures of social capital. Predictors of social capital are established, at both the individual and group levels, to examine the association between these predictors and learners' participation frequencies. We discuss our choice of HLM as a modeling approach over ordinary least squares (OLS) regression methods. We then describe how data is collected from the site of study, AllAboutCircuits.com, and how the modeling approach is conceptualized and used for assessment purposes. The importance of this work lies not only on sheer participation figures – it derives from the argument that online discussion fosters productive collaborative learning and individual reflection.**

Keywords—assessment; online discussion forums; hierarchical linear modeling; electrical and computer engineering

I. Introduction

Since the advent of the Internet, online discussion forums have emerged as effective educational tools capable of supporting teaching and learning in a variety of educational settings [1]. The use of online discussion forums in college curricula can enhance student learning, including facilitation of individual reflection [2] and social interaction [3]. Online discussion forums feature heavily in learning management systems (i.e. Blackboard) and online courses as a web application to facilitate computer-mediated communication between students and instructors. However, more recently, there is growing evidence that online discussion forums are also used to build and support online communities in many areas of interest and practice [4]. In the Electrical and Computer Engineering (ECE) domain, online communities have flourished in membership and some of the most popular online communities associated with the ECE domain feature thousands of learners and millions of learning contributions. They include Arduino.cc (>120,000 members), AllAboutCircuits.com (>190,000 members) and Electro-tech-Online.com (>180,000 members). The large numbers of learning activities that take place in these forums indicate that online communities are learning spaces with significant reach and alert us to the growing importance of assessing online educational data. These numbers also suggest that ECE online communities have flourished in membership and have become a powerful complement to informal learning opportunities available to engineering learners. As such, it has never been more important to understand technologies that assist engineering students with their learning beyond the classroom.

II. Assessment Challenges

There are two major challenges in the assessment of learning and participation on of online discussion forums, and they are posed by the inherent structure of online forums and the nature of online educational data. The first challenge is concerned with the hierarchical structure of online discussion forums. Discussion threads (which consist of messages arranged by order of posting) are contained in distinct sub-forums and result in the formation of a hierarchical structure [5]. Assessment approaches have to account for contextual differences between distinct sub-forums. Secondly, there are methodological challenges in assessing massive archives of educational data originating from learners' participation in online activities and interactions with each other. Participation and interaction data are not explicitly represented on discussion threads, and will require further data processing before educational measurement and analysis can be performed. With these challenges in mind, our research goal is to propose an assessment approach that takes into account: 1) the hierarchical structure of discussion forums in which discussion are carried out in distinct sub-forums each catered for a specific ECE area or purpose; and 2) the interactions among participating learners which are indicative of collaboration and social interaction.

III. Theoretical Framework

Within the broader context of education, there is growing realization that the situativity (contextual and social aspects) of learning are as important as cognitive considerations [6]. For instance, situated cognition theories suggest that learning is conceived as a social process of enculturation and participation in a community of practice [7]. In addition, social constructivist views of learning suggest that knowledge is socially constructed rather than transmitted from one to another. With this heightened emphasis on the social aspects of learning, social capital has emerged as a concept that relates to the assessment of learning and participation [8]. According to this view, the accumulation of social capital can be viewed as the outcome of the process of learning interactions between members of a community and exist as knowledge or identity resources [8].

The concept of social capital affords insights into the strength of ties between individuals in a social network and the extent of individual access to the social connections that give access to information or resources [9]. Particularly, social capital can be understood through Burt's theory of structural holes [10]. According to this theoretical perspective, social capital is defined as the ability to broker information and resources over structural holes. In particular, an individual develops social capital when positioned in a gap within a social network (called a structural hole) to broker the flow of information or resources between unconnected parts of the network. Researchers studying online communities have suggested that internet use supplement an individual's social capital and that the amount of social capital available to an individual directly influences the quality of information received [8, 11]. These notions suggest that social capital is an appropriate construct for examining the quality of participation in online discussion forums.

In order to derive quantitative measures of learners' social capital, we first construction the social network of the online discussion community using parsed data of web pages (see section VI) before applying network measures across the individual and group levels. At the individual level, we turn to three measures that are indicative of an individual's social capital: betweenness, closeness and degree centrality. Betweenness and closeness allows us to measure the extent to which individuals occupy advantageous positions within the social network [12]. On the other hand, degree centrality refers to the measure of the number of direct ties an individual has with others [12]. At the group level, social capital can be characterized by 1) network density which reflects the overall intensity of connected units in the social network; and 2) group size which refers to the number of learners who have contributed to the discussion group [13].

IV. Research Site

The education setting for this research is an informal online discussion forum for electrical engineering titled "All About Circuits". Asides from being a prominent online community with close to 200,000 members, its explicit emphasis on electronics and electrical circuits makes it an appropriate site to assess engineering learning and participation. The forums comprise of numerous discussion sub-forums which serve as open spaces for discussion on a variety of topics associated with electrical and electronics engineering. The discussion forums are hierarchically structured. Take, for instance, the site of study for this research AllAboutCircuits.com. There are five main discussion sections comprising of 1-4 sub-forums: "Electronics", "Software, Microcomputing, and Communications", "Circuits and Projects", "Abstract" and "Community" (see Table 1). As shown, the hierarchical structure of the forums requires an assessment approach that is capable of analyzing nested data – and we highlight why and how HLM is used in this proposed study.

TABLE 1 Hierachical Structure of AllAboutCircuits Forums

Discussion Section	# of Sub-Forums	Titles of Sub-Forums
Electronics	4	General Electronics Chat, The Project Forums, Homework Help, Electronics Resources
Software, Micro-computing, and Communications	4	Programmer's Corner, Embedded Systems and Microcontrollers, Computing and Networks, Radio and Communications
Circuits and Projects	1	The Completed Projects Collection
Abstract	3	Maths, Physics, General Science
Community	3	Off-Topic, The Flea Market, Feedback and Suggestions

V. Proposed Methodology

HLM is a regression approach that readily accounts for the nested nature of data and the estimation of the impacts of factors at different levels of analysis [14]. HLM offers advantages over OLS as it allows for the estimation of a separate set of regression coefficients for each organizational unit and does not assume independence between cases, which can result in more accurate calculations of Type I error rates [14]. These considerations are of importance as online discussion forums are often hierarchically structured into smaller sections and learner collaboration violates the assumption that observations are independent of each other. Furthermore, HLM also allows the researcher to better address the issue of aggregation biases and the heterogeneity of regression [15].

In this research, we propose to use HLM, a multilevel modeling approach, to assess the quality of online participation through examining the association between learners' participation frequencies and social capital measures at both individual (Level 1) and group (Level 2) levels. Individual level measures include betweenness centrality (X_{1j}), closeness centrality (X_{2j}) and degree centrality (X_{3j}). Group level measures include network density (W_{1j}) and group size (W_{2j}). Our proposed models are as follows (the variables can be consulted in Tables II and III):

Level 1 Model: $$Y_{ij} = \beta_{0j} + \beta_{1j}X_{1j} + \beta_{2j}X_{2j} + \beta_{3j}X_{3j} + r_{ij}$$

Level 2 Model:
$$\begin{aligned} \beta_{0j} &= \gamma_{00} + \gamma_{01}W_{1j} + \gamma_{02}W_{2j} + u_{0j} \\ \beta_{1j} &= \gamma_{10} + \gamma_{11}W_{1j} + \gamma_{12}W_{2j} + u_{1j} \\ \beta_{2j} &= \gamma_{20} + \gamma_{21}W_{1j} + \gamma_{22}W_{2j} + u_{2j} \\ \beta_{3j} &= \gamma_{30} + \gamma_{31}W_{1j} + \gamma_{32}W_{2j} + u_{3j} \end{aligned}$$

TABLE II. Level 1 Variables

Variable	Description
Y_{ij}	Participation frequency of learner *i* in discussion section *j*
β_{qj}	Level 1 coefficient associated with discussion section *j* where q = (0, 1, 2, 3)
X_{qij}	Level 1 predictor for learner i in discussion section *j*
r_{ij}	Level 1 random error

TABLE III. LEVEL 2 VARIABLES

Variable	Description
β_{qj}	Level 1 coefficient associated with j where q = (0, 1, 2, 3)
γ_{qs}	Level 2 coefficient associated with predictor s where s = (0, 1, 2)
W_{sj}	Level 2 predictor for discussion section j
u_{qj}	Level 2 random error

VI. DATA COLLECTION

The data was collected from the online discussion forum "All about Circuits" using an automated web crawler. In total, a total of 87,264 HTML web page files spanning eight years across 16 discussion sections were collected. A Python scraping program was written to extract participant information and textual contribution from the web pages into a MySQL database (See Table IV). Then, learners' longitudinal contribution data was compiled from extracted information through a MySQL script and includes several variables such as post count, thread count and learners' tenure in the forums. The social network was then developed from this database.

TABLE IV. PARTICIPATION DATA SUMMARY

Variables	Total Count
Membership	192,643
Discussion Topics	87,592
Messages	504,040
Word Count	4,313,551

VII. SUMMARY

In this paper, we propose an HLM approach towards the assessment of participation in online discussion forums which can be further extended to engineering coursework or Massive Open Online Courses (MOOCs). This is especially so considering that many engineering classes use learning management systems such as Blackboard and Moodle where online discussion forums are widely used. Similarly, MOOCs instructors rely heavily on discussion forums to interact with students and to foster collaboration between learners [16]. The immediate next step is to evaluate our statistical model with the collected dataset.

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Instructional Strategies for Teaching Science Online

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***Abstract*—This work in progress reports the design and initial implementation of a complete online statistics course. It focuses on applications and adaptations of effective instructional strategies based on current research and best practice of teaching quantitative oriented courses (math, statistics, and engineering) online. The online statistics course was an introductory course and covered common statistical concepts and their applications in educational research for graduate students in educational technology. The course was equivalent to an undergraduate level statistics class for students majoring in science, technology, math, and engineering (STEM). Thus the implications of this project in terms of effective instructional strategies and online course design are relevant to a board audience including course designers, instructors, and students in science and engineering.**

Keywords--teaching online; statistics; instructional strategies

I. INTRODUCTION

Online courses continue to grow unprecedentedly in higher education. According to the tenth annual survey released by the Sloan Consortium, more than 6.7 million students took at least one online course during the fall of 2011 [1]. In addition, thirty-two percent of postsecondary students took at least one course online in 2011. In practice, more instructors are teaching or will teach online courses. However, teaching online is fundamentally different from teaching in a face-to-face setting [2], [3]. Instructors teaching online find it more difficult and time-consuming to teach. It is even more difficult to teach science and other quantitative orientated courses completely online because these courses usually require more hands-on activities and live demonstrations [4]. Meanwhile more educators agree that quantitative orientated courses such as math and statistics can be effectively taught online despite of their application-based nature [4], [5]. However, little has been done in developing effective instructional strategies for teaching such courses online [4]. The research aspect of this project in addition to the design and implementation of an online course was to investigate student's feedback and perspectives on the effectiveness of the instructional strategies and activities adopted in a complete online statistics course.

This work in progress reports the design and initial implementation of a full online statistics course, focusing on applications and adaptations of effective instructional strategies based on current research and best practice of teaching quantitative oriented courses online. The statistics course was intended for graduate students who were pursuing their masters' degrees in the field of educational technology. The course covered common statistical concepts and their applications in educational research. It was equivalent to an undergraduate level statistics course for students majoring in STEM fields.

II. INSTRUCTIONAL STRATEGIES ADOPTED

There were not many studies on effective instructional strategies for teaching science online. Thus the author extended the literature review on effective instructional strategies and best practice for teaching science online to quantitative oriented courses which include math, statistics and engineering. Four main strategies are most frequently adopted and implemented: (1) promoting interactivity through asynchronous and synchronous communications or delivery [7] - [8], [2], (2) facilitating the applications of concepts using strategies such as problem-based learning [10], [12] ; (3) using video demonstrations (such as screencasts for demonstrating tools and programs) [13], [14], and (4) conveying a strong social presence or a sense of belonging to a learning community [17] - [18].

Main instructional strategies adopted in this online statistics course included: online discussion forum, video demonstrations of statistical tests and procedures in SPSS, case studies of published research articles, mini projects, learning module reflections. The course used Moodle (a learning management system) to host all the course content. Table 1 briefly summarizes the literature review and instructional strategies adopted in the course

Interaction can be promoted through either synchronous or asynchronous communication modes. Synchronous communication involves real-time interaction such as instant messaging, chat rooms, and online office hours. They address concerns immediately [8] and are believed to be more effective than asynchronous delivery mode [9]. However, they are often not practical for students that have difficulty meeting at fixed times. Asynchronous communication allows students to have more flexibility and work at their own pace [8], [11]. A drawback to this approach is a delayed time response and difficulty in collaboration. Regardless of delivery modes, conveying a strong social presence is essential to connecting with students in online

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courses [17], [18]. This improves perceived instructor support [17] and promotes students' participation. Effective teaching strategies also include the use of problem-based learning [11], case studies [3], and video demonstrations [13], [14]. Although time consuming and challenging to implement online, these methods promote engagement, help students construct their own knowledge [5], [3], and enhance teaching statistical software packages [15].

III. PRELIMINARY RESULTS

The preliminary analysis of all students' reflections submitted for six modules of the course indicated that all instructional strategies adopted were effective. Due to the page limit, we will not discuss details of the results. This online course will be redesigned based on the student's feedback (reflections) on the initial implementation and will also be incorporated with some mobile learning components during the summer of 2013. The mobile learning components include but are not limited to the following: allowing course website accessible via smart phones and iPads; incorporating some components for motivating and alleviating students' fear and anxiety toward learning statistics; incorporating some content-based Apps. for students to manipulate some difficult concepts, such as types of errors. The redesigned course will be offered again in Fall 2013.

TABLE 1. EFFECTIVE INSTRUCTIONAL STRATEGIES REVIEWED AND ADOPTED

Strategies/ activities	How to achieve?	Pros & Cons
Interactivity, [6], [7], [2]	Synchronous communication/delivery mode [8], [9] •*Instant message through course website* •*Chat rooms* •*Office hours provided*	• Pros: More effective than text-based asynchronous delivery mode [9]; Enables students to be active & collaborative learners [7]; Promote higher level cognitive skills [7], [2]; Address concerns immediately, and immerse in problem-solving and decision-making processes [8]; • Cons: Cost more for equipment; Not practical –meet in fixed time/travel [11]
	Asynchronous communication/delivery mode [8], [12] •*Online discussion forum* •*emails*	• Pros: Enables students to be active & collaborative learners [6] -[7], [2]; Work at their own pace, offers greater flexibility and have more time to reflect on their learning [8], [11]; • Cons: Unsatisfied with instructors' responses at a delayed time [5]; Unease of collaborating [5]
Applications of concepts [10], [12]	•Problem-based learning (PBL) [11] •Case studies [3] •*Case studies* •*Mini projects*	• Pros: Increase engagement [5], [3]; Help students construct their own statistical knowledge [5], [3]; Allows students to play a more proactive role in their learning [3]; • Cons: Time consuming to prepare; Not easily implemented in online
Video demonstrations [13], [14]	•Different tools/programs •Existing videos from Internet •*Screencasts* •*Introduction videos*	• Pros: Enhance teaching statistical software packages online [15]; Cons: Length limit and should only contain the right amount of information [11], [16]
Social presence [17], [18]	•Video introduction & instructor profile [16], [19] •Discussion forum •Different communication channels [20] •*Video introduction & instructor profile* •*Discussion forum* •*Different communication channels*	Pros: Improve perceived instructor support [17]; Promote students' participation in learning activities;

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The Lord of PhD: Fellowship of the Dissertation - A guide to surviving the pursuit of a PhD

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***Abstract*—Allegories have been used to represent ideas, concepts, and processes, primarily in classical literature. In engineering education, allegories have been used to describe the different roles within academia [1]. Here, we focus specifically on the path of a doctoral student in engineering working towards earning their degree and completing a dissertation. The path will be discussed as an allegory to "The Lord of the Rings" by J.R.R. Tolkien [2]. This allegory explores the milestones, characters, barriers, and support doctoral students will meet along their journey. The session will utilize identity-trajectory to guide discussion and encourage attendees to explore and share their experiences. The session is aimed at providing guidelines to students progressing through a doctoral degree and to assist graduate advisors in supporting their students on this journey.**

Keywords—Graduate Education, Identity-Trajectory

I. Goals of the Session

The goal of this session is to help graduate students reflect on the journey toward graduation as they begin to navigate their way through a doctoral degree; highlighting the different people and events they will meet along the way. The broader purpose of the session is to inform graduate students of the challenges and difficulties that will arise on the journey and the friendship, guidance, courage, and risk and that will be required to succeed.

II. Description of Session Content

When pursuing a PhD, many students struggle with the process and expectations of the degree. This can discourage degree completion and cause frustration for students, advisors, and all involved. This special session aims to describe the PhD process in a way that many students and faculty may be able to relate to.

This session will use an allegorical approach to highlight the similarities between obtaining a PhD and the fantasy series "The Lord of the Rings" by J.R.R. Tolkien [2]. Frodo (the graduate student) is given the one ring (dissertation funding) by Gandalf (his PhD advisor) and asked to shepherd the ring to its end (a PhD dissertation). Throughout the story, Frodo encounters a variety of individuals and faces a number of challenges that can be compared to the process that a graduate student follows in order to achieve their degree.

The use of identity-trajectory will guide the discussion and the key points that are discussed throughout the special session. Identity-trajectory has been used to theorize the development of graduate students and early career academics through three primary strands: *intellectual*, *institutional*, and *network*. These strands will be tied into the allegory as it is discussed. The *intellectual* strand deals with the contributions a person makes to their field through coursework, research, and publications. This will be discussed through the lens of the outcomes of various events within the story. The *institutional* strand deals with the resources, department structure, rules, and organization that contribute to the identity of a professional. This will be discussed in the context of the path taken and the various tools and resources utilized in shepherding the ring. Finally, *network* addresses the professional relationships, relationships, collaborations, and affiliations that contribute to the professional identity of an individual [3]. The different relationships between the characters in the story will be compared to the relationships a PhD student establishes during their graduate career.

III. Session Agenda

The session is planned to run on the following timeline:

(00 - 05 min) Introduce the beginning of the story to the Lord of the Rings

(05 - 15 min) Have participants in groups explore who each character is within the story, and what aspects of a PhD the story represents following the key components of identity-trajectory. Each group reports their perspective

(15 - 20 min) Have participants identify who they are in the story, where they are in the process, and who are the people they have met along their journey

(20 - 80 min: in 15 minute increments) Dividing the story into four arcs, facilitators will present a summary of the key story elements and characters. Participants will then work in their small groups to discuss and identify who/what those key elements are within the context of the discussion and

how they fit within the story of obtaining a PhD. After each small group discussion, facilitators will present their interpretation of the work and who/what each of the characters/events represents.

- Arc 1 (Access to intellectual development experiences, institution)
  - Hobbiton - BS, MS work
  - The Prancing Pony - Graduate course work
  - Weathertop – Qualifier

- Arc 2 (Institution, Network)
  - Rivendell - Committee Formation

- Arc 3 (Institution)
  - Moria - Advisor leaving/a change in advisor/advisee relationship
  - Orc battle at the end of Fellowship – Prelim
  - Meeting Gollum - Proposal (setting a path to the end)

- Arc 4 (Intellectual/ Network)
  - Shelob - Unexpected challenge collecting data
  - Climbing Mount Doom - When you need Sam to carry you to the end
  - Inside Mount Doom - Defense

(80-90 min) Wrap up

IV. Description of Anticipated Audience

The anticipated audience for this special session primarily includes students interested or currently pursuing a PhD and those involved in guiding graduate students through the PhD process (graduate advisors & committee members). Graduate coordinators and heads of graduate committees may also benefit from the content and discussion being raised. While the presenters are all current or former PhD students from engineering education programs, the ideas and issues presented should apply to all PhD programs and the discussion will not be engineering education-centric beyond recognizing engineering education as the lens through which the presenters have the greatest experience.

V. Outcomes and Future Work

Participants will reflect on their experiences, share their perceptions of the path to a dissertation, thus providing participants working towards a PhD with the knowledge of what to expect on their journey beyond the logistical milestones. The workshop also intends to provide faculty and academic administrators a constructive avenue to "re"-understand the graduate education experience to ensure success of their graduate students.

The research team will continue to investigate the barriers and constructive experiences of life in academia in order to highlight resources and tools that help participants with their career routes in engineering education.

VI. Author Information

James Pembridge graduated from Virginia Tech with a PhD in Engineering Education. His recent work has explored the formation of doctoral committees within the field of Engineering Education. The work specifically identifies the technical, professional, and personal characteristics of both the committee chair and the committee members [4].

Stephanie Cutler is a PhD candidate in Engineering Education at Virginia Tech. She was an NSF IGERT Fellow and assisted with the assessment of the VT IGERT program focusing on the impact of an interdisciplinary curriculum the on graduate student experience [5, 6]. She also assisted with the development and implementation of an orientation program for the VT Engineering Education PhD program [7].

Matthew Verleger graduated from Purdue University with a PhD in Engineering Education. As a graduate student, he helped launch the ASEE Student Division [8] in an effort to help provide a voice to student members within the larger national organization. He was also extensively involved with university-level training of graduate teaching assistants [9].

Lauren D. Thomas is a PhD candidate in Engineering Education at Virginia Tech. Her dissertation explored the identity-trajectory of graduate students in optics and photonics doctoral programs. She has chaired the Graduate Engineering Education Consortium for Students, GEECS, an organization focused on the development graduate students invested in engineering education research [10].

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Integration by Design: Bringing Science, Math, and Technology Together Through the Engineering Design Process

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Abstract – **The primary goal of this mini-workshop is to assist participants in developing engineering- and art-based design projects that reinforce concepts in mathematics and science, thus providing an integrative environment for learning. The emerging STEAM (STEM + art, which is also a design discipline) approach emphasizes a hands-on, project-based, interdisciplinary approach to the study of science, technology, engineering, and math (STEM). To emphasize the importance of using engineering design principles to integrate learning in science and math and gain technological literacy, we refer to this approach as STEAMd. This mini-workshop will be of interest to those involved in P-16 engineering education and in developing a philosophy of engineering education that stresses an integrative approach to instruction and practice grounded in design, the fundamental process of engineering.**

Index Terms – Engineering design process, Engineering Teaching Kits, integrative STEAMd, P-16 engineering education.

INTRODUCTION

Engineering is a design-based profession. We develop artifacts, be they objects or processes, as solutions to an identified and investigated problem. The artifacts are referred to as "technology," and their design is grounded in principles of the natural world as expressed by mathematics and science even though the principles may not be well-understood or even articulated. As pointed out by Henry Petroski [1], engineering can occur and has occurred ahead of scientific knowledge. The act of engineering may also further our knowledge of mathematics and science, providing a synergistic, integrative environment for learning.

The primary goal of this mini-workshop is to assist participants in developing engineering- and art-based design projects that reinforce concepts in mathematics and science. Art joins its fellow design profession, engineering, in developing artifacts that are both aesthetically appealing as well as functional. The emerging STEAM (STEM + art) approach emphasizes a hands-on, project-based, interdisciplinary approach to the study of science, technology, engineering, and math (STEM). To emphasize the importance of using engineering design principles to integrate learning in science and math and gain technological literacy, we refer to this approach as STEAMd.

Engineering Teaching Kits (ETKs) serve as guides for developing the design projects. ETKs are self-contained STEAMd education standards-based units grounded in the constructivist philosophy of education [2], [3] and the principles of guided inquiry and active learning [4] which engage students in a series of age-appropriate engineering design challenges to reinforce selected concepts in math, science, and technological literacy. They were initially developed in conjunction with the Virginia Middle School Engineering Education Initiative (VMSEEI) for students in grades 6 – 8 [e.g., 5 and 6], but have been proven scalable for use by students throughout P – 16.

By the end of the workshop, participants will be introduced to key concepts in the engineering design process and to the STEAMd movement, and be able to identify methods for using engineering design to integrate STEAM studies seamlessly and transparently as well as strategies for strengthening students' key "21st century skills" such as systems thinking, critical thinking, and problem-solving.

STEM TO STEAMD

While the intersection of engineering and humanities has long enhanced and reinforced learning in the disciplines, the active integration of art, music, and composition activities in STEM studies has been gaining prominence during the past few years; see, for example, [7] and [8]. The Claremont Graduate College has started publishing *The STEAM Journal* [9], and papers on STEAM initiatives are increasingly being presented at conferences [e.g., 10 and 11]. The addition of "d"esign to the STEAM acronym recognizes that art and engineering are design-based disciplines, design is an integrative process, and that creativity is a necessary skill for engineers to master [12].

ENGINEERING DESIGN PROCESS

The engineering design process is at the heart of the discipline. ABET Student Outcome 3(c) directly addresses the need to know and apply the process. The cornerstone and capstone model, providing design education at the beginning and completion of the undergraduate engineering program, is widely used.

There are many process models in use, but for the most part they have several features in common: engineering

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design is problem-based and starts with the identification of a problem and research on an issue; a design space is defined; solutions are developed and evaluated; the best solution is selected for prototyping; an internally iterative cycle of build-test-evaluate occurs; and, when a stopping rule is encountered, the artifact is reviewed to determine if it meets expectations (within tolerances) or whether the design team needs to re-enter the process at a phase appropriate to the amount of redesign needed. Throughout, there is communication among team members and with client(s).

ETK BACKGROUND

Since 2002, teams of students and faculty at the University of Virginia (UVa) have developed, tested, and distributed ETKs for use in middle school science and math classes [5], [6]. An ETK is a set of five 50 minute standards-based lesson plans designed to teach targeted math and science concepts in the context of the engineering design process. Lessons are structured to develop understanding of key concepts at both abstract and concrete levels.

The primary goal of ETKs is to promote awareness of and excitement about the nature of engineering. Each ETK emphasizes the engineering design approach to problem solving through a series of design challenges, and includes real-world constraints such as budget, cost, time, risk, reliability, safety, and customer needs and demands. Students develop an appreciation for the tradeoffs involved in the practice of engineering, and how engineering decisions have an impact on society and the environment.

ETKs are also designed to integrate other subjects in the curriculum with the exploration of math, science, and engineering concepts. For example, an interdisciplinary team of eighth-grade teachers at a Central Virginia middle school uses the *Catapults in Action* ETK as the basis for a week-long series of integrated classes on medieval history, folding history, art, and language arts activities into the study of catapults and projectile motion. The potential for similar multidisciplinary activities can be found in all ETKs and thus make them appropriate for use in STEAM activities.

A recent addition to our ETKs is a set of activities and instruments to assess and remediate misconceptions in mathematics and science. A concept is a mental construct or model that helps a person organize knowledge. It is inductively built from interactions and experiences. [3] Misconceptions, also known as an alternative framework or theory develop from an incomplete or flawed development process and can be resistant to change [3, 13, 14]. We are using adapted/authored concept inventories to assess misconceptions, and discrepant events to provide an opportunity for reformulating misconceptions; see, for example, [15]. Another addition is a detailed guide for parents and teachers, in part to promote the family engineering movement [16] and in part to provide additional support to activity leaders.

Over 50 ETKs are in various stages of development; a dozen are in frequent use in schools in the United States and several other countries in both classroom and professional development workshop settings. The most popular ETKs are *RaPower* (solar cars), *Save the Penguins* (heat transfer), *HoverHoos* (hovercrafts), *Under Pressure* (submersible vehicles), *Brainiacs* (brain surgery/biomedical engineering), *Catapults in Action* (projectile motion), *Bridges to Engineering* (bridge design and construction), *Electricity Rocks* (electromagnetism and sound), *Filtering Ideas* (water filtration), and *Aerospace Vehicles* (planes and rockets).

WORKSHOP AGENDA

The workshop is structured as follows:

- **Welcome and Introductions** (10 minutes)
- **Initial Exercises** (20 minutes)
  Participants will work through a set of multimedia STEAMd activities designed to pique interest in the practice of the engineering design process. ETKs used include *Art in Motion* (robotics). See Figures 1 (a) and (b).
- **Overview of Important Concepts** (15 minutes)
  We will review research on the STEAMd movement and its demonstrated abilities to engage students in integrated learning, on best STEAMd practices, and on the engineering design process. A group discussion of experiences and concerns will follow.
- **Follow-on Activities** (30 minutes)
  Participants will work in groups with the facilitators to continue working through the design activities. We will also discuss scaling the activities to various grade levels. This discussion will include a review of expectations as to cognitive development and skill levels for students in those grades.
- **Concluding Activities and Discussions** (15 minutes)

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FIGURE 1A
CREATING AN ART IN MOTION ROBOT
FIE 2012 [12]

FIGURE 1B
ART IN MOTION ROBOT IN ACTION
FIE 2012 [12]

Management of Distributed Collaborative Learning Environments based on a Concept Map Paradigm and Natural Interfaces

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***Abstract*— Collaborative learning is an effective educational method that plays an essential role in theories such as Constructivism and Knowledge Building. Studies have shown that collaborative work in small groups significantly improves learning when supported by concept maps. Although useful in collaborative environments, most applications available for the development of concept maps are designed for personal or small tablet computers, which can limit student communication in a team. In addition, the use of these applications usually requires learning or training periods, which can also interfere with the learning process. In this paper, we present a software tool for generating concept maps and constructing learning spaces under both local and distributed collaboration scenarios. Our system uses a natural interface with multi-touch and multi-user capabilities. It was specifically designed for tabletop systems, which provide a large horizontal interactive surface suitable for collaboration and face-to-face communication. The tool is also available in other platforms, which makes it useful in a variety of classroom orchestration settings. Finally we present the results of a preliminary usability study of our tool in a real educational environment.**

Keywords— collaborative learning; natural interfaces; tabletops; concept maps

I. Introduction

Several educational theories, such as constructivism and knowledge building, support teaching techniques based on collaborative learning. According to these approaches, learning is a gradual process where each member of the group feels committed to the learning of the others, generating positive interdependence. This is a type of active learning that happens in a non-competitive community, in which all group members, the students, play an active role in the process, collaborating in the construction of knowledge, and contributing to the learning of their teammates. In a collaborative environment, knowledge resides in the group instead of the individual, and it is the student himself who draws his own knowledge.

Different tools can be used to support collaborative learning. Concept maps, for example, are one of the most popular. Concept maps are tools for organizing and representing knowledge in a graphical form. Several studies have shown that when collaborative work is supported by the use of concept maps, the overall learning experience improves significantly.

In general, technology can be a valuable tool in the development of new techniques for collaborative learning, particularly in the construction of concept maps. There exists a vast collection of software available that facilitates the creation of concept maps. Most applications, however, are designed for personal or small tablet computers, which can limit face-to-face communication in a team. Additionally, the learning curve for many of these tools is steep, which can interfere with the teaching/learning process, especially with young students.

Collaborative learning experiences can be greatly enriched when teams from different schools, or even different nationalities, are included in the learning group. This feature, however, is not fully covered by existing tools, at least in a simple and non-invasive way.

In this paper, we present and evaluate our own computer system (hardware and software), designed to create concept maps using graphical information and combining real and virtual elements. Our system provides a natural interface, with multi-touch and multi-user capabilities, that is intuitive (so no training is required) and intended for devices with large interactive surfaces, like tabletops, where communication between students in a team can still be face-to-face.

Our system promotes collaborative work in an intuitive way and is suitable for different classroom orchestration scenarios. In the most general case, users can define a collaborative group comprised of multiple teams, which may be geographically dispersed, and create a common virtual workspace where students can interact with their teams or with remote teams, sharing experiences and information in real time.

II. Related Work

Many studies have demonstrated that teamwork is beneficial for learning. When working in small groups, communication between students promotes positive cognitive and affective outcomes [1, 2, 3, 4, 5].

Concept maps are graphical tools for organizing and representing knowledge that can enhance the learning experience when used in collaborative learning scenarios. In a study by [6], the authors reported that when students work cooperatively and construct concept maps to guide their learning, significantly greater learning outcomes occur.

In general, technology is useful in a team environment because it facilitates the exchange, retrieval, organization and presentation of information and results. On the other hand, technology can become a barrier in the learning process if it interferes with student communication within a group. When students work in teams, but in front of a computer, their focus is on the screen space [7], which significantly reduces communication between team members. A solution to this problem was suggested by [8]. In this work, the authors concluded that the use of interactive tabletop systems as teaching tools can favor a true collaborative environment and face-to-face communication between students. Tabletop systems provide a large multi-touch surface suitable for gathering around, so multiple users can interact with the information collaboratively. Recent work in collaborative development of concept maps using tabletop interfaces is described by [9].

In terms of classroom orchestration in collaborative learning scenarios with tabletops, students are placed in small groups working as teams in "local mode". In these cases, instructors must remain attentive to the evolution of each group. A classroom orchestration of similar kind was analyzed by [10]. In this case, the authors proposed the automatic generation of team participation indicators, which may be useful to the instructor in terms of evaluating the students.

III. Description of the System

In this paper, we present a tool to manage and organize graphical information in a structured way using diagrams with hierarchical relationships, and suitable for the creation of concept maps. Our tool was designed as a multiplatform application and compatible with the TUIO protocol [11], which guarantees compatibility with the majority of the Human Centered Interface (HCI) devices based on large tangible multi-touch and multi-user surfaces, like Tabletops. In a classroom environment, the tool offers the best functionality when used with devices with large horizontal interaction surfaces, which facilitates face-to-face communication between students. Additionally, tabletops provide natural interfaces, so users can use their hands and fingers to interact with the system and break the barrier that may be present with other type of technology.

A. *Interface*

As one of the goals of this work, we decided to simplify the interface of the tool as much as possible to guarantee minimum interference with the teaching/learning process.

Initially, an empty board is presented to the users. Concept maps can be defined by adding available information items to the board. Information items are simple images in JPG or PNG format located in a specific folder. Our software continuously checks the contents of this folder and automatically updates the information on the board when changes are detected. When a new image is added to the folder, it automatically appears on the board. To protect the internal integrity of the application, the folder with the content files must only have permissions to add files. The delete operation can only be performed from the tool itself.

The content folder can also be synchronized with a file hosting service that offers cloud storage (like Dropbox). This way, the information items can be shared by multiple computers on the Internet and new items can be added to the board remotely.

Every image available on the board behaves like a real card or "token" which can be moved by dragging it with one finger. Tokens can be rotated and scaled by using two fingers (via gestures on a multi-touch interface). Additionally, since it is a multi-user system, many students can interact with the tokens simultaneously. We can also zoom and pan the board using gestures by tapping on any available space on the board.

To establish a hierarchical relationship between two tokens, the child token should be moved until it interferes with the parent token, resulting in a hierarchical tree. A tree can be linked to another tree in a similar manner, by simply dragging their root node until it interferes with the token to which it must be linked. When a tree is moved by dragging its root node, all its children move with it.

To break a hierarchical relationship between two tokens, users can drag the tokens apart (with one finger on each token). If the application is used on a computer without tactile capabilities, the right mouse button can be used to click on the link between the two nodes.

When tapping and holding the finger on an item, a contextual menu appears beside it, offering the following options: copy item, copy sub-tree, delete item and delete sub-tree. To paste an object, we must tap and hold on an available area of the board, and the object will appear on it. If all instances of an object on the board are deleted, the information file associated with it inside the folder will also be deleted. Again, the right mouse button can be used to simulate this behavior if using a computer with no tactile capabilities.

Creating a Concept Map with our tool required adding "concepts" in the form of images (as described previously) and establishing relationships between them using connections to create propositions (see Fig. 1).

In order to make the digital information items as natural as possible, we propose the use of handwritten text. Since the tool uses only graphical information, text is also represented as images. To add concepts or transitions in textual form, users can write the text on a piece of paper and a take a picture with a digital camera or smart phone. Software tools for digital image processing or any other system which allows representing text graphically may also be used.

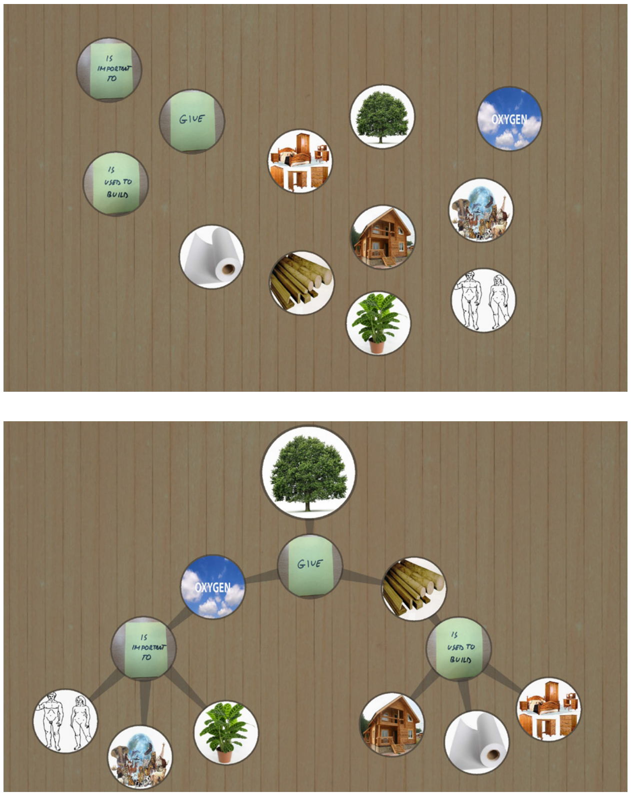

Fig. 1. Concepts and labels added to the work space of the system (top) and with relations (bottom).

B. *Tabletop System*

We developed our own tabletop system (see Fig. 2), which turns any physical flat surface into an interactive surface with multi-user and multi-touch capabilities. The system is comprised of a stereo video projector and two cameras that provide a stereoscopic view of the interaction surface. The cameras take images (stereo-pairs) of the user's hands and the objects placed on the surface and the software recognizes the position of each finger, including the distance to the table.

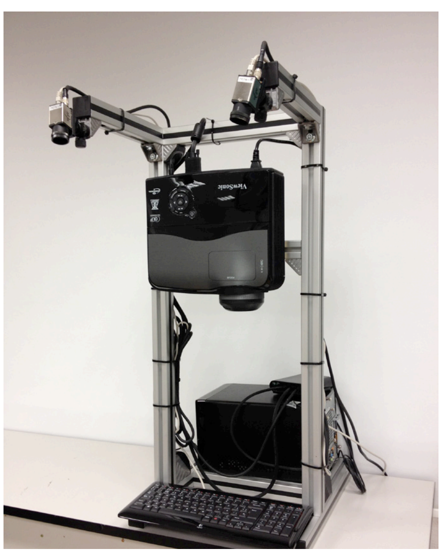

Fig. 2. Tabletop system designed by our research group.

Using our tabletop system, students can convert their own workspace into an interactive surface, i.e. the same surface can be used as a traditional workspace or as a digital space, combining the advantages of both scenarios (see Fig. 3 and Fig. 4).

When used in "digital mode", the software interface integrates virtual content with the real world according to the principles of ubiquitous computing and natural interfaces. An interesting aspect that we observed when our system was tested in an educational environment is that in "digital mode" students maintained the same levels of communication that they did when working in "traditional mode."

Fig. 3. Students working in "traditional mode" before turning the tabletop system on.

Fig. 4. Students working in "digital mode" with the tabletop system.

Our software can also be used in conjunction with Augmented Reality (AR) technology. When an AR marker is detected, its position and orientation in space is calculated and the 3D content is rendered in real time.

C. *Other platforms*

Although tabletop technology is ideal for collaborative learning environments, the use of other devices, such as desktop computers, tablets, and interactive whiteboards (see Fig. 5), offers interesting possibilities for classroom orchestration, particularly in distributed collaborative scenarios.

Fig. 5. Students using our system with a digital whiteboard.

IV. SYSTEM ARCHITECTURE

The two major pieces of our software system include the use of Unity as the 3D engine and the TUIO protocol to ensure compatibility with most multi-touch and multi-user interface devices.

The system architecture is based on classic client-server model, where a server supports the entire application, and multiple clients (different teams) connect to it via TCP/IP, as shown in Fig. 6. The entire workspace is created on the server and each client has a view of it. All clients' interactions are transmitted to the server, which updates the scene and transmits the changes back to the clients.

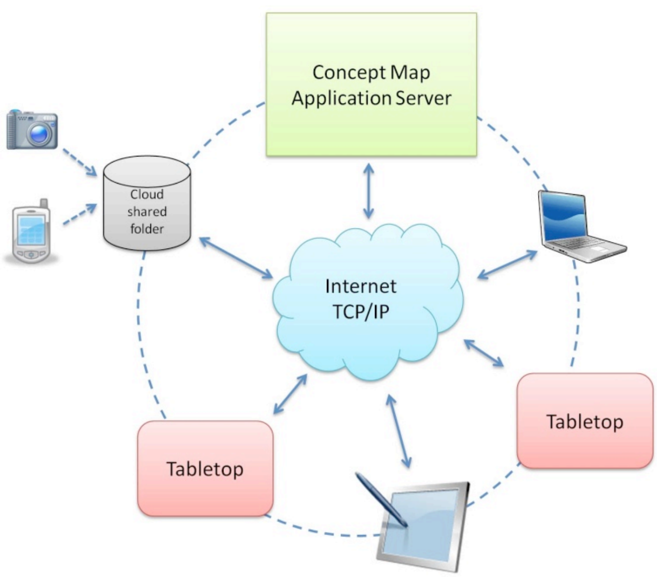

Fig. 6. Representation of the system architecture.

The exchange and sharing of information between teams takes place according to the concept of cloud computing. Basically, the exchange of information is carried out through a folder that is shared by all computers in the workgroup, including the application server, in a file server located in the cloud. The application server continually checks the contents of this folder. When changes are detected, the scene is updated for all clients. For instance, if the server detects the addition of a new image, it will automatically build the object and place it on the board.

Most file servers in the cloud provide applications for smart phones to automatically synchronize the images captured by the device camera with a shared folder on the file server. We take advantage of this feature as a simple alternative to add new information to the concept map. Therefore, users can add information to the board just by taking pictures of images on a book, handwritten notes, etc. Our system automatically synchronizes new images with the shared folder on the server. Few seconds later, captured images will appear on the interactive surface.

V. COLLABORATIVE LEARNING SCENARIOS

We propose three collaborative scenarios for our system: local collaboration, extended local collaboration and distributed collaboration.

A. *Local collaboration*

In this scenario, students gather around a common workspace generated by the tabletop system developed by our research team (any interactive surface that is TUIO compatible can be used). This common workspace is created by converting a traditional working environment (e.g. a table) into an interactive surface with multi-touch and multi-user capabilities. In this setting, students can interact simultaneously with the surface and still maintain face-to-face communication.

B. *Extended local collaboration*

With our system, students can collaborate remotely with team members who may be in different locations. For instance, two geographically dispersed teams can establish a connection to the application server, which will create a common workspace that simulates the same physical space for all users. In this type of collaboration, not all members of the team have a physical face-to-face communication, but this gap can be filled by a video conferencing system running in parallel.

C. *Distributed collaboration*

In a true collaborative learning environment, students' interactions are not limited to the domain of one team. There are also interactions between teams. Students typically walk around the room talking to other teams and looking at the work done by other students.

Our system can simulate this form of collaboration by presenting a large common space around which the respective boards of each team are arranged, as shown in Fig. 7. The common area reinforces the idea of collaborative learning and represents a common working space independent from team locations.

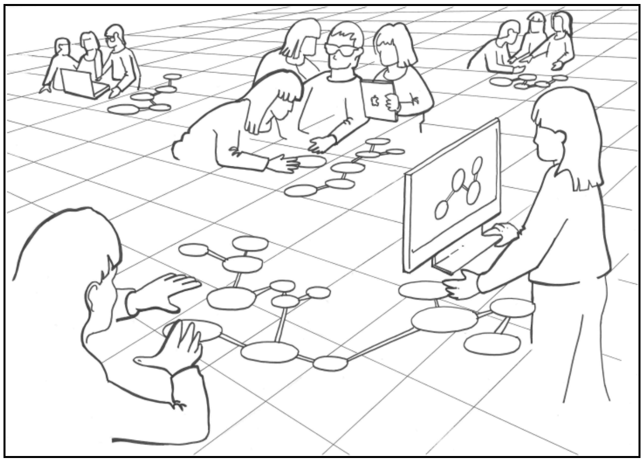

Fig. 7. Representation of the virtual workspace in a distributed collaborative scenario.

To establish a minimum organization, colored zones are used to identify each team, as shown in Fig. 8. With pan and zoom operations, teams can move to the work areas of other teams and look at their work, or collaborate with them. By zooming out far enough, it is possible to see the common area and all team workspaces at the same time. As mentioned above, zoom and pan operations are performed by gestures on the board.

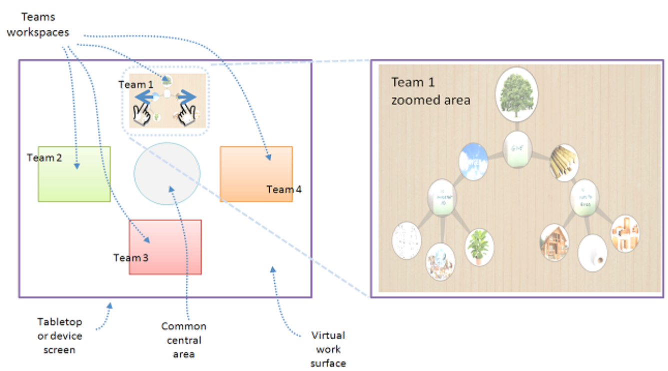

Fig. 8. Schematic representation of the work surface with the areas reserved for teams and common central space (left). Representation of a zoom operation to visualize a team area over tabletop or device screen (right).

If a team needs to use information from other teams, copy and paste tools can bring that information to the team workspace. The common area of the board is used as a shared repository of information, where teams can go and get information items. In a distributed collaborative scenario, when a new image is added to the shared folder of the system, its associated virtual token will appear on the board in this common area.

VI. Pilot Experience and Usability Study

A usability study of our system was conducted with twenty high school students. Participants were divided into four groups of five. The experience was conducted in two rounds, with two teams at a time. No students had prior experience with the system. Basic operating instructions were given by the teacher at the beginning of the session.

For our test, we asked participants to create a concept map about the historical evolution of computing, from its beginnings to present. Both groups of students were equipped with our tabletop system. Initially, participants were asked to collect relevant information from textbooks, the internet, papers, etc, and place the materials on the workspace to start building the concept map. Students worked in a distributed collaborative scenario, sharing group information using copy and paste operations.

To add textual information to the concept map, participants used paper labels, which were then photographed with a smart phone and introduced into the system via the synchronized shared folder on the server in the cloud (see Fig. 9).

Fig. 9. Student using a smart phone to capture a handwritten text note.

Collaboration and teamwork using our tabletop system was successful both at the local level (members of the same team) and between the two teams that participated in the distributed collaborative scenario. In addition, teachers were pleased with the quality of the concept maps submitted by the teams.

Finally, a five-point Likert scale was used to evaluate the usability of the system and the participants' opinions. The questionnaire and the results are summarized Table I.

TABLE I. Usability Questionnaire and Results

Question		Mean	Std. deviation
1	The tool is easy to use	4.60	0.50
2	The tool is easy to understand	4.20	0.70
3	Learning how to operate is easy	4.70	0.47
4	Learning how to operate is fast	4.90	0.31
5	Remembering how to operate is easy	4.65	0.49
6	Teamwork is easy	3.90	0.64
7	Overall, I found the system easy to use	4.60	0.50
8	Overall, I found the system useful	4.35	0.49

Although this is a simple evaluation with a small sample of twenty students, the results obtained provide a positive first impression.

VII. CONCLUSIONS AND FUTURE WORK

Collaborative learning is a teaching methodology well recognized by the educational community. Concept maps are tools that can effectively support this paradigm.

In this paper we have presented a system that facilitates the creation of concept maps based on collaborative learning workspaces. Our tool was specifically designed for tabletop systems, which offer a large multi-user and multi-touch interactive surface and facilitate face-to-face communication between students. These devices can transform traditional workspaces into digital ones, blurring the lines between the two.

Because of its distributed architecture, our system can accommodate multiple student groups in a variety of learning and collaborative work configurations, including teams located in different geographical locations. The flexibility of the system opens many possibilities for classroom orchestration.

A preliminary study was conducted to evaluate our tool. Although a relatively small sample of students was used, positive results in terms of usability and user satisfaction were obtained, confirming the effectiveness of the system as a collaborative learning tool.

Further evaluation with larger samples of students is still pending. A more comprehensive analysis will provide more reliable and statistically significant results. We are also interested in comparing student performance and communication levels in environments where only tabletop systems are used as opposed to more traditional settings.

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Experiencing Disruptive Behavior in a Team Using "Moles"

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***Abstract*— The ability to work on a team is a paramount skill for every engineer. The capability to understand, identify and work through team problems will significantly enhance the engineer's ability to deliver a high quality product on time and within budget. Far too often, however, the experience of working as a team, with its challenges, is overlooked in the student's education. The Department of Software Engineering at Rochester Institute of Technology introduced an activity in their Freshman Seminar course to help students work in a team-based environment. The specific focus was interacting with problematic team members. This team activity involved student "moles" covertly being inserted to act in a disruptive fashion. At the end of the activity, the teams reassembled to discuss the task the team had been assigned to do. The instructor revealed the role of the "moles" at this point, and the teams discussed the effect their behaviors had on team effectiveness and the strategies used to deal with the disruptive behaviors. The students have praised the activity, finding it to be different, exciting and educational. This paper describes the "mole" activity, our observations of the results, and provides suggestions for future use in coursework.**

Keywords—Teamwork, software engineering, group activity, group project, team dynamics

I. INTRODUCTION

Rochester Institute of Technology has offered an undergraduate degree in software engineering for over 15 years. All first year Software Engineering students are required to take a Software Engineering freshman seminar course [1] during their first term. The learning outcomes for the course are to instill in our first year students a sense of engineering practice and professionalism, along with the distinctive perspective of software engineering.

During each session of the course, students are exposed to different software engineering principles. Some of which include requirements gathering, software testing, general problem solving, software development processes and working as a team. The "mole" activity is conducted during this team activity. To achieve its learning outcomes, our course couches all the activities in the context of software engineering, but many of the exercises, and particularly this "moles" activity, have broad applicability for other disciplines.

Today's software applications are often very large and complex, and must be created by teams of software developers [2]. Proper and meaningful collaboration among the team members is of paramount importance for ensuring the success of the project. Even though working as a team is an important skill to have, many engineering students graduate without sufficient preparation to function as part of a team and are unable to cope with many of the inherent challenges of teamwork [3-5].

In order to address these issues, we created the "mole" activity as part of our freshman seminar course. The goal of this exercise is to have students experience many of the challenges of working on a team, and specifically in this case, dealing with problematic team members.

II. ACTIVITY OVERVIEW

The "mole" activity was first introduced in the Fall of 2011 and has seen very positive results and outstanding student feedback. There are exercises in the course where the students experience aspects of teamwork, including team-based coding and presentation activities. The "moles" activity was created to broaden the exposure to team activity, and to have the students directly deal with problems a team may face, such as troublesome team members. These are issues which were reported by many students in subsequent courses and in the workplace during their co-ops.

The purpose of this exercise is to allow students to gain experience identifying several positive and negative team dynamics and to understand how to remain the most productive when encountering these situations. An additional goal is to help students identify when they themselves are unknowingly falling into one of the described detrimental roles.

III. ROLES

There are identified roles each mole may play. These may change over time and instructors are encouraged to modify these roles or add others as they see fit. Many of these roles closely align with problematic areas that have been identified in previous research [6].

The Absentee: The goal of this role is to mimic a team member who is missing or otherwise not in contact with the team for large periods of time. The student is instructed to excuse themselves without providing any reason for leaving, and stay away for a significant portion of the activity. When physically present, the students are asked to contribute to the team and act like they normally would. Students have carried out this role by simply walking out of the meeting location for a few minutes randomly during the activity. In subsequent school related work, students have expressed problems with team members showing up late for team meetings, having to leave early, or just missing a significant number of meetings. This is a common occurrence in a university setting where students have a wide variety of other activities and classes that also demand their attention [7]. Similarly, in the workplace team members may be unwilling or unable to attend many team meetings because they are overcommitted to several projects.

The Disagreer: The purpose of this individual is to actively impede the progress of their team by arbitrarily disagreeing with decisions that their group makes. One option is for this team member to disagree with every third decision that their team makes, no matter what it is. This may be something as minor as the type of font selected for a presentation or disagreeing on a key decision for the assignment. This is a role which students will often encounter, for both productive and detrimental reasons. Many times, teammates will disagree regarding a topic, which may lead to constructive outcomes. The ensuing conversation and subsequent possible evolution is something which is a key advantage to the team environment. However, sometimes these disagreements can sidetrack a team and lead to unnecessary problems [8-10]. A key lesson for students is how to react to these individuals in the future. Will they react to them in a constructive manner or will they respond destructively? Will the team try to work through the disagreements to form a consensus, or merely try to ignore the person?

The Disruptor: The mission of this role is to disrupt or sidetrack their team in any way necessary. This may be done by showing irrelevant YouTube videos to their team, creating side conversations wherever possible, or frankly doing whatever they can in order to get their team off topic. This role mimics a situation that students will inevitably encounter in both the classroom and the workplace [6, 8, 9]. Based on conversations with students, one of the biggest pitfalls that is detrimental to their productivity is being side tracked during team meetings.

The Know-It-All: This role is slightly related to The Disagreer role discussed earlier. The student in this role will purport to being an expert in every aspect of the team's work. The know-it-all's ideas are always better than all the other team members' ideas and should be adopted by the team. This team member often will speak the loudest and shout down others. It is common for the other team members to disconnect from the team work and let the know-it-all do everything, especially if work already completed by others is redone the way that the know-it-all thinks is best. To have productive meetings where each team member has an equal voice, a team needs to find ways to not let the know-it-all dominate all team decisions, such as, voting on a choice when a consensus it not reached, and having all team members agree to abide by the results of the vote.

The Non-Contributor: This role is instructed to not play any part in their team’s activity. This person's main focus is to not directly affect their team’s progress in any way. They should neither assist nor impede their team. If they are explicitly asked by their teammates to contribute in some way, they should shrug off this request. The purpose of this role is to mimic a team member who contributes nothing to their project. Unfortunately, the reality, in both academia and industry, is that some team members do not contribute to projects. This is for a variety of reasons, including “senioritis” or simply a lack of overall motivation to work on the project [11]. In this activity, students have performed this role by merely putting their heads down and sitting quietly for the duration of the team meeting, or to work on homework for another course. Students will often complain about being penalized if there is a non-contributor on the team. On the one hand, it is the instructor's task to identify when this has happened, and make appropriate adjustments to the grading using peer evaluations [12] or another mechanism. This is also an opportunity for students to learn to deal with a non-performing team member, who despite what students believe, are not immediately fired, and often live long lives in the industrial setting being a challenge for each team on which they work.

IV. ACTIVITY DESCRIPTION

The first step in the activity is to break the class into groups of roughly 5 students. This will create teams that are large enough to only be partially affected by the “moles”, but small enough so that they will be adequately felt. Additionally, this is often close to the size of the team that most students will subsequently work on in their future careers in both industry and academia [13, 14]. Once the teams are formed, students are told they will be given approximately 40 minutes to work on a small presentation. The exact activity does not matter, and instructors can select an exercise that links to the goals of the class. The activity should be relatively easy and allow for a high level of interactions amongst the team members. In our case, the stated goal of the exercise was to prepare a presentation on the challenges of communicating with a customer during requirements gathering.

Immediately before the teams are released, one person from each group is asked to speak privately with the instructor for a few moments under the guise that there was some minor problem with a homework submission or another trivial issue. These individuals are to become the “moles”. In the private conversation with the instructor, the true roles for the selected students are revealed to them. Each of these "mole" students is assigned a different role and may even assist in the assignment process. For example, a student with a fancy new smartphone would be a good candidate to be a disruptor because they could lead their team off topic by showing them the features of this new and interesting device. It is important that the students have a reasonable level of input in the assignment of their roles because each student will be more likely to do a good job acting out the role if he or she is more confident and comfortable with the one assigned.

After the roles have been assigned, the students join their teams for the activity in the most discreet way possible. It is important that each team have their own, relatively secluded area to work on the faux activity. This is so they will not be disturbed by any other groups. In the past, teams have been alerted that something was awry when they not only witnessed their own teammates acting abnormally, but when other groups had team members also acting in an atypical fashion. For the purposes of the post-activity discussion, the instructor needs to observe each team and how they react to the moles. The instructor should do this in a discrete fashion so as not to tip off the team to the true motives for the activity. In our course, this is not much of a problem because the students are accustomed to the instructor and student course assistants observing team activities which occur in every class session.

Once the allotted activity time has concluded, all the teams come back to the classroom and the moles are revealed along with the roles they were playing. It is important to not force the students to guess the "moles" as they will likely be far too shy to make public accusations. Additionally, this could lead to some awkward situations if any students incorrectly state that a teammate was a mole, when in fact they were not.

V. GOALS OF POST-ACTIVITY DISCUSSION

Students derive a large part of this activity's benefits during the post-activity discussion. This is an exercise which the instructor is expected to moderate, and to point the students in the general areas of what they should be discussing. However, the instructor needs to be careful to allow the students to properly interact during this component and let their thoughts be heard. During this discussion, student involvement and thought needs to be fostered as much as possible. Approximately 15 minutes was allotted for this discussion.

There are several possible areas that may be addressed in the post-activity discussion. The first is how the students reacted to the moles. Students should be asked to identify, consider, and elaborate on how they responded to their problematic teammates. This is something they likely have yet to consider. If the students fail to contemplate their thoughts and actions, they will lose many of the benefits of the overall activity. It is only through understanding their own thoughts and actions that they will be able to recognize their reactions and make the proper behavioral adjustments when they encounter similar situations in the future.

Ultimately, the discussion should revolve around two central topics. The first is how each student should react to teammates when they are acting improperly. Secondly, each student should learn to self-identify when they are becoming one of the detrimental teammates as conveyed by the moles. When working with problematic team members, the first step is to consciously recognize them. Many students stated that during this activity they noticed these problematic members. However, it wasn't until after the activity and the discussion that they consciously thought about these individuals and their behavior, and how the team could achieve a change in behavior, or work around it. In future team activities, students should be alert for problematic behaviors, such as those exhibited by the "moles".

Once these problematic behaviors are identified, students should understand how to deal with them. Many students stated that they recognized these behaviors, but chose to ignore them, or worse, decided to join in with the destructive activities of their problematic teammates. These "moles" represented a harmful type of team member students are likely to encounter. Each of these roles should be dealt with in different ways when encountered in groups. It is important for students to recognize how to properly identify and appropriately respond to these team members.

The second major discussion topic is how students should learn to self-identify when they are falling into one of these disruptive roles. There is no such thing as perfect team members. We all have areas where we could improve ourselves with regard to working in a team. A goal of this self-identification exercise is to identify our own tendencies toward disruptive behavior, recognize when we are exhibiting one or more of these behaviors, and how we can change the behavior or prevent it from occurring in the first place.

To start this aspect of the discussion, restate the roles that the moles took and have the students quietly think about times when they exhibited one of these behaviors. The students should not be forced to discuss any of these occurrences. Many will be simply too embarrassed to publicly state their shortcomings. Many students would merely not participate in this discussion component, or would be likely to be only partially honest or forthcoming. This component should represent a period of complete open and honest discussion. The environment should be as friendly and positive as possible to foster a good learning environment. Any aspects which make the students feel uneasy or less than totally forthcoming should be avoided.

VI. STUDENT FEEDBACK

The student reaction to the "moles" activity has been generally very good. Most students were very surprised that the moles were planted in their teams, which is a testament to the acting ability of the students. Many even went so far as to apologize to the moles for getting so upset and frustrated with them during the meeting. Students have also stated that the activity was very enjoyable. This is very important because we believe that students ultimately learn better when they are enjoying themselves.

Following are representative samples of written feedback we have received:

> "When we were actually *trying* to work, it was a pain - but it really helped drive the point home. In your SE career, you're going to have that one person on your team who is going to be the bane of your success; they'll show up late, distract the group, do little if *anything.* Instead of complaining about how annoying these people are to work with, we should have enough experience with them to know how to run a successful group *with* them."

> "The mole activity was an extremely fun day in freshman seminar! I thought it was quite a useful activity because it was a demonstration of the sorts of dynamics one can expect to encounter in a group/team environment, which is critical in our field."

During the subsequent discussion, students described how they worked with these moles. Many would simply ignore these problematic team members. This is typically the case when teams are dealing with the “non-contributors.” Teams generally find it easier to just ignore and forget these members rather than confront them about their lack of effort and unwillingness to contribute. This is very interesting because one of the main problems that our upper level students complain about is team members who do not contribute their fair share of the workload to group projects.

While not often the case, when students did directly address the mole during the activity about his or her problematic tendency, it was typically done in a destructive rather than a constructive manner. Students would often become angry with the mole, resort to confrontational discussions, and finally ignore the problematic team member. Part of the subsequent discussion should be about the proper way to confront a team member about his or her behavior.

Students note that the disruptor "mole" also had a negative effect on the team by bringing the team off topic and keeping them from being productive. However, more than with the other roles, it had the added effect of turning other students into disruptors themselves. In many cases, the wave of disruption would resemble a virus spreading through the team.

Students also found it interesting that even though they recognized the mole and the actions he or she was taking, they never really thought about classifying it. They never really viewed problematic team members as falling into different classifications. Being able to identify the behavior brings with it the benefit of known solutions that the team can use to attempt to correct the non-productive behavior.

VII. FUTURE WORK AND IMPROVEMENTS

Even with the success of the activity, there is room for improvement. One enhancement would be the identification of more “mole” roles. Despite the variety of roles currently used, there are likely others which have yet to be recognized that may represent additional problematic areas for team collaboration. Future instructors are encouraged to identify and share these new roles as they are discovered. Additionally, if instructors adopt this activity for use in classes other than software engineering, they are encouraged to create moles which may better reflect their specific course area.

Monitoring the student activity is another area that we feel has the potential to be highly effective for gauging team collaboration. Currently, it is very difficult to observe teams and their interactions without creating suspicions among the students. Additionally, when an instructor is present or observing any team activities, students generally act differently. This is a problem that may be difficult to overcome. Without witnessing these interactions, the instructor risks missing key points and interactions among the team which would provide interesting points to highlight during the subsequent discussion. This is not as large a problem for our course because instructor observation of team activities happens regularly.

VIII. CONCLUSION

Experiencing disruptive behavior in a team using “moles” is an interesting and innovative activity for helping students learn how to work as part of a team. Many of the aspects of working on a team are far too often overlooked in the field of engineering education. The primary focus of this work was dealing with problematic team members. While the exercise described here was with students in a software engineering course, there is no reason why it cannot be used as-is, or moderately altered, with courses in other disciplines. The activity went very well and has been met with positive student feedback for being both an enjoyable, but also very educational activity.

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Evaluating the Effectiveness of a Cooperative Learning Approach in Engineering Education in China

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***Abstract*— The need for teamwork skills has been recognised as one of the key requirements for engineering graduates by industries world-wide, including in China. A pilot on teamwork training was conducted in a joint degree programme between a leading British university and a top Chinese university in 2011. This paper attempts to evaluate the effectiveness of this cooperative learning practice to Chinese engineering students and to identify the gap between the declarative knowledge and the skill-based outcomes. This evaluation focuses on the open-ended and qualitative items in students' expectations agreements, team function evaluation forms, peer ratings, and questionnaires. The data collected were analysed using descriptive statistics, with class observation and informal interview responses also being discussed. This qualitative study provides a good supplement to the previous quantitative findings and contributes to understanding by displaying how students perceived a Cooperative Learning practice in a mainland Chinese context, and how they reacted to the experience. It also provides an insight into the underlying cultural considerations behind the team behaviour. Instructors can design and improve team tasks for Chinese students based on these findings.**

Keywords — Cooperative Learning; teamwork; peer rating; evaluation; effectiveness; Chinese engineering students;

I. INTRODUCTION

Teamwork skills have been recognised as one of the key skills required for engineering graduates by industries world-wide, including in China. Every year a large number of engineering students graduate in China and, with the rapidly rising influence of China in the global economy, how to effectively teach technical teamwork to Chinese engineering students needs to be studied urgently, especially as most of the teamwork training in China is undertaken in after-class activities rather than in an academic setting.

A pilot practice on teamwork training was conducted in a joint degree programme between a leading British university and a top Chinese university in 2011 [1]. This programme aims to mix the best of teaching approaches from China and the UK, and it includes more emphasis on professional skills than is usual in other Chinese degree programmes. In the experiment, many successful Cooperative Learning (CL) practices from the West [2] were used in the Personal Development Plan (PDP) module that takes team working as one of its key teaching objectives. Students were asked to complete a task in groups with the basic teamwork concepts and skills being introduced at the beginning; they were encouraged to improve their team performance during the process by drafting and signing the experiment agreement and filling the mid-term evaluation form. At the end of the task, students rated the team performance of the team members including themselves. The detailed strategies can be found in one previous paper [1], and the experiment results had been analysed in another paper [3].

However, an important aspect is how effective the teaching of these skills is, evaluated by how well the students learn the skills. This paper attempts to evaluate the effectiveness of this Cooperative Learning practice to Chinese engineering students and to identify the gap between the declarative knowledge and the skill-based outcomes. It was noted that students' skills that inform their team behaviour are influenced more by their inherited practices and cultural norms than the declarative knowledge learned at the beginning. Many interesting results found in the class observation are also analysed.

II. RELATED RESEARCH

Many studies report successful practice in classroom-based teaching of team work, the most popular being to assign group projects in technical modules [2, 4]. Researchers often comment on the teacher-controlled factors that influence students' team experience [5, 6], and many computer systems have been developed to help the process of group formation, administration and teamwork assessment [7-11]. Some researchers reviewed the peer assessment of group work [12], and some educators modified the peer rating instrument and procedure to enhance the consistency, reliability, and validity of the assessment [13, 14].

However, other researchers and educators argue that teamwork skills cannot be learned through *ad hoc* project experience without teaching; it is a learned skill, and should be taught, practised and assessed as other academic skills [15-17].

However, a teaching strategy can only succeed when it facilitates students' learning. Many educators shed light on students' response to the cooperative learning arrangement

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and their perspectives on how teamwork can best be learned [18, 19].

III. Methodology

This qualitative study aims to evaluate the effectiveness of the tested CL approach in mainland Chinese context as a supplement to the previous quantitative findings [3].

Data for evaluation was collected from four main sources: students' expectation agreements, team function evaluation forms, peer ratings, and questionnaires; class observation and informal interview responses were also considered.

The data was analysed using inductive text analysis and descriptive statistics. The responses were coded using open coding [20] to label each response with simple words and phrases. Common key words and phrases were identified and organised into clusters.

IV. Evaluation Results

This section will mainly evaluate how the experiment strategies and mechanisms achieved their teaching objectives and learning outcomes; and whether students understood and performed what we wanted them to do.

A. Instruction of Teamwork Skills

It is agreed that students cannot gain team skills by just working in groups [21]. They are not born to know teamwork skills, and these skills must be taught deliberately with as other academic skills. However, technical modules often have tight schedules plus a large amount of teaching content and the instructors do not have enough training on teamwork teaching, so the most common situation is that students are allocated into groups to complete an assignment but are not given any instruction on how to work in groups.

In the experimental PDP class that takes teamwork skills as one of its main objectives, a brief introduction to these skills was given at the beginning. This included team effectiveness, team development stages, assertive communication skills, social skills, interpersonal skills, and conflict resolution skills. Other skills, like interviewing, questioning, exchanging ideas, giving advice, defending oneself, and summarizing information, are introduced and practised in later PDP tasks throughout the whole undergraduate period.

However, because of the time limitation, it is only possible to schedule a two-hour lecture to set up the PDP task and give basic knowledge of teamwork skills. According to the questionnaire results, students found that the instruction is not enough: 90% of the students in the experiment wanted the instructor to check work and progress at least once a week. It is also noted that there is a gap between declarative knowledge and skill-based outcomes: 60% students found "*little help*" in having instructor guidance for improving team effectiveness - "*students feel that the skills and guidance is very useful, but often forget to use, or do not know how to use, the skills in practice*".

Declarative knowledge is easy to learn, but skills are difficult to acquire. Students found the knowledge and skills were very useful, but often forgot or did not know how to use them in practice. They also expressed the desire for more specific practice and instruction during the process.

Because of time constraints, the skills had only been introduced but not been practised to any extent within the class. It is suggested that more time be allocated so students can do more exercises to practice skills within class, such as brainstorming skills, decision-making skills, group-meeting skills, conflict-resolution skills, listening skills, clear-expression skills, summarizing skills, and assertive communication skills. Different forms can be used for this practice - including lectures, tutorials, workshops, and clinic sessions.

B. Team Expectations Agreement

After the introduction of team skills, students were asked to work out an expectation agreement for their teams. They were expected to list the rules and expectations they agreed as a team to adopt. Everyone signed the sheet to indicate their agreement and intention to fulfil them. They were told that the expectations were for their use and benefit; if they made the list thorough without being unrealistic, they would give themselves the best chance.

Western cultures place emphasis upon rules, laws, equity and contracts that should be applied in all situations, irrespective of personal relationships. However it is very different in the Chinese culture, which puts more emphasis on relationships instead of rules: people have obligations to those they know personally, and each situation is treated differently [22]. Chinese people are usually motivated to complete tasks because of a sense of personal loyalty and attachment to others in the group, but are not compelled by rules [22]. Therefore the following questions were addressed: (i) is there any resistance from students in making and following rules and expectations; (ii) do they know how to make rules; and (iii) what kind of rules will they make.

The result was very inspiring: all the 24 groups took it seriously and worked out a detailed expectation agreement. This indicated that students were concerned to improve team effectiveness using rules and intended to use the skills and knowledge they learned to drive their behaviour.

The expectations they listed can be grouped into six categories: (i) meetings, (ii) decision making, (iii) leadership, (iv) discussion, (v) interpersonal and conflict resolution, and (vi) project management.

1) Meetings

Most of the groups expected all members to attend meetings on time, ask for leave if they could not attend, concentrate on tasks, and maintain focus during the meeting. One group had even more concrete meeting rules: they decided the frequency and duration of meetings, and stated that there was zero tolerance for lateness of 10 minutes and above: "*Have a meeting twice a week; no one can be 10 minutes late; meeting time should be limited to 30 minutes*".

The expectations were more about discipline, but no group mentioned having an agenda and capturing action items. Students were not used to making meeting agendas and minutes so this meeting skill should be taught and practised more.

This could be explained by the *polychromic time rhythm* valued by Asian people, who change plans and deadlines frequently and consider schedules as goals rather than as imperatives [23]. However this fluidity does not help coping with time pressure and raising work efficiency in groups so that there is a need for Chinese students to learn how to make and follow meeting agendas and project plans.

2) Decision making

Eleven of the 24 groups agreed on the decision making method: eight groups chose majority rule voting for the best, and three groups decided on consensus instead of majority rule. Chinese people normally vote for majority to show democracy when making decisions as it is an easy way to reach a final decision but not the best way. People in collectivist cultures are disposed to subordinate their personal interests to collective goals [24]: the majority's interests and choice are often perceived as the collective interest. However the majority decision may not be the best solution as it stops alternative discussion and hinders group synergy. Sometimes the real situation with majority voting is that with majority voting the minority may in fact impose a decision on the majority. They pretend to ask "*we are all agreed on this, right?*" to suppress dissension. Only the brave members will speak out against that, but normally in order to save face to both themselves and others, Chinese people will keep silent to avoid confrontation to maintain the group harmony. However, CL encourages different ideas, constructive conflicts and discussions to reach a consensus that surpasses the sum of individuals'. Students should be aware of the benefit of the consensus approach, and practise how to make a consensus within a group.

3) Leadership

From students' statements, it was clear that they preferred sole leadership, and interestingly they liked to use the word "*obey*" to describe the action they took in response to the leader's orders and arrangements. People depended on a good leader to lead them to success. It was believed that obeying the leader's order was the most efficient route to success with no doubts or different ideas being encouraged. Only one group expected shared leadership and confirmed the accountability of each member.

In many Asian cultures, leadership is more about management of people than management of work [25]. A good leader acts as a moral example who receives high-level loyalty and devotion from team members. Personalities rather than work-related competence are more likely to be the criteria for leadership [22]. Team members need to follow the leader's order and arrangement. In addition, influenced by Confucius' value of unequal relationships, people need a leader to maintain group harmony and stability. Without a leader, the group does not know how to work. This is quite different from the shared leadership advocated by CL [26]: each member has a job to do and the team does not have a formal leader.

4) Discussion

In the discussion category, students encouraged different opinions, creative ideas, active participation, good listening skills, and critical remarks in a constructive, respectful, and polite way. This indicated that students became aware of professional communication skills and welcomed open and fruitful discussion by giving constructive feedback.

5) Interpersonal and conflict resolution

Students agreed on the following aspects in interpersonal relations and conflict resolution: willingness to know each other; showing respect and care to each other; trusting others; being open-hearted, honest, considerate, tolerate, modest, and helpful; avoiding blaming others or attacking them; dealing with anger, insults and disagreements peacefully; and correcting mistakes immediately. A few groups expected no arguments and avoided conflicts.

CL emphasises "*face-to-face promotive interaction*" to challenge each other's conclusions and reasoning [26] and encourages constructive conflicts, which involve disagreements over thoughts and different views on how to work further [27]. Chinese students in a collectivist culture are traditionally perceived to value the harmonious relationship within the group [28]. They are more emotionally controlled, and prefer indirect communication [22]. Because of the strong emphasis on harmony and face in the collectivist culture, Chinese people are not encouraged to speak out, to question or to criticise. In order to save face, speakers often become very defensive after expressing their opinions. If other people put up different views or disagreements, they feel humiliated so that constructive conflicts turn into affective conflicts, involving personal friction, rivalries, and clashing personalities [29]. Affective conflicts are destructive to productivity and also a threat to group harmony. Therefore, when the problem is approached in different ways, people often choose to avoid it, bypassing the topic of conflict, or being "*obliging*", or asking for mediation from a high-status individual [29].

Though the Chinese students in this experiment showed desire for open discussion and different ideas, they were very careful in coping with differences by controlling emotions and using majority voting to solve conflicts. However the awareness of the concept to relate professionally and maturely to different ideas and feedbacks was something they had learnt.

6) Project management

Some groups also listed expectations on project management: they expected members to follow the project schedule, take care of equipment, reduce expense, and divide work fairly.

Some of the expectations were not concrete. Some listed the general objectives of team work: cooperate with others, work efficiently, build an effective communication mechanism, have a good leader; and be creative. Some propagandised team spirit: be united, confident, full of passion, and optimistic, never be selfish, put the team's interests first and create a harmonious atmosphere. These slogan expectations were not realistic: they do not actually tell team members how to achieve goals and what to do. But this reflected that traditional Chinese teamwork training is focused on the cultivation of a collective spirit instead of skill-based practice. Collective teamwork advocates maintaining collective interests by sacrificing personal interests.

C. Evaluation of Progress Towards an Effective Team

Students were asked to evaluate, against the intended learning outcomes, how well their team functioned in the middle of the task and to list changes they all agreed to make. This step reinforced students' team knowledge, and initiated voluntary improvement through evaluation.

The most common problem reported by nine groups is that members were not well-prepared for meetings. The second biggest problem (eight groups) is the lack of good listening skills: constantly interrupting each other or talking in pairs without listening.

Chinese people are not encouraged to speak out or to question, so do they know how to evaluate? This mid-term evaluation was intended to teach evaluation skills and problem-solving skills. Students need to learn how to evaluate based on behaviour instead of attitude, and be able to make concrete and specific work plans to solve problems. In general, students' evaluation was effective, and their problem-solving plans were specific and practical.

Regarding the problem of late attendance for meetings, some groups worked out very specific rules: (i) everyone attend the meeting five minutes early; (ii) circulate the meeting time three days beforehand; iii) get everyone to confirm they can make it and can come on time.

Regarding the problem of no preparation for meetings, some of the rules were also concrete: (i) before the meeting, the monitor will tell everyone the topic of the meeting, so members could think about it and work out their own thoughts and constructive solutions; (ii) each member should summarise their own opinions [1] in general before group discussion; (iii) prepare fully individually before the meeting to make brainstorming effective.

Regarding the team role problem, some groups requested that: (i) the coordinator takes more responsibility in the detailed task; (ii) to combine the roles of monitor, sceptic and checker to one role because they found there was not an absolute boundary between the three roles; (iii) to divide the work into roles as well as specific tasks; (iv) to elect a person to be responsible for the whole work; and (v) to establish a supervisory mechanism.

D. Peer Rating

How to assess teamwork and individual contributions has always been an issue for instructors when marking group work. Among various evaluation mechanisms, peer rating has been found the most effective one to get insight into individual contribution and performance. Many peer rating systems and schemes have been developed [12]. The evaluation schemes can be grouped into two approaches: one is a qualitative approach to assess "*team citizenship*"; and the other assesses the contribution and effort invested by each team member to the final product [30] [31].

We adopted the peer rating system used by Oakley and colleagues [2], which emphasises how people contribute cooperatively to team goals, but not on their academic ability for their own individual work. Working together with others to develop synergy is very important. This reinforces the training of teamwork skills to meet the learning outcomes.

This system sets up a behaviour anchored criteria (the behavioural characteristics of good teamwork), and explains the meanings of the rating list ranging from "*excellent*" to "*no show*" in terms of individual team performance. However the peer rating was still based on a subjective judgement of observable performance and effort. The validity, reliability and objectiveness of the rating are areas that need to be considered.

1) Do they understand the rating criteria?

Students were asked to rate team members including themselves using the rating words (excellent, very good…no show), and were also asked to give justifying commentary. We investigate these commentaries to see how they understood the rating criteria and how they made the judgement. Students' commentary included the following topics:

- Listed what each member did in the task, for example: shoot the video; direct the show; act in the play; make PowerPoint slides; edit the video; organise meetings; put forward a proposal and revise our plan; look after for the equipment; search information.
- How each member fulfilled their work: are they a good director/editor/actor/leader/checker; can they shoot video in high quality; can they make good presentation slides or write a good script.
- Their team performance: did they attend all meetings, but did not contribute much; did they finish their own work and help others; did they have lots of good/creative/amazing ideas and advice; were they a good listener; did they share ideas with us; were they absent for some meetings/activities; did they point out problems and help to solve them; did they need more courage to intervene; were they punctual and well-prepared; were they sometimes late and contributed very little.
- General appraisal: were they active, creative, full of passion, careful, easy-going, enthusiastic, generous, hard-working, or talented; did they have an open mind; were they technically good, diligent, earnest, selfless, efficient, or humorous; did they devote a lot to the work.

This study demonstrated that students understood the rating criteria, and they inclined to rate each other based on their general judgement of a person, which also includes their contribution and ability. However, some commentary did not justify the ratings. One example is shown in Table I: all the commentaries were good, but the ratings were different.

[1] Some people might not have conveyed their ideas clearly and systematically before.

It was also noted that students were very generous in giving good ratings ("*excellent*" and "*very good*"). Within the 134 sample students there were 44 students who gave all the team members "*excellent*" ratings, and 15 students who gave all the team members "*very good*" ratings.

Some people might argue that this does not reflect reality, giving everyone the same mark or the full mark. The reason for this phenomenon might be that people do not want to offend others even though the marking is anonymous.

2) Consistency of the marking

The overall rating is generally consistent. However we also found differences in rating to a team member: some members found her work was fine and satisfactory, while others felt she did little (Table II).

There is another example: one student rated a team member "satisfactory" with commentary "*He played a role in the advertisement, but he did not make many suggestions for the advertisement.*", while the others rated him "excellent" or "very good" with comments "*good actor, share ideas, good skills in video editing*".

3) Can students rate themselves and others objectively?

It has often been doubted whether self-rating is objective: people may over-rate or under-rate themselves. A previous statistical test showed that there was no significant difference between self-rating and average peer rating for individuals ($Z=-1.509$, $Sig.=p=0.131>0.05$). This indicated that the Chinese students in the experiment did not over-rate or under-rate themselves when evaluating their team working.

In a previous survey, when students were asked whether they would evaluate members' work including themselves objectively, (i) 60% reported "*Yes*"; (ii) 27.5% of them chose "*No, avoid to make some group members too embarrassed*"; (iii) 7.5% said they would evaluate themselves highly; and (iv) 5% said they would evaluate themselves harshly.

Interestingly any inconsistent rating (normally a lower rating) often came from the student themself, which means students often underrate themselves. For example, one student rated himself "satisfactory" with comments "*As the coordinator, I should carry more load and take more responsibilities*", while others rated him "excellent" and "very good". We found that students were often modest in self commentary: "*I should pay more attention to the task*"; "*Just perform ordinary, have potential to improve*". This is in keeping with the modest characteristics of Chinese people. Confucius told people to do self-questioning and self-examination before a conflict or problem, instead of blaming others. Therefore if the team does not perform well, they often blame themselves.

4) Did they give marks using the same grading scales?

It is true that students often have different understanding of the grading scales. Some people are generous in giving high marks while some are very mean and strict in rating. It was found that in one group, all the others rated group members with "*excellent*" or "*very good*", but one member rated others all with "*satisfactory*". Making the rating criteria more particular might help reduce the marking difference.

TABLE I. COMMENTARIES DO NOT JUSTIFY RATINGS - EXAMPLE

A	Very good	Helped the team work effectively and made the ppt
B	Very good	Came up with good ideas about the ad
C	Satisfactory	Made the video well
D	Satisfactory	Came up with ideas and acted well
E	Satisfactory	Acted as the main character in the video perfectly

TABLE II. DIFFERENT RATING FOR THE SAME PERSON

A	ordinary	a little careless (*This is self rating.*)
B	deficient	She had done nearly nothing
C	satisfactory	compliant
D	satisfactory	She could finish her job.
E	satisfactory	Can complete the task in time, and have her own opinions.
F	superficial	I don't know what she has really done

E. Team Roles and Individual Contribution

Through class observation and final presentation questions, it was found that students got used to single-leader groups even though they were assigned different roles immediately after the groups were formed: the coordinator or the monitor was often considered as the sole leader. The task was often parcelled out into parts and each member did one part. Students only completed and took responsibility for their part of the academic task, but did not care about others' work or undertake other responsibilities for the team. Therefore, getting them to perform the other roles (such as Checker, Sceptic) seems like a vain hope.

Members did not normally understand each other's contributions. For example, students did not know what software was used to edit the video and how it worked except for the one who made the video. Others cannot present the work if they were not assigned to make the presentation slides.

During the final presentation, one group made several typographical mistakes (Beijing Duke instead of Beijing Duck) in their slides. When the Checker and Sceptic were asked whether they checked the slides, they shook their heads and looked at a third person who made the slides. This implied that they thought this was the responsibility of the one who made the slides, but not theirs. In another group, when they were asked about the meaning of a sentence in the slides ("*Wish you a fair wind*" in a kite advert), nobody in the group could answer and all explained that the one who made the slides was sick and did not show up!

V. STUDENTS' FEEDBACK

Students are the best judge as to whether a teaching approach is effective or not. This section mainly examines the perspectives of students towards this team training practice and their suggestions.

A survey was conducted after the experiment and the results had been analysed in a previous paper [32]. 52.5% of the experiment students reported "*very satisfied with the team experience in the PDP task*", and 35% of them stated "*somewhat satisfied*". Students in the experiment group reported a higher satisfaction with the team experience (3.35[2])

[2] A Likert five-point scale was used to calculate the satisfaction mark for each response from "very satisfied" (4) to "very dissatisfied" (0)

than the non-experiment students (3.17). More experiment students (97.4%) felt the group coursework helped them learn teamwork skills than the non-experiment students (87.5%). This team training practice was acknowledged and welcomed by the students overall.

A. Attitude toward future group work

81.6% students preferred to work in groups in future coursework projects. The reasons they preferred group work are summarised in Table IIII.

B. What they learn from the project?

Students learned a lot from the project: it brought challenges to their inherited and cultural views. Details are shown in Table IV.

One student explained their new understanding about values and leadership: *"I learn that each member's value is equal. We should respect each other, even though there is a relationship between a leader and team members."* This contradicts the traditional monopolistic leadership in China and respects equal opportunity of expression.

C. The Biggest Problem Students Found in the Process of the Group Work

Students also listed the biggest problems they found in the process of the group work (Table V). These problems need be studied and illustrated when delivering team skills training in the future.

D. Suggestions to Teamwork Training

Some students thought this PDP task (advertisement video making) is very good and recommend more group coursework like this. About one quarter of the students expressed their demand for more group coursework, projects, exercises and activities. They wanted more opportunities to practise team working. One student even suggested reducing or stopping traditional individual assignments and having more group coursework.

Some students recommended designing more group coursework with a lot of originality. Some suggested training team skills in playing interesting games, which will make the communication and cooperation more natural and effective. Some students asked for more time and space for the team project. When talking about the method of forming, they gave some suggestions: (i) allocate students from different classes into a group; (ii) let students choose their own groups; (iii) let different students form a group every time.

Many students wanted more training on team skills: (i) set up a course to train team skills; (ii) teach more useful team knowledge and skills; (iii) give more specific advice and examples; (iv) have more interaction between students and instructor. One student stated: "*If time permitted, I hope the teacher or instructor can talk with each group individually, or the person individually, which is better, but I think they might not have that much time.*"

TABLE III. REASONS WHY TO CHOOSE GROUP WORKS IN THE FUTURE

Group work can help to develop teamwork skills, and interpersonal skills.
Teamwork is important and interesting.
It is a pleasure to work together with others, and they can learn a lot from each other.
Group members share ideas and help with each other to improve together.
Group work is more efficient and time-saving; it makes the hard technical tasks easier to accomplish.
Nobody is good at everything, and teamwork gathers all the powers together.

TABLE IV. WHAT THE STUDENTS LEARNED FROM THE PROJECT, PREPARING THEM FOR REAL LIFE

Teamwork makes life more efficient and interesting, and we can make more friends.
It helps me to have team spirit, and be more responsible.
Respect other's opinion in a team.
Cooperation helps us do work more easily and make the result better.
Learning to get along with others is important.
Everyone has their advantages; we should believe others and let them do what they are good at.
Communicate with other team members;
Listen to others' advices;
Control our temper when we have different opinions;
Give other people opportunity to express their opinions;
The proper way to express our ideas and give feedbacks to others' ideas;
Be considerate of feelings of others; never be authoritarian and rigor to others;
Compromising with others;
Make agenda before meetings;
Make plan before work;
How to lead a group;
Actually learn more academically.

TABLE V. THE BIGGEST TEAM PROBLEMS STUDENTS FOUND

Time management problems;
Lack of inspiration and creative ideas;
Lack of work enthusiasm;
Uneven distribution of work;
Group parceled the work into parts, and members only did their part of work individually;
Some people did less and took advantage of others when they found the others can do more;
Some people did not fullfill their responsibilities in team because they were too lazy, or only concentrated on their own studies, or were busy with other things;
Some members finished their work late;
Difficulty to find a common meeting time because everyone had their own arrangement;
Do not have enough time to communicate with each other;
Group leader did not show the leadership at some key point;
Different people have different ideas, and it is difficult to reach an agreement or consensus;
Some people did not listen to other's opinion carefully or seriously during discussion;
Some people did not express their own opinions but just agree with others' opinions;
Some people attended meetings late;
How to relate with strange members at the first meeting;
How to break the ice when all members keep silent in the meeting.
Some members were monopolistic and bossy;
Some members were academically weak and did not want to try their best to contribute.

VI. CONCLUSION AND FUTURE WORK

This CL practice is a pilot attempt to Chinese engineering students. It brought a positive attitude to team work to the students and most of the students were satisfied with the team experience, and wanted more training and practice on team skills.

It was found that most of the experiment strategies and mechanisms achieved their teaching objectives and learning outcomes. Students generally understood and performed what we wanted them to do. However we also identified a gap between the declarative knowledge and the skill-based outcomes. The transfer from knowledge to skills needs more practice and exercises. Furthermore, the inherited practices and cultural norms also have a big influence on team behaviour.

This CL practice is generally effective in team work training, though some mechanisms were not suitable to the Chinese students and appropriate changes and modifications are required. Students also gave many useful suggestions to the future work. This qualitative study has been a good supplementary to the previous quantitative findings, and gives a good understanding on how Chinese engineering students react in a CL practice.

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Integrating Communication Skills in Data Structures and Algorithms Courses

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***Abstract*—While the improvement of computer science students' communication skills has frequently been called for in the literature, employers continue to feel that recent graduates are not equipped with the writing, speaking, and teaming skills essential in the 21st century workplace. One problem with previous approaches is that they often teach communication skills in dedicated courses rather than integrating them into technical classes across the curriculum. In this paper, we report on a multi-institutional faculty team's efforts to integrate communication skills into mid-level data structures and algorithms courses as part of a larger NSF-funded project to enact integrated reform throughout computer science/software engineering curricula. We present an outline of assignments designed to develop communication skills (writing, speaking, reading, listening, and teaming) intertwined with technical skills, and discuss our preliminary efforts to assess these efforts. Our work reflects a general approach to incorporate communication activities *within the computer science curricula* and to help students learn and communicate technical content in academic and professional settings.**

Keywords— Data Structures, Algorithms, Communication Skills.

I. Introduction

Based upon years of experience in industry, coupled with direct contact with students in academia, we can emphatically state the obvious: most computer science students do not know how to communicate well. The technical skills new employees possess are potentially lost due to an inability to effectively articulate a coherent design, idea, or plan [1]. Even students who land their dream job often have difficulty working as part of a team or presenting ideas, either orally or in writing, to peers, management, or customers. These difficulties lead to frustration and an inability to make a difference in their field.

For many computer science students, communication curricula are part of their general liberal arts education and are typically focused on the social sciences and humanities. As a result, students are often not learning and practicing relevant communication skills (writing, speaking, and teaming) *in their discipline*, and often do not see the importance of developing those skills. Frequently they imagine the typical computer science job as sitting in an isolated cubicle, trying to build the latest video game or killer app.

As part of a National Science Foundation CPATH grant, we teamed up with academics and professionals, including communication-across-the-curriculum specialists from the United States and abroad, to address this gap [2]. By having a consistent thread of communication instruction for students throughout their computer science education, ranging from introductory Computer Science to Software Engineering and Capstone courses, the emphasis on integrating communication skills (reading, writing, listening, speaking, and teaming) with technical content becomes a primary curricular feature. With this approach, students not only acquire the technical and analytical capabilities they need, but are also able to communicate effectively and excel in their field.

This paper focuses on our work with integrating communication skills into *data structures and algorithms* courses, early in the curricula (typically after CS1). Two years were spent designing assignments to expose students to both technical concepts learned in class and the related communications skills necessary to provide coherent, complete, and professional deliverables. Faculty members from four institutions, including a communication specialist, were involved in creating and implementing this new curriculum, evaluating its effectiveness, and refining assignments to make them available to colleagues at other institutions.

Here we offer related work in Section II, and describe the participating institutions in Section III. Section IV presents the different assignment paradigms that were implemented to address different communication skills. Finally, Section V presents some reflections, preliminary evaluations, concluding thoughts and potential future directions.

II. Related Work

A number of universities have attempted to create courses for their majors that deal exclusively with communication skills. Northwest Missouri State University addresses the issue of oral communication skills for their computer science undergraduates through a seminar course [3]. Denison University introduces communication skills to computer science and mathematics students through a jointly led lab [4], focusing on the improvement of their oral communication skills. The University of Toronto created a new course entitled "Communication Skills for Computer Scientists" [5]. Still, as noted previously, rather than integrating communication skills within existing computer science courses, these institutions focus on the creation of a separate course that works solely on students' writing, speaking, and interpersonal communications.

More relevant to our project, Hartman introduced writing skills into a data structures course, specifically in assignments dealing with analysis of algorithms [6]. Based on accreditation guidelines, Beard et al. identified the soft-skills most sought by

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employers, and created a model for producing and evaluating relevant activities [7]. However, the curriculum was designed around accounting courses and not traditional computer science. Falkner et al. present a theoretical framework for assisting instructors with integrating communication skills in the introductory computer science courses (i.e., CS1/CS2) [8]. They provide some guiding principles and methodologies that can be incorporated early in the computer science curricula, along with initial feedback from students.

A broad view of communication skills, including writing, speaking, and teamwork, has also been supported in several studies. Gruba and Sondergaard report on the use of a conference run by the students in a computer science course so that they can work on their communication skills as well as learn technical content[9]. Students were tasked with the responsibility to create, host, and participate in a public research conference, offering opportunities for a wide range of communication activities in a real-world setting. In a 2006 paper, Hoffman et al. describe activities at Quinnipiac University to capitalize on the potential for communication tasks to help students "write to learn" technical content, as well as to communicate that learning [10].

A caution on curricular redesign is provided by Cilleirs, who found a discrepancy between instructor and student perceptions of the value of communication, particularly writing, activities [11]. The study suggests that while students perceive academic writing activities as beneficial in the construction of a report, many times the actual activities used by instructors are not perceived by students as being useful. Such cautions are essential to consider when integrating communication assignments to fulfill technical content learning.

III. INSTITUTIONAL CONTEXTS

In what follows, we describe each of our institutional contexts: overall demographics, the computer science curriculum, and the place of data structures and algorithms within that curriculum.

Miami University

Miami University, located in Oxford, OH, is a mid-sized public University stressing a balance between research and teaching. The Department of Computer Science and Software Engineering has about 300 undergraduate majors and 20 Masters' students, with a typical class size from 20 to 40. The data structures course is the third programming course, while the algorithms course is generally taken by upper classmen.

North Carolina State University

North Carolina State University, located in Raleigh, NC, is a large, public research-oriented institution. The computer science department has about 600 undergraduate majors and roughly the same number of graduate students. Except for the CS1 course, a multi-section lecture/lab combination with 30 students per section, a typical core undergraduate class has from 60 to over 100 students. Class size presents a special challenge to an instructor who wants to introduce communication skills. As at Miami, the data structures course is the third in a sequence of Java-based programming courses.

Tennessee Technological University

Tennessee Technological University (TTU), located in Cookeville, TN, is classified as a medium-sized, public, rural university, with a computer science enrollment of over 300 students, primarily undergraduates. Most students come into the program with little programming experience, having had no access to computer science classes in high school. At TTU, the data structures and algorithms course is second in the introductory sequence of C++ courses, with class size ranging from 40 to 70 students.

IV. ASSIGNMENT PARADIGMS FOR COMMUNICATION SKILLS

This project defines *communication* in terms of five modes: reading, writing, listening, speaking, and teaming. While data structures and algorithms courses feature considerable technical content, at the core they require students to design solutions (specific data structures or algorithmic approaches) to fit particular computing problems. This design element and the implementation of the design quite naturally lead to a wide variety of communication activities that mirror the types of communication students will need to do in the workplace; thus, the real-world element adds value to these tasks and is often highly motivating for students.

In the following sections we discuss various paradigms or overarching categories that we utilized to incorporate communication skills within a data structures and algorithms course. For each paradigm, we present a brief description of the work-place or professional scenario for the particular communication skills, as well as offer assignment examples. One will note that many of the concepts we implemented are applicable to courses other than data structures.

All of the assignment frameworks described in this paper and detailed descriptions of the assignments (as well as others) can be found at http://cs-comm.lib.muohio.edu/.

A. Program Design: Reading and Writing

Designing and implementing a program is probably the most common assignment (across all institutions) for students. They are given a problem to be solved, and they are responsible for designing, building and testing their solution. With this type of assignment, we incorporate two communication skills: reading and writing.

The *reading* skill is manifested in giving the students a task that requires them to do research. For example, in one assignment, we require students to implement a random number generator, a topic not covered in their textbook, and thus requires they search the literature – a situation they will encounter many times in the workplace. The particular goal is not important; the assignment template is constructed in such a way that the the appropriate communication skills are independent of the data structures concepts being introduced (e.g., stacks or queues) and thus can easily be adapted by other instructors to their own assignments.

The *writing* skill is integrated into the assignment by having the students design an application from scratch. To provide some guidance, a design template is provided that includes three parts for the students to populate: pseudo-code;

design decisions; and design issues/notes. The students limit their design document to no more than two pages (relieving some of the grading workload), and are required to submit coherent, grammatically correct, well-written text. A key concept the students must understand is that in the workplace, an employee's ability to convey their ideas in written form is important at many levels: conveying design decisions to their peers, presenting ideas to project managers, and presenting potentially transformative ideas to upper management.

B. Omitting Details: Listening and Writing

In the workplace, not only must software engineers be able to read technical material and write coherently, but they also must listen well. Customers will sit down with the problem solvers to talk about their problem(s), and it is up to the developer to listen and ask appropriate questions.

In the *listening skills* paradigm, assignments are handed out in paper form or posted on the class website, where class time is spent reviewing the assignment and answering questions. To integrate listening exercises, the assignment explanation includes two *verbal requirements* that cannot be found in the written description – the discussion of a feature that the program needs to accomplish is omitted. Because the students are told upfront that some of the required features of the assignment will be given verbally, and cannot be found anywhere in the written documentation that was distributed, the students listen carefully to the program specifications and ask questions about what they just heard.

C. Collaborative Design: Teaming, Reading, Writing, Speaking and Listening

The ability to work in a team is arguably the most important communication skill. Most software engineering projects involve multiple people, from business analysts to designers, coders, testers, managers, and customers. The ability to communicate both internally (i.e., within your company) as well as externally (i.e., with your customer) is vital to the success of a project.

This paradigm can incorporate all five of the communication skills: reading, writing, teaming, speaking, and listening. The reading and writing skills occur through the same avenues as mentioned previously. However, because the initial design is done as a team, students can view and analyze other students' interpretations of the assignment (i.e., what they read), as well as see and comprehend other students' design ideas (i.e., through their writings).

We present two examples of the collaborative-design paradigm, used at two different universities. Both involve team effort toward writing a design and giving an (optional) presentation of it. Each student, working individually, is then required to implement a design, not necessarily the one proposed by their own team. These examples can be adapted to many practically-motivated situations in which the data structure(s) to be used are not explicitly given.

Example 1

The students explore the idea of using queues to create a simulator, such as an airport runway or a car wash.

The initial design is done as a team exercise, with some minimal time given during class for team meetings, followed by individual implementations of their chosen design. By working together, students will learn different approaches for creating a design from other members of their team. The first deliverable, an initial design document, is submitted for a grade about one week after receiving the assignment. This requires students to craft a design before implementing a program – combatting the common tendency to create a design as an afterthought.

After the teams have submitted their design document, one class period is spent on 5-7 minute design presentations. This exercise incorporates speaking and reinforces listening in a different way. To get a grade for their presentation, each student must present some aspect of their team's design. This is a light introduction to public speaking, as each student only gets about 1-2 minutes to talk. In addition, because students are standing in the front of the class with their team, it is less intimidating as they have a support group for answering any questions from the class. Listening is reinforced because students are permitted to use any design they want for their actual implementation, so by listening and paying attention to other teams' designs, they may find a design choice they prefer better than their own. While not a gradable aspect of the assignment, it is definitely motivating to the students to know that they can use another team's design.

After working as a team on an initial design document (and presentation), the students are then on their own to actually implement a solution. And, as mentioned above, they can choose to use their team's design, another team's design, or their own individual design.

Example 2

The students explore an approach to searching and replacing data in a text file as motivated by the following situation: Suppose that the only strings you are allowed to replace are words – contiguous strings with no embedded spaces or punctuation. A situation like this might occur if you want to rename variables in a program.

As in the previous example, there are two phases: a team design followed by individual implementation. Because this assignment is more complex – non-trivial interaction between data structures and more design decisions – the allotted time for the design document is three weeks, with an additional week for preparing the presentation. Team dynamics thus becomes a more prominent factor. An additional feature in this assignment is a test plan, submitted along with the design. In the workplace, developers and testers must often communicate about designs that will integrate a new feature (e.g., the word search/replace added to an editor). A test plan is a critical aspect of the communication between a requirements engineer and the designer. It ensures that each understands the expected behavior of the software under a variety of circumstances

D. Justifying Choices: Reflecting and Writing

As teachers, we hope our students learn from their mistakes and apply their knowledge to solving new problems. As we use exams to gauge students' understanding of course material, programming assignments are intended to see if they can apply what they have learned in the construction of a piece of software.

After students have crafted designs as members of a team and read (or heard presentations of) the designs submitted by others, their learning can be further enhanced if they are challenged to compose a design document individually. For this task to be successful, it is important that the instructor evaluate the design *before* an implementation (if any) is submitted. Students are, in effect, being asked to make judgments about their own work and that of others and to apply these judgments to their subsequent work. For instance, in our examples, students are successful when they understand the pros and cons of different data structures. Reflection on prior experience with communication skills, particularly writing, but also speaking, is essential for continued improvement of these skills in the workplace. Naturally the proposed paradigm is applicable in any context where students have had opportunity to interact with the work (writing or speaking) of their peers.

E. Experimental Comparison: Writing

The choice of an appropriate data structure or algorithm is often based on carefully crafted experiments using relevant problem instances. Students can be asked to apply competing algorithms (or data structures) to large instances of the same problem, drawn from both real and randomly generated data. In one example assignment, students are asked to compare six different algorithms for counting the number of occurrences of each word in a text. The assignment provides a collection of large text files, drawn from articles and books, and a generator for random text files with various characteristics. The writing component of this assignment is the creation of a report that outlines the scope of the experiment (algorithms and instances used), the results obtained and the interpretations thereof (e.g., does theoretical analysis predict actual run-time?). Creating useful and evocative charts – difficult even for experienced writers – is an important component of this type of assignment.

F. Creative Endeavors: Reading, Writing, Teaming and Speaking

In addition to the traditional classroom modes of gauging students' communication skills, students can demonstrate various communication skills through creative endeavors. Exercises include using media such as blogs and wikis to allow students to implement someone else's design (reading and comprehension) or communicate within their team (writing and teaming).

In one example, large class size makes it infeasible to assign individual (i.e., non-team) design assignments. Thus, a twist on the design presentations is employed using YouTube. Students are directed to post a video, limited to three minutes, containing a discussion of their design. Advantages of this approach include: (1) allowing students to work on their speaking skills in a non-intimidating environment; (2) prompting students to learn how to use a popular media website; and (3) allowing instructors to watch the design presentations at their leisure in a short amount of time.

G. Organization and Clarity Through Proofs: Writing

In one institution's theoretically-oriented algorithms course, we assigned problems as much for the writing challenge as well as the technical challenge. Correctness proofs and problem reductions tend to work well: such proofs frequently address a single concept, allowing the student to better focus on a well-written proof. The nature of many proofs dictate a natural template for students once they have solved the problem, and this structure simplifies the problem of providing feedback. It is easy to identify and comment on a failure to mention the crucial point, or to build steps of the proof in a logical and complete progression.

NP-Hardness reductions provide a particularly good example of how proofs can be effectively used to develop writing skills. The central element of such a proof is that of reducing one problem to another in polynomial time, i.e., to show that a polynomial-time algorithm for problem A implies one for problem B. To make this main idea more accessible to students we ask them to think of the reduction in terms of an implementation: we suppose the existence of a (black-box) implementation of an algorithm for A and ask them to design an algorithm for B using it. Given carefully chosen problem-pairs (Partition to Sum of Subsets being a good place to start), even the weaker students can usually grasp the idea.

The more challenging part of this exercise, one that involves communication skills, is for students to prove that the reduction is correct. They need to prove two different results (that the proposed transformation never results in either false positives or false negatives). Within each proof direction, the student will need to clearly state the central point and support it with arguments – not technically difficult, but challenging for the writer to lay out clearly. The writer must avoid conflating distinct concepts (leading to lack of clarity); leaving out one of the two arguments altogether; or failing to properly structure one or both of the arguments (e.g., neglecting to explain what they are proving). Providing clear, useful feedback is usually a simple task: the almost mandatory structure of the solution allows the grader to easily identify problems with the writing and explain why these problems inhibit clarity.

V. REFLECTION AND EVALUATION

While systematic evaluation of the success of our curricular and pedagogical efforts was not always possible, we offer in this section a combination of reflection, evaluation, and student impressions (from survey data) as a starting point for revision of our assignments. We structure this section around the particular communication modes and tasks we implemented.

A. Reflection and Writing Activities

Design and Experimental Comparison Documents. Design documents are pervasive throughout the curriculum and in the workplace. Data structures and algorithms courses often present the first situation where design focuses on more than the implementation of a simple algorithm or a single C++/Java class. Among the design documents submitted (for Example 2, Section IV.C), most lacked a good overview, consisting primarily of detailed pseudo-code and/or detailed UML. These students had learned UML in a previous course but had only limited exposure to high-level pseudo-code. Writing a well-organized overview is the most important, and apparently the most lacking, skill. One could use examples of excellent work from a previous semester – one student came up with a professional quality document – as models, provided that the assignments were not too similar. Models addressing the appropriate level of competence are harder to craft or find in the literature.

The experimental comparison assignment imposed a challenge not normally encountered in the curriculum, yet extremely important in the workplace: presenting data in the form of tables and charts with explanations. The primary issue with the students' charts was scaling: lines frequently ended up on top of each other. Tables were often hard to read; they did not line up properly or presented far too much detail. In explanations of the data there were two issues: misguided explanations (technical) and poorly organized blow-by-blow descriptions (writing). Future uses of similar assignments might be preceded by examples from the literature, where both good and bad examples of data presentation abound.

Proof-based Exercises. In the proof assignments there was a core set of writing-related problems that reflect specific problem types in the student's general writing ability. Examples include:

Failure to explain premise (poor writing structure): The average student frequently fails to explain what they are proving. Presenting a clear thesis is necessary in good writing; in identifying this problem we hope to help students organize their thoughts and lay a proper foundation for their writing.

Excessive use of notation (poor presentation): Students confuse "proof" with "algebra," apparently believing the latter is mandatory in the former. We emphasize that notation should be used only to facilitate understanding (as short-hand for concepts too cumbersome to write in prose): a proof without Greek symbols is acceptable. Making students aware of overuse of notation forces them to focus on clarity and on the use of appropriate tools.

Failure to connect ideas (poor logical presentation): Students often make logical jumps or fail to explain connections they have correctly made in their own minds. This problem becomes easier to both spot and explain in proofs than essay-based writing, allowing us to provide useful feedback.

Superfluous statements (problems with concise writing): It is not unusual for a student to attempt to say the right thing by way of saying everything. Again, in a mathematical proof it is generally easy to spot irrelevant comments and provide useful feedback.

The above observations about proofs are based on an upper-level algorithms class, but the ideas apply also to data structures classes that incorporate smaller proofs into project assignments. For example, students may be asked to prove assertions related to the correctness or runtime of a program.

B. Reflections on Speaking Activities

On the whole, both the formal in-class presentations and less-formal, student-made videos were successful in helping with speaking skills. For the collaborative design assignment most groups gave what appeared to be well-rehearsed presentations, given either by one group member or several. Almost all presentations adhered to the time limit (imposed in Example 2 of Section IV.C), allowing for a lively question and answer period.

We found that most of the students enjoyed the YouTube *speaking* exercise and were sometimes very creative in the process. Submissions ranged from voice-narrated computer animation to a "60 Minutes" television show parody. The ease of using video equipment, usually embedded in their laptops, made this a fun and easy assignment for the students and an effective vehicle for improving communication skills.

C. Reflections on Teaming Activities

In capstone courses, teams are often based on a set of complex criteria (e.g. Layton et al. [12]) but this approach is unnecessarily time-consuming for our purposes. In our case, team assignments were based on a ranking of students with respect to performance earlier in the semester, using one of two strategies to form groups: (1) including a range of student ranks in each group; or (2) grouping students by rank [13].

In using strategy (1), we hoped that weaker students would learn from stronger ones. This outcome was observed directly in a few cases. Of 18 teams of size three or four students, most appeared cohesive (based on student peer evaluations and instructor observation). However, three of the teams had one member who contributed little or nothing and another team had a member who was completely unable to contact the other three, and therefore ended up doing the assignment alone.

One of the authors had used strategy (1) in an earlier semester, but switched to strategy (2) based on the work of Braught et al. [13]. The justification is that a group of good students will be driven to produce even more, while a group of poor students will realize that they need to step up if they want to succeed. After making this change in team dynamics, the instructor noticed superior work from the top students – they reached out and tried interesting ideas – while most members of the bottom groups actually contributed to their team's efforts, sometimes with surprisingly good results. One disadvantage of the latter approach, observed in a context requiring more complex tasks, is that the poor students make little, if any, progress.

All communication skill assignments presented grading challenges. We relied solely on peer ratings for assessment of teamwork. Speaking was only lightly graded: any reasonable attempt resulted in credit. Thus, most of the grading burden focused on writing. One of the authors advertised a rough breakdown to the students (10 points for each of several aspects), but was then faced with the difficulty of deciding between, say, a 4 and a 7; furthermore, each such decision had to be justified. A more reasonable approach would be a simple checklist of items each worth only 1 or 2 points, such as "a table that summarizes data effectively." This would obviate the need for justification and allow the instructor to focus instead on constructive feedback: positive encouragement and suggestions for improvement.

D. Students' Reflections on Communication Activities

While logistics and a lack of resources precluded comprehensive assessment of this project, we did conduct an assessment of student perceptions of their communication skills before and after a team design assignment in one course – see Section IV-C. Students were given an attitude survey at the beginning and end of the semester; 32 out of 61 students participated. The questions asked students to rate their ability in each of the following: (a) *reading* technical specifications, including assignments, documentation, etc.; (b) *writing* technical documents, including descriptions of algorithms and experimental results, designs, etc.; (c) giving audience appropriate presentations (*speaking*); and (d) working effectively with a team of peers to accomplish a common goal (*teaming*). Ratings ranged from very good (5) to very poor (1).

On average, the students rated themselves more positively at the end of the semester in three of the four categories: the average scores increased from 4.09±0.13 to 4.25 ±0.13 for reading, 3.50±0.12 to 3.75±0.11 for writing and 3.66±0.14 to 3.78±0.14 for speaking. (The ±'s here indicate standard error.) Teaming was a different story: there the average rating dropped from 4.19±0.13 to 4.16±0.12. Students were more confident about their teaming ability at the beginning of the semester than about any other skill. The lack of improvement might reflect the fact that nine students (in the sample of 32), who rated themselves more poorly at the end, were predominantly ones whose teams fared badly. The presence of carefully designed and positively regarded team assignments in the second semester Java course and an emphasis on pair programming in the introductory course could explain the initial high confidence in teaming ability. Clearly more careful attention could be paid to the teaming aspect of our proposed assignments.

Prior experiences in these skills were elicited with the prompt, "Please list the courses (including CSC 316) and/or industry settings (e.g., co-ops) in which you practiced [reading, writing, speaking or teaming skills listed in detail]." Only 21 of the 32 students reported having done reading in CS1 even though the prompt specifically mentioned "assignment specifications." The number increased to 31 for CS2. Prior writing experience was reported by 5 for CS1 and 23 for CS2. Teaming went from 8 in CS1 (pair programming is a part of that course) to 27 in CS2, where teams of four or five are now standard. The significant prior (presumably positive) teaming experience explains the beginning-of-semester confidence (and later drop thereof) with respect to that skill. As expected, there were only a few reports of speaking experience in CS1 and CS2 – 10 in the latter. But nine additional students reported speaking experience in industry, English courses and/or other CS courses. Clearly, prior experience was a significant factor in the better than average initial confidence ratings of students for four of the communication skills.

VI. CONCLUSIONS AND FUTURE WORK

The central point of the work described here is to bridge the gap between CS1 courses, where communication activities are typically low-stakes, and software engineering and capstone courses, where communication is a major part of course content. We address this transition via a collection of assignment paradigms that can be used to seamlessly integrate communication skills with technical content.

The activities we describe are only starting points for integrating communication skills into the computer science curriculum, generally, and data structures and algorithms courses, specifically. We do acknowledge (and have experienced) that large class sizes, last-minute teaching assignments, and skeptical students (and colleagues) are challenges to this work. However, we strongly feel that inducing students to develop the communication skills required of professionals *along with the technical content of these courses* is well worth the time and effort.

In future semesters, we imagine several possible directions:

- *Tracking actual improvement in communication skills as the semester progresses and/or in follow-on courses*. There was an attempt to match the pre/post attitude survey in the course at one institution with another attitude survey in the capstone course, but there was no comparative *evaluation of actual communication skills*. Even the attitude survey did not allow for adequate comparison between students that were exposed to the above-mentioned assignments and students who were not; the questions were not coordinated and it could not be determined how many students (if any) took both surveys.
- *Evaluating the impact of communication assignments on technical skills*. There is a legitimate concern that these assignments require additional class time and/or reduce the portion of a student's grade dependent on technical competence. Anecdotal evidence suggests that increased emphasis on communication skills neither decreases nor increases technical competence. A more rigorous assessment of this observation would be useful.
- *Using professional-quality examples of work demonstrating the communication skills*. High-quality student work from previous semesters (anonymized) could serve this purpose. Speaking and teaming present difficult challenges. In case of the former, industry advisers have suggested use of examples provided by them; the process of developing a functioning team would probably have to be taught and supervised by a specialist, as is done at one of our institutions.

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Let's do it OR *Deal with it*: Teamwork in Project-based Learning

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***Abstract*—Project-based course is based on teamwork and most of work is done and presented as a team. Team grouping rule is one of the most important issues. In project-based experimental course *Optoelectronic Instrument Experiments* (OIE), several different rules were attempted, each of which produced complaints by some students. After several trials of different grouping rule, we realized that there is no perfect rule which can satisfy everyone. Instead of changing the rule, trying to find a way to persuade the students to accept and support their group willingly might be a better solution. In this semester, the project teams are entirely determined by lot and several teamwork inspirational approaches are introduced to inspire team spirit in the course. Our purpose is to find a way to make student learn the interpersonal skill of working in team. Let's do it, not just deal with it inactively.**

Keywords—Project-based learning, engineering-involved courses, Teamwork

I. INTRODUCTION

The necessity of restoring the balance between practice and science in higher education has long been acknowledged in educational literature, which is now even more pertinent to engineering education. The situation is similar in Chinese undergraduate education.

To educate students how to learn rather than teaching them specific techniques, contemporary engineering education should focus more explicitly on skills including problem-solving, communication, teamwork and leadership skills. As engineering educators, the engineer in education field whose products are students, we view quality teaching of undergraduates as being on par with other scholarly responsibilities and achievements. Equipping students with a range of important professional skills, such as project management, teamwork and cross-cultural communication can be achieved in a carefully managed open ended project course[1]. Project-based learning dealing with key aspects of product design and realization has been acknowledged by many academic institutions as an appropriate means in the training of adaptable, reliable and responsive engineering students[2]. In 2009, a 12-week-long project-based experimental course Optoelectronic Instrument Experiments (OIE) was launched at the School of Opto-Electronics, Beijing Institute of Technology[3]. Our purpose is to help students to improve their engineering practical and personal skills as well as their team collaboration.

Collaboration is one of the most treasured attributes for a qualified contemporary engineer. That's the reason why teamwork is emphasized in OIE course. However, initial resistance to team-based approaches from individual students is quite common and students are not born knowing how to work effectively in teams[4-6]. According to the survey that was conducted at the end of each academic year among all the students who had taken the OIE course, some of the students complained that the grouping rule and the team assessment manner was unfair. Instead of changing the rule, trying to find a way to persuade the students to accept and support their group willingly might be a better solution. In this semester, the project teams are entirely determined by lot and several teamwork inspirational approaches are introduced to inspire team spirit in the course. In this paper, we will give the detail of our tryout and analyses.

II. TEAMWORK PEDAGOGY AND ISSUES IN OIE

A. OIE: The Project-based Course

OIE is a lecture-lab course which aims to familiarize students with the principal ideas of optoelectronic apparatus design and train students to apply the knowledge to identifying, analyzing and solving problems in optoelectronic system construction. We try to expose the students to "real" engineering early. After some brief general topics on optoelectronic instruments and introduction to several successful design examples, the students are assigned to teams and each team chooses one project to implement in twelve weeks. Through the mini simulative "Cycle of Professional Practice"[7], students will learn how to integrate the knowledge and techniques they have learned previously, and use different kinds of components and devices to construct an optoelectronic instrument.

The main difference from the other project-based courses is that the OIE course is compulsory, which means every student must take this course. In our opinion, students are the products of their college. Elite education may help several excellent students to achieve huge success, but we prefer to the results that all the students turn to be qualified products. All the students who are majoring in Measurement & Control Technology and Instruments have to gain the OIE credit to get their bachelor degree. We are trying our best to impel them to be prepared for the real engineering environment they have to throw themselves into soon.

B. Teamwork Pedagogy and Issues

In order to work in modern team-based environments, students must develop the interpersonal skills of teamwork. That's the reason why teamwork is emphasized in the course. The teamwork pedagogies in OIE are summarized as following:

1) Instructor Team: The OIE course has a 6-member instructor team, including full professors, associate professors

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and lecturers. Lectures in the beginning weeks are given by different teachers, each being adept at one specific aspect such as optical design, mechanical structure or image processing. While they are working as consultants/ advisers/ supervisors in the course, it simulates a team of experts helping the students. This special pedagogy proved to be attractive to all types of students and met to the needs and issues of the broader community.

2) Team Assessment: In the grading phase the teamwork is underscored reasonably. At the end of the course, each student is to hand in their own final project report and a mutual assessment form on which each student should grade his teammates and himself in both technical contribution and collaboration. After the teachers mark all the reports and the average score given by his teammates are calculated, along with the competitive examination estimation, each student has three scores: report score, mutual assessment score and competitive examination team score. The final score of the course is determined by the three factors. The grade of each student is influenced by the team score, that is, if the team does not work well, the team member, no matter how outstanding his personal capabilities are, will suffer a lower grade.

The OIE course has been carried out four academic years. The experience of this course has led to insights in teaching style design, especially with respect to engineering-involved courses. It also helped us find several unsolved issues, most of them involved in team grouping rules.

In the OIE course, there are two alternative team grouping rules: free combination and assigned team manner. Free combination is preferred by some active students because they want to work with classmates who share the same interests and are at a similar competence level. But some introverted students might be ignored or underestimated by their classmates. Furthermore, it could induce initial competence gaps between the teams and the gap will widen as projects progress, which is definitely not what we desire since we view OIE not only a course for professional skill training but a chance for building confidence in engineering field. Assigned team manner was applied in OIE since engineers rarely have the opportunity of choosing their team colleagues in practice. We want to expose the student to a real engineering environment and let them deal with it. Unfortunately but understandably, this assigned grouping approach produced complaints by several students and the repellent mood did reduce the team spirit.

III. WHAT'S NEW THIS SEMESTER

The OIE course is compulsory, which means every student must take this course. Willing or not, students had to work their project out as a team under certain grouping rule. In order to minimize the gap among students' groups and try to ensure that they are in the similar beginning level, several different assigned rules were attempted in OIE: according to the student's academic records in previous courses, according to the level of student's activity, or the teachers' impression. Each of them produced complaints by several students.

We believe in the power of teamwork and we insist that it should be taken into account in grading a project-based course. We also are aware that students could learn more and be more creative with less repellent and conflicting moods. After several trials of different grouping rule, we realized that there is no perfect rule which can satisfy everyone. Instead of changing rule, trying to find a way to persuade the students to accept and support their group willingly might be a better solution.

In this semester, the project teams are entirely determined by lot and several teamwork inspirational approaches are introduced to inspire team spirit in the course at the beginning of the class. Our purpose is to find a way to make student learn the interpersonal skill of working in team. Let's do it, not just deal with it inactively.

A. Team Grouping

The first class of OIE is arranged for team grouping. In this semester, the students are grouped "providentially". Some poker cards with funny pictures are prepared before, the total number of which equals to number of the students who have signed up for the OIE course. Every student is asked to draw a card from the poker card pile when he enters the classroom. Just when they enjoy the funny view on their cards and become curious what it is for, the grouping rule is announced. The students who got the same suits and numbers are grouped as a team.

Most of students do not "hate" any of their classmates. They just do not like the feeling of being assigned. The project teams are entirely determined by the cards they choose by themselves, which could induce less conflicting mood even the teammates are not who they are expecting.

After the announcement of grouping rule, the students are given about five minutes to find their teammates, name their team and elect a team leader. Then after five more minutes' preparation, each team is required to give a 5-minute speech in front of the class and the instructor team. The speech is supposed to include the following information: the brief introduction to each team member; the most remarkable personality of each member; the origin of their team title; the expectation of the course; and at least one strong point that exceed other teams. All members of the team should take a role in the speech.

The team grouping class works as the icebreaker as well. Most Chinese students are reticent and lack of the courage to express themselves. Usually contradictory in teamwork stems from poor communication and misunderstanding. The first work they do together is naming their own team and finding their strong points, which is helpful to familiarize them with each other quickly and build the initiatory team spirit. Furthermore, the joint speech also can help students to begin to practice oral presentation which is one of engineering skills the OIE course aims to help the students to gain.

B. Team Spirit

One of the major missions for project-based course OIE is to teach the students to work together with good team spirit which is about supporting their team, respecting others and most of all encouraging their team mates. What we do for inspiring the team spirits of the students this semester is to give them more pressure.

In OIE course, after the students are grouped into several engineering teams, each group is required to choose a project from about fifteen available ones each of which comes from real engineering projects or is a simplification of teachers' research. That is what they will devote to as a team in the following twelve weeks. They are given about a week for analyzing problems to be resolved, investigating information, generating alternative solutions, disassembling and modularizing assignment, and dividing work among the group. Then in the following week, the students (as a team) should present their project plans to the teachers who are in charge of the course and also some invited faculties who have rich experience in engineering research. They are to present the analysis, their conception and design of the assigned projects, and the project budget. The teachers ask questions, give advice and approve budgets, then decide whether the team and their plan are ready to be implemented or not. The team whose project plan fails to pass the teachers' evaluation has to redo all the preparation and presentation.

This semester, during the project plan approving phase, we were more strict to and even a little more critical of the students team and their project plan on purpose, especially on some issues which seemed due to insufficient team communication, such as assignment modularizing and work dividing. Most of the teams failed the first round and had to redo project plan and the presentation. During the process, the team member united much closely and the team spirit or team cohesion were strengthened effectively. The greater the external force adds, the more solid the structure is. It seems true in OIE course.

C. Benefit Distribution in Teamwork

In real engineering environment, teamwork is not only about implementing the project, solving the problem and completing the work, but also about distributing the profit. We try to expose the students to "real" engineering early, benefit distribution must be involved.

In a project-based course, the most direct benefit to the students is their scores. As we mentioned, in the grading phase of OIE, the teamwork was underscored reasonably. The final score of the course was determined by final mutual assessment score and competitive examination team score, which can also be counted as a kind of profit distribution. This semester, we are attempting to bring the rule of distribution according to work into the whole process of the project. The OIE has intensive classes. In each class every team is given a certain amount of credits and asked to distribute the credits to each team member according to what he have done this time before the class is dismissed. If everyone works hard equally in this class, each will earn the average credits. Otherwise the one who makes more technical contribution and collaboration will get higher scores. These scores from each class will form the daily credit of each team member.

At the end of this semester, we plan to give every team a credit package according to the final competitive examination. Every team member will get his final score by dividing the whole package in proportion to their daily credit. The superior team will earn a bigger package and the hardest worker gain the highest final score.

Our purpose is to let the student realize and understand the benefit distribution in real engineering team, as well as to inspire the students to further efforts. So far, the daily credit assessment does drive the student to invest more energy in their projects.

IV. Discussion and Future Work

Since the capability to work in teams has become a key requirement on engineering graduates, education not only embraces technical competence but also necessitates interpersonal skills. In this paper, we give several of our new tryouts and the analysis on teamwork training in the project-based course OIE. The outcome of these new trials should be criticized by the students.

At the beginning and the end of each academic year, surveys constructed based on several aspects(such as the course organization, the teachers' team, the pedagogy, and the expectation of the course, etc.) are conducted among all the students who have taken the OIE course. Besides the regular surveys, this year each respondent is asked to give a self-evaluation on their teamwork skill before and after taking the course. According to the preliminary statistics, about 75.44% participant think that the course is helpful to improve their teamwork skill and their self-awareness of being a team-member, while 14.04% of them feel it is useless and 10.53% feel the course hurts their self-confidence in collaboration. We are working on the further data collation and analysis. Hit or miss, we will give our investigations further.

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EXPLORES: An Integrated Learning Environment to Produce Industry Ready Graduates

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***Abstract*—To maintain competitive advantages in today's global market, US companies are challenging higher education institutions to bridge competency gaps between industry workforce needs and what is provided by engineering education programs. To meet this challenge, the Mechanical Engineering program at the University of Cincinnati proposes the EXPLORES (Experiential and Problem-based Learning within Opportunities for Real-world Engineering Settings) model where students from freshman year onwards are exposed to real-world industrial problems that have a direct bearing on fundamental engineering concepts. The EXPLORES model is implemented in a learner-centered, knowledge-centered, assessment-centered, and community-centered student learning environment. Although inclusion of real-world industrial problems into engineering curriculum is not a new invention, the EXPLORES model is unique in the following aspects: (1) the problems span multiple courses so students need to have the ability to synthesize knowledge acquired from different courses in order to develop complete solutions; (2) industry partners are an integral part of the education process by providing problem design, periodic feedback, and expert solution; and (3) an on-line virtual company framework is used to facilitate information sharing and motivate student learning.**

Keywords—problem based learning; industrial problems; learning environment, manufacturing processes; engineering statistics

I. INTRODUCTION

Traditionally, engineering students are taught in a classroom setting with the instructor explaining various concepts and deriving the appropriate mathematical relationships. The instructor may also present some applications of these concepts. However, students may not really appreciate the true learning of these concepts unless they are tied to a real-world industrial problem that has a direct bearing on the concepts. Tying the teaching of a concept to the student actually participating in the application of this concept in an industrial setting may result in lifelong retention of the concept [1-3]. In addition, an optimal solution to a larger industrial problem requires appropriate synthesis and adaptation of multiple concepts in a discipline or across disciplines in a comprehensive manner. Currently available curricula at most engineering institutions do not include a systematic study of real-world problems, although some organize problems disparately among different courses. The present practice hinders the development of common understanding among students to integrate concepts from different courses to solve larger real-world problems. Because prevailing engineering education pedagogies do not target real-world problem solving in a comprehensive manner, our graduates need to go through a substantial period of after-hire training before they can contribute to their employers.

The EXPLORES (Experiential and Problem-based Learning within Opportunities for Real-world Engineering Settings) model is proposed to bridge competency gaps between industry workforce needs and what is provided by engineering education programs. It is implemented in a learner-centered, knowledge-centered, assessment-centered, and community-centered student learning environment, as shown in Fig. 1. Specifically, real-world industrial problems are identified that can be broken down into sub-problems and mapped to a selected set of key concepts taught in clusters of core courses in the Mechanical Engineering curriculum. These case problems are presented under a virtual company framework. Students post their work in the virtual company repository during different stages of the learning process. Their solutions and procedures are then viewed by the instructor, industry partners, and other students who provide periodical feedback. Industry experts would then meet with students to discuss the pros and cons of the solutions from a real-world perspective. The efficacy of the EXPLORES model is being evaluated in two pre-junior courses; namely, Manufacturing Processes and Engineering Statistical Methods.

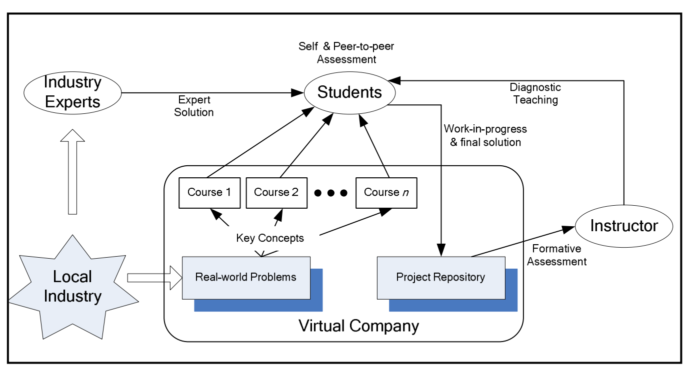

Fig. 1. A learner-centered, knowledge-centered, assessment-centered, and community-centered student learning enivornment.

II. Scientific and Educational Feasibility

The academic community has long recognized that individuals have a variety of learning styles and preferences for receiving and processing information [4]. Research has demonstrated that traditional methods used to teach students are not congruent with many individuals' preferred method for receiving information [5]. In engineering, we have seen that undergraduate education has failed to provide instruction in a manner that is engaging and relevant to large numbers of students [6]. While the explanation given for years was that these students were simply not suited to engineering, other educational leaders have suggested that our traditional educational paradigm has failed significant numbers of students [7, 8]. To meet this challenge in engineering education, we should remember that students are driven by passion, curiosity, engagement, and dreams; and thus we should focus on the environment in which they learn [9]. In fact, Jamieson and Lohmann [10] pointed out that "engineering education innovation is about designing effective learning environments."

The EXPLORES model is rooted in the problem-based learning (PBL) pedagogy while emphasizing the development of a learning environment that is conducive to knowledge acquisition and retention. A few recent studies showed that integrated approach of PBL pedagogy and online delivery model enhanced students' learning attitudes [11], better prepared students for applying the knowledge learned in the classroom [12], and provided a coherent and comprehensive learning environment [13, 14]. These evidences support the presentation of real-world industrial problems using a virtual company framework. Students will have a better understanding of the industrial environment, why they are learning Mechanical Engineering, and how they can apply what they learned to solve problems that have a direct bearing on company missions.

III. Expected Outcome And Evaluation Plan

The expected benefit of this project is that by unifying engineering education with industrial reality, undergraduates will be better educated in applying theory to real-world problems; thus allowing every stakeholder to maximize their return on investment in the education process. In addition, corporations will have better qualified applicants for their job openings, and faculty will have better awareness of the needs of corporate America, thus building an infrastructure of partnerships and networks for both education and research.

The project evaluation will be conducted by the University of Cincinnati's Evaluation Services Center (UCESC). Both quantitative and qualitative methods will be used in conducting formative and summative evaluations. Formative evaluation is meant to track the progress of the project and implement improvements within the duration of the two-year project period. Summative evaluation will be conducted to determine the extent of project success that will be measured in terms of students' outcomes. The major participants in this evaluation are the pre-junior engineering college students participating in two pilot courses implementing the EXPLORES model. The program theory is: students who experienced the EXPLORES model in learning the chosen engineering courses will be more motivated to learn and will manifest better critical thinking skills and greater applied engineering knowledge and skills needed by the industry compared with similar students who were trained with the same courses but were in traditional classrooms.

IV. Importance to the Education Community

To the best of our knowledge, no one has previously attempted to frame a curriculum around a corporate structure and actively involve industrial partners in engineering education. We focus on mapping a few key concepts in each course to projects based on real-world industrial problems. In-depth coverage of these key concepts and their application to real-world problems supports learning with understanding, which is important for the development of expertise [4]. In addition, students will see the usefulness of the key concepts and can apply them to solve problems that have a direct impact to local industry. They will feel that they are contributing to the community and thus are motivated to learn [15-17]. Making industrial partners an integral part of the education process can demonstrate to students what expertise looks like while providing a non-intrusive feedback mechanism. Students can learn to assess their own work as well as the work of their peers; and thus help everyone learn more effectively [18].

V. Project Status and Preliminary Result

This project started in May 2012. The initial focus was on developing the web-based virtual company (current website address http://uc-star.info/v1.9.uc-star.info, version number may change and an official site will be created once the virtual company is fully developed). The company was named STAR Corp. Technical Center. It has two departments; namely, Manufacturing (corresponding to the Manufacturing Processes course) and Quality Assurance (corresponding to the Engineering Statistical Methods course). There are three types of users, summarized as follows:

- *Engineers*. They are students who will be working on projects pertinent to the courses that they are taking.
- *Directors*. They are course instructors who will assign projects to the engineers, monitor project progress, and assess the performance of the engineers.
- *Consultants*. They are industrial experts who will provide feedback to the engineers.

Industrial case problems are currently being developed. These problems will be presented as projects in appropriate departments of the virtual company and assigned to engineers. Students in the Manufacturing Processes and Engineering Statistical Methods courses will be working on these projects starting Fall 2013 and Spring 2014, respectively. Their performance will be compared to that of the students taking traditional courses without implementing the EXPLORES model. The performance data of these traditional course students are currently being collected (Manufacturing Processes in Spring 2013 and Engineering Statistical Methods in Fall 2013).

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Teaching Business Analytics

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***Abstract*— It is essential to prepare students with knowledge and skills in area of business analytics (BA) which will help business to process data, find patterns and relations, develop insights from past transactions, and make prediction. We develop hands-on labs to teach business analytics to students in Computer Science, Information Technology, and Software Engineering disciplines. Our hands-on labs can be adopted in courses such as database systems, data warehousing, data mining, etc. We use enterprise BA tools including MS SQL Server Business Intelligence and Cognos 10 platforms, which are essential to increase student interests, improve student learning, and enhance student confidence. Our hands-on labs contain three parts with one is built upon another: 1) Data integration; 2) Data Warehouse; and 3) Business analytics.**

Keywords— business analytics, hands-on learning, data analytics

I. INTRODUCTION

An increased number of businesses are using computerized system to gain competitive advantages and make decision, given continuous large amount of data collected from consumers, employees, suppliers, competitors and product inventory. McKinsey's research [1] says there will be a shortage of talent necessary for organization to take advantage of big data. "By 2018, the United States alone could face a shortage of 140,000 to 190,000 people with deep analytical skills as well as 1.5 million managers and analysts with the know-how to use the analysis of big data to make effective decisions."

In observation of this demand, we have developed a series of new hands-on labs on data analytics with real-world and business relevance. Student will first experience generation of data mart and Extract, Transform and Load (ETL) processes in data integration part. ETL is important because it lifts data from transactional systems to operational data stores, data warehouses, and BA platforms. In the part of data warehouse, students will exercise with data warehousing, data dimension, cube and online analytical processing (OLAP). Students create, edit, import, export, and deploy cube models over the relational warehouse schema to perform deeper multi-dimensional analysis across multiple business variables and large data sets. Students also use optimization techniques from cube to improve the performance of online analytical processing (OLAP) queries. In the part of business analytics, students will be taught data mining and artificial intelligence (AI) concepts and algorithms which are then used in decision making. Students use data mining models (clustering, associations, classification, and prediction) to gain business insights. Students also experience rich presentation components, visual analysis of data mining results and interactive tools. BA helps students to apply techniques to assist decision making in business relevant fields.

The innovation of our hands on labs on business analytics lies in engagement of students into enterprise products with real-world business settings, exploration of efficacy of BA as an inter-disciplinary field, and sharpening student skills by data sets with real-world relevance. Examples of skills include:

- Being able to exploring data to discover new relationships and patterns (data mining)
- Being able to explain why a certain result occurred (statistical analysis, quantitative analysis)
- Being able to evaluate previous and alternative decisions (A/B testing, multivariate testing)
- Being able to predict future trends (predictive modeling, predictive analytics)

Being able to visually analyze data (computational modeling, human computer interaction, and graphics)

II. HANDS-ON LABS ON BUSINESS ANALYTICS

Hands-on learning approaches engage students actively and thoughtfully in learning [2]. Students in a hands-on science program remember the material better, feel a sense of accomplishment when the task is completed, and are able to transfer that experience easier to other learning situations [3]. These benefits are achieved because "more than one method of learning is accessed" in hands-on learning and "the information has a better chance of being stored in the memory for useful retrieval" [3]. Naturally, the best teaching method is to offer interactive exercises based on problem solving. Resources and hands-on labs are lacking in the area of business analytics although they are important in preparing needed skills for future workforce. We developed the following hands-on labs in BA.

A. Labs on Data Integration, Transformation, and Loading

Students first create a data mart as a repository for data to be used as a source for business analytics. The data can come from various resources such as online transactional processing (OLTP) systems, XML files or databases. The data marts are architected using either a star schema or snowflake schema. The data marts are not much useful for decision making until they contain enough useful data. Students will then change

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location of data by copying it from the OLTP databases or other locations into the data mart, which is called data integration. They will also be required to transform the data from the format required by OLTP to the format required by the data mart if data sources are heterogeneous. Foreign key values will be verified during load of the data, which enables implementation of data mart without foreign key constraints. Figure 1 shows a data flow that loads a table to a data mart.

Learning outcomes:

Students will be able to understand incomplete and heterogeneous nature of data sources. They will be able to create a data mart by data integration, transformation, and loading services.

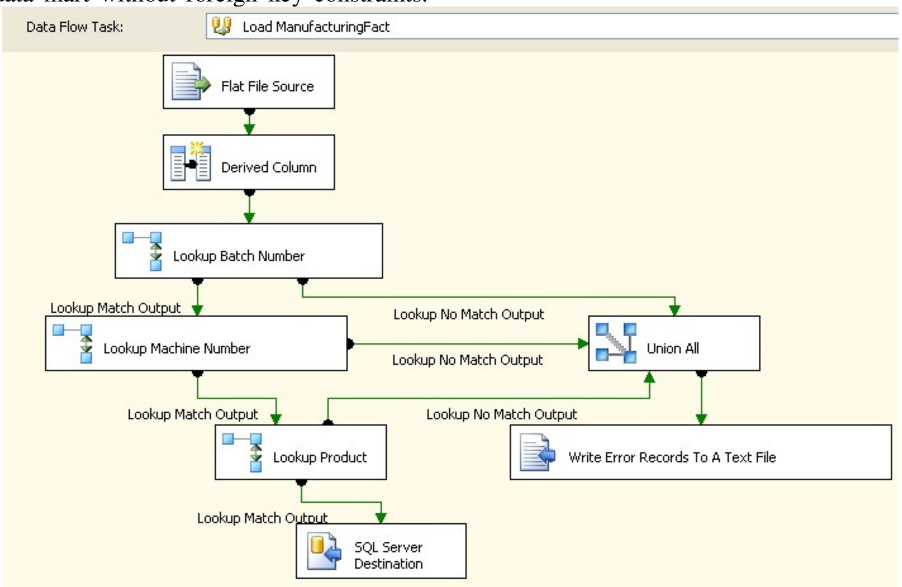

Figure 1 Load data into a data mart

B. Labs on Business Analytics

In these labs students need to access the data mart to populate and update the information in the OLAP cube which has measures, dimensions and attributes. Measures provide the actual information that the users of our cubes are interested in. Dimensions allow students to slice and dice the measures in the cube until they find the meaningful business relevance hidden among all of the numbers. Dimensions provide understandable phrases in business language to define what may be cryptic in a transactional database system. Students have a variety of dimension such as time in their cube to measure groups to perform meaningful analysis on the cube. Additionally, students will also include information discovered by data mining algorithms in their cubes.

Students will also apply data mining algorithms to discover patterns and business relevant results out of their data mart. Data mining allows them to utilize computer power to combine huge amount of data to find meaningful information. The data mining algorithms include classification, regression, association, sequence analysis, and probability predictions. Figure 2 shows how to use decision trees to predict and analyze data using SQL server Business Intelligence Development Studio.

Learning outcomes:

Students will be able to gain business related information by dimensions of data. They will also be able to mine information using related data mining algorithms.

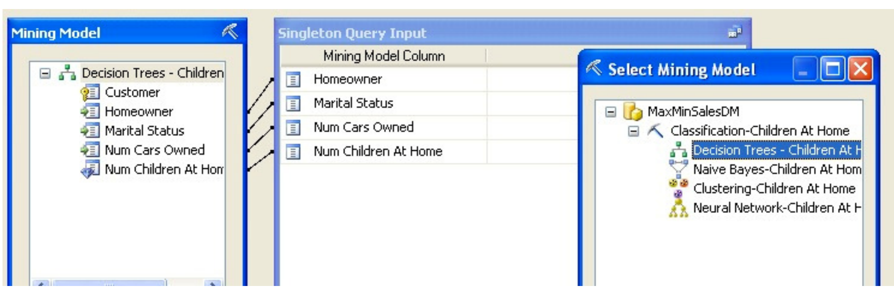

Figure 2 Employ a data mining model for business analytics

C. Labs on Reporting and Delivery of Business Analytics

In the business analytics world, the report is king. Reporting services enables both developers and users to create report. Students devliver reports to demonstrate results of their analysis of data sources. Figure 3 shows an examples of report in the form of interactive dashboard. In this report, students are trying to where and why products are the most frequently returned, and that have the biggest impact on the company's profit. This example comes from one of IBM Cognos Business Intelligence Examples [5].

Learning outcomes:
Students will be able to create a report and interactive dashboard, which supports business related decision making.

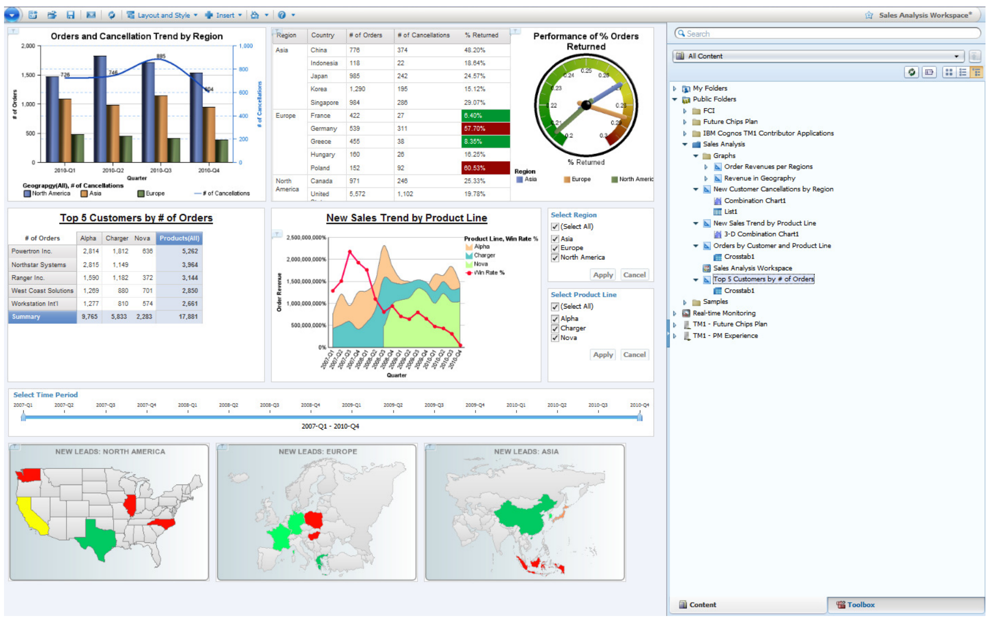

Figure 3 Interactive sales analysis dashboard

III. CONCLUSION AND FUTURE WORKS

These new hands-on labs on business analytics promotes students' learning interest in big data analytics and improves their learning by practices. We received positive feedback when we used them in fall 2012. Their feedbacks manifest a promising effect of the developed labs in helping students with practicing the "learning by doing" methodology, engaging students in learning and interacting with big data. We are current working with local companies for more real-world relevant projects such as Smart Grid in order to bridge hands-on learning with project-based learning (PBL). The PBL will ensure deeper understanding over content coverage. In PBL, complex problem solving skills are developed rather than learning skills in isolation [4].
We will also explore and develop more hands-on labs on business analytics using Open Source Software such as Hadoop, STORM. Meanwhile, we will make dataset that we used available to academic community.

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Authentic Learning of Mobile Security with Case Studies

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Abstract— **This work-in-progress paper presents an approach to authentic learning of mobile security through real-world-scenario case studies. Five sets of case studies are being developed to cover the state-of-the-art of mobile security knowledge and practices. Some of the developed case studies are being implemented in related courses and the preliminary feedback is positive.**

Keywords- Authentic Learning, Case Study, Mobile Security

I. Introduction

Owing to their ultra-portability, enriched functionality, and ease of use, smart mobile devices, such as Android and iOS based smartphones and tablets, play more and more important roles in many aspects of our society. Users increasingly use their mobile devices to access to the wealth of information available on the Internet, to store sensitive data, to communicate and entertain, and to process many of their daily tasks. These, however, also attract attackers to extend their targets to mobile platforms, resulting in a rapidly increasing number of mobile threats and a growing sophistication of mobile attacks [1-4]. In this work, we use the notion of mobile security to cover the topics of security and privacy issues, attacks, and defenses involved in the use of smart mobile devices. The mobile security is at the intersection of wireless communication, mobile computing, and computer security; and has its unique characteristics, such as introducing new and unique mobile security threats. Few existing security courses cover the full spectrum of mobile security topics; in addition, dedicated courses and effective materials on mobile security are sparse. This calls for efforts to promote mobile security education and to foster qualified mobile security professionals.

This work-in-progress paper presents an approach to authentic learning of mobile security through real-world-scenario case studies. Authentic learning situates students in learning contexts where they encounter activities that involve problems and investigations reflective of those they are likely to face in their real world professional contexts [5, 6]. A recent report pointed out that rather than only teaching students abstract concepts and assigning students abstract exercises, engaging students in real-world settings will benefit student effective learning in security education [7]. In this work, we approach to authentic learning of mobile security via the design of learning materials into real-world scenario cases, and take advantage of mobile device as the authentic learning platform, which will also help create a portable and affordable security-learning tool.

Courses focused on mobile security remain sparse in most computing curricula. Tague offered a mobile security course at the Carnegie Mellon University [8, 9]; however, it was a project-based course that provided students with topics for discuss and explore. In contrast, our work emphasizes on learning mobile security through real-world case analysis and hands-on experience, and we develop the materials for the learning. The application of Android in the education of various computer science subjects is obtaining increasing interests. For example, Andrus and Nieh [10] developed a series of five Android kernel programming projects and an Android virtual laboratory to teach an introductory operating system course; Kurkovsky [11] used mobile game development as a motivational tool to engage students early in the curriculum; and Loveland [12] described the use of Google Android mobile platform and Google's Web Toolkit to provide students with experience in designing and implementing user interfaces for mobile and web applications. The above works showed that the use of Android engaged students' interests in learning and improved effectiveness. Our work focuses on using Android to promote the study of mobile security and we directly use mobile devices and applications for security analysis and practice.

II. Case Study Design

To implement the authentic learning for mobile security, this work employs the following strategies in the development of the case studies, including: 1) connecting the abstract security concepts to real-world mobile security cases so that students can better understand the concepts and can work more actively and effectively with facts and realistic problems; 2) designing each case from both of the attack and defense perspectives so that students can gain more insights and can design better defense solutions via the experience with actual attacks; 3) infusing hands-on practices in the course of case studies and designing most of the practices in such a way that they can be performed on mobile devices directly; 4) encouraging students to identify for themselves the mobile security issues; and 5) providing students with opportunity of reflection in action so that they can learn how and when to use particular strategies for problem solving. Following the above

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strategies, we are developing five sets of case studies, including:

- Mobile Malware. Case studies that 1) discuss the mobile malware attacking strategies and demonstrate instances of real-world Android malware; and 2) discuss the defense methods and instruct on practicing defense solutions.
- Secure Mobile Coding. Case studies that 1) use code examples to demonstrate the security weakness or unsecure coding patterns in the development of different Android app components, including *Activity*, *Intent*, *Service*, *Content Provider*, and *Broadcast Receiver*; and 2) discuss the best practices for improving the security of the Android app coding, such as using explicit *Intent Filter* to avoid *Intent* spoofing.
- Cryptography on Mobile Devices. Case studies that 1) discuss how to utilize the built-in cryptography mechanisms (e.g., SSL or VPN settings) to improve the security of data in device (database storage, shared memory, shared preferences, internal and external storage), on Cloud, or in the course of network communications; and 2) discuss how to program with Android/Java cryptography libraries to enhance the security of mobile apps.
- Access Control. Case studies that 1) discuss the Android permission model, including its basic concepts, use cases, weaknesses, and enhancements; and 2) discuss other access control and authentication mechanisms for mobile devices and application, including single sign-on and two-factor authentication.
- Mobile Privacy. Case studies that demonstrate the leakage of privacy-related data from mobile devices and communications (e.g., location information, user behavior and usage patterns), and discuss the configurations and best practices for mobile privacy enhancement.

As an example, the set of mobile malware case studies consists of an introductory case study and a set of individual malware case studies. The introductory case study summarizes the state-of-the-art mobile malware research (e.g., [13, 14]) and the malware reports from leading mobile security companies. Each individual malware case study introduces a family of real-world mobile malware, covering the topics of the attackers' incentives (e.g., Premium Calls/SMS or Information Stealing), attacking strategies (e.g., repackaging or update attacks), and existing defense solutions. It is observed that the number of new instances and variants of existing mobile malware families increases rapidly, but the number of new malware families grows rather slowly [14]. We will prepare for each case study at least one real instance of mobile malware in the family so that students can experience the actual attacks in a sandbox environment (i.e., an Android emulator on a virtual machine with experimental settings and data) and analyze the malicious behaviors and features. Each individual malware case study will also instruct student on practicing defense methods. Current mobile malware defense methods include app analysis (static/dynamic/permission analysis), configuration of system security settings, watchdogs, and user education. As the mobile malware evolves, the introductory case study will be updated and new cases will be developed and added into our individual malware case study set.

Fig. 1. Work Flow of a Premium SMS Android Trojan App in Our Mobile Malware Case Studies. (① the Trojan app is downloaded and installed on the victime's device; ② when the Trojan app is activated by the victim, it sends a notification with the victim's information to the hacker; ③ the hacker sends the commands to the Trojan app to ④ send SMS to premium numbers or send Ad SMS to others; and ⑤ the trojan app clears messaging history.)

Fig. 1 illustrates the work flow of an instance of Android Trojan in one of our individual malware case studies. The Trojan app pretends itself as an Asian Gourmet Android app, performs command and control communication with the hacker, and stealthily sends short messages (SMS) to premium numbers or advertisements to others. In the defense practices, students will be instructed on developing an Android SMS Monitoring App, which monitors the messaging actions in the background and sends notifications to users when suspicious messaging are detected. Note that in the latest version of Android 4.2 (Jelly Bean), Google provides similar kinds of control of premium SMS to enhance the Android security.

III. Conclusion

This work-in-progress paper presents an approach to authentic learning of mobile security through real-world-scenario case studies. We describe our strategies in developing the five sets of mobile security case studies and present more detail design of the set of mobile malware case studies.

Some of the developed case studies are being implemented in CS mobile security class and IT wireless security class. The preliminary feedback from students is positive. Students have gained hands-on real world experiences on mobile security with Android mobile devices, which also greatly promoted students' self-efficacy and confidence in their mobile security learning.

In the future work, we will continue to improve the design of the case studies, complete the case study development, and conduct extensive evaluations.

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Developing a remote release mechanism in support of unmanned aerial systems: A comparison of two separate approaches in freshman engineering design.

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Abstract- **As restrictions on operating small unmanned aerial systems (sUAS) in the United States national airspace system (NAS) have compounded university researchers in this discipline have had to react by developing increasingly more novel ways to collect remote sensing data. Current restrictions by the Federal Aviation Administration (FAA) require universities to apply for a Certificate of Authorization (COA) to operate any remote control device for the purposes of research. Previously, many universities operated under Advisory Circular (AC) 91-57 (for model aircraft operators). University research does not fall under this circular and therefore, alternative methods of gathering aerial images in support of the universities remote sensing projects needed to be explored.**

The freshman engineering design course at the University of Maryland Eastern Shore is a multidisciplinary and collaborative effort between the Engineering Program and Aviation Sciences Program faculty. Introductory engineering design process theory is taught by engineering faculty while students engage in an experiential exercise in problem solving with the Aviation faculty serving the role of a client with a specific problem that needs to be remedied.

This paper outlines the freshmen engineering design process from the introduction of the initial problem statement, mid-term review and final product delivery of a remote release system for a non-powered glider sensor system. The aviation faculty serving as the client is involved with the class from initial team selection to evaluation of the final product and student's presentation abilities.

Students were asked to design a remote release system that would support the deployment of the client's glider platform from an existing kite lifting device. The freshman design class was divided into two groups and asked to design systems that would meet the clients design criteria. The authors present an in depth comparison of design approaches, execution and lessons learned. Group leadership dynamics are considered.

Index Terms – Remote release, sUAS, engineering design.

INTRODUCTION

One of the issues confronting learning environments is the ability to integrate diversity of approach both in teaching and learning modalities. With the freshman engineering course we have attempted to use the diverse faculty in the department (engineering and aviation sciences programs' faculty), to structure projects that advance engineering principles as well as proof of concept in its application to the aviation program.

The benefit for students is that they are able to engage the faculty both as clients and instructors that result in a variety of learning modes. For this project, the class size was large enough to be divided into two groups. This provided the faculty an opportunity to study the students' applications of engineering principles as well as the approach to finding solutions given the same problem. Engineering design concepts with emphasis on various aspects of planning, developing and product design via hands-on approach was the key to this course experience. It also enhanced the students' communication skills and teamwork. Product visualization utilizing computer software such as word processing, PowerPoint, and spreadsheet enhanced the students' ability to collaborate in defining, developing, and designing a working prototype. Students learned the components of product development such as brainstorming, time allocation, project management, alternative designs, and cost constraints.

Furthermore, the students in the class engaged in teamwork in a multidisciplinary environment such that the reality of cooperation in a global economy became a lesson realized early in their freshman engineering year in college. With a dynamic marketplace, graduates need to be able to interact effectively in diverse fields. One important goal of multidisciplinary design is to identify the many solutions needed to solve a single problem while keeping in mind the many differing objectives of the overall project [2]. A multidisciplinary approach to engineering design is valuable in that it asks that students make certain that, "…advances in performance,… technology, or discipline(s), must be much more highly integrated than in the past" [1]. Students partaking in the engineering exercise are forced to confront concepts outside of their normal field of expertise in the short span of a semester and make decisions on a cost and design schedule.

CUSTOMER REQUIREMENTS AND CONSTRAINTS

Client Requirement: Design a remote release device that can successfully deploy a model airplane from a kite with a minimum altitude of 300 feet.

Constraints included:

The model airplane being released from the specified altitude and gliding unassisted to the earth.

The kite system does not interfere with the flight or path of the released airplane.

Students can predict, with relative precision, the flight path of the released aircraft.

TEAM PROJECT EVALUATION

Student leaders were selected using a selection survey tool. Group members met to determine team responsibilities and areas of specialization. The group decided to break the team tasks into the following categories:

- Picavet
- Kite
- Remote Release System
- Model Airplane

All other tasks such as group reports, purchasing items, and aiding other teams were shared by all members of the group.

Students were required to keep a weekly log, make periodic reports to the course instructor and propose a tentative timeline to the client that would be compared to the actual timeline and schedule at the end of the semester.

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INNOVATIVE DESIGN

After researching kite based imaging platforms, students determined that a picavet system would provide a stable mounting system for the robotic release system. Students constructed the "T" type picavet out of string, eye screws and wood (Figure 1.)

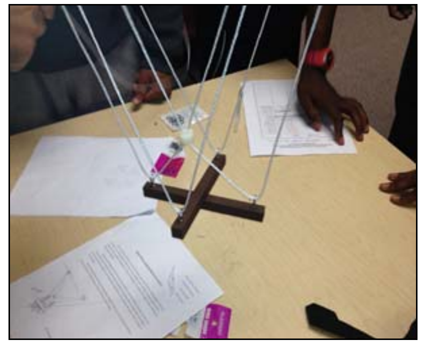


FIGURE 1. Group 2 Picavet system

The remote controlled robotic arm was attached to the picavet which would then hold and eventually release the glide (Figure 2).

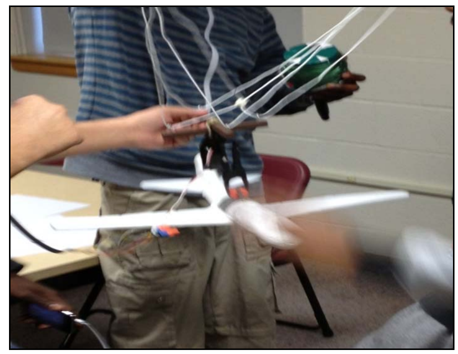


FIGURE 2. Group 2 release system with glider

Group 1 went with a different approach. They utilized the off-the-shelf items shown in figure 5 below to remotely release the system via a RC servo unit.

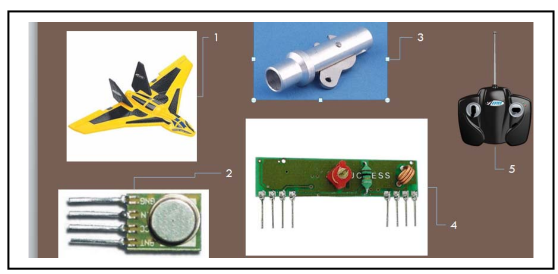


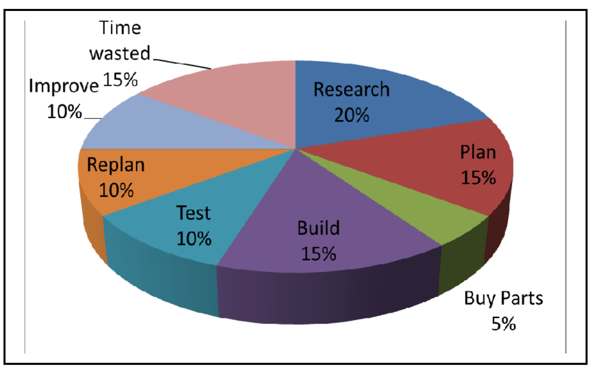
Figure 3. Cannibalized parts for Group 1

The kite integration group from group 2 was focused on stability issues with launching the system and determining how best to attach the system to the string line (Figure 4).

FIGURE 4. Kite system

FINAL TIME USAGE BREAKDOWN

In the end, less time was spent (Figure 14) on research and planning then expected by both groups. The build time was consistent with early predictions but less time was spent on testing (originally planned for 15%). Re-planning, improvements and time wasted was reported comprising over a third (35%) of project time.



In their final report to the faculty and client, the students identified the following challenges they encountered during the design process:

- Communication Issues
- Conflict with deciding on a design system
- Wasn't able to find a cheap car to use for the original solution
- Delayed Shipments
- The wire attached to the Picavet system was too heavy for the kite.
- The string was damaged accidently by a group member.
- The robotic arm broke due to faulty connection to the kite and had to be repaired.
- How to measure the altitude of the kite.

Overall, the project was a success. The challenges of time, resources and limited subject knowledge required students to brainstorm and react whenever a new challenge arose. Students reported that working in a team environment was extremely difficult. Regardless, they were proud of the project outcome and indicated that they had a great sense of accomplishment considering the constraints, limitations and challenges. The analysis of the leadership qualities and level of students' cooperation will be provided in the oral presentation of this paper.

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A Community College Blended Learning Classroom Experience through Artificial Intelligence in Games

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***Abstract*—We report on the experience of teaching an industry-validated course on Artificial Intelligence in Computer Games within the Simulation and Game Design department at a two-year community college during a 16-week semester. The course format used a blended learning just-in-time teaching approach, which included active learning programming exercises and one-on-one student interactions. Moskal's Attitudes Toward Computer Science survey showed a positive and significant increase in students in both interest (W(10) = 25, p = 0.011) and professional (W(10) = 49.5, p = 0.037) constructs. The Felder-Soloman Index of Learning Styles (n = 14) failed to identify any statistically significant differences in learning styles when compared to a four-year CS1 class. In the final class evaluation, 8 out of 13 students (62%) strongly or very strongly preferred the blended learning approach. We validated this course through four semi-structured interviews with game companies. The interview results suggest that companies are strongly favorable to the course content and structure. The results of this work serve as a template that community colleges can adopt for their curriculum.**

I. Introduction

Community college students face a unique set of challenges that differ in many ways from those of traditional four-year University college students. A significant number of community college students enter their programs lacking study skills and the academic maturity needed to handle more rigorous, self-directed approaches used in traditional colleges [1]. Many of these students have responsibilities outside of school, placing further demands on their time and financial resources. For these students, community colleges must serve as a critical bridge between academia and industry and provide them with a practical and industry-focused education that prepares them for the workforce. At the end of a two-year program, students are expected to have sufficient training so that they can be placed into entry-level positions in their respective fields immediately after graduation. Given these student and instructional differences, we believe that educators should not tacitly assume that pedagogical approaches and experiences that have been successful in traditional institutions can be applied with equal success at the community college level; these approaches must be once again validated in a two-year setting.

Students in community colleges typically restrict themselves to a focused curriculum that emphasizes skills practical for industry. As such, community colleges must make continual efforts to ensure that their courses are relevant and useful to the industry jobs students are seeking. This task cannot be accomplished in isolation, and can only be successful when academia and industry collaborate in curriculum design. We argue that this collaboration must occur not only at the program level, but also at the individual course level, so that each course itself is validated as being appropriate to the types of skills that industry demands.

It is with this understanding that we report on the experience of teaching an elective, pilot course on Artificial Intelligence (AI) in Computer Games within the Simulation and Game Design curriculum at a two-year community college during the 16-week Fall 2012 semester. An advisory committee comprised of both academic and industry members identified the following three criteria for success: 1) to evaluate if teaching computational thinking through game design can positively increase attitudes about Computer Science; 2) to assess student reactions to a blended learning classroom experience; and 3) to validate whether the learning objectives of the course are relevant and useful to industry.

The course format used a blended learning approach, which consisted of discussions, in-class active learning programming exercises, and one-on-one student interactions with the instructor.[1] We minimized the use of formal lecture; when necessary, we delivered lecture content using a just-in-time teaching approach [2] to address observed student difficulties. The course content can be summarized as five weeks of learning the Python programming language through a game context that emphasized algorithmic thinking, with the remaining semester time spent on AI for games topics.

To evaluate instructional compatibility with pedagogical techniques used in four-year institutions, students completed the Felder-Soloman Index of Learning Styles (ILS) questionnaire [3] ($n = 14$). To identify changes in student attitudes, students completed the Moskal's Attitudes Toward Computer Science survey [4] ($n = 10$) twice during the semester. To determine whether our blended learning classroom approach was well-received, students completed a final evaluation ($n = 13$) with 5-point Likert-item questions. Finally, to validate our course, we performed semi-structured interviews with four local game companies.

The results of this work serve as a template for community colleges considering the adoption of specific pedagogical approaches in the classroom or for colleges who wish to adopt a prepared, industry-validated AI course in its entirety. The results also highlight the effectiveness of using a blended learning approach at the community college level.

[1] We recognize that the definition of blended learning varies widely in the education community. We are less interested in constructing a strict definition, and far more interested in whether or not the techniques are useful to students.

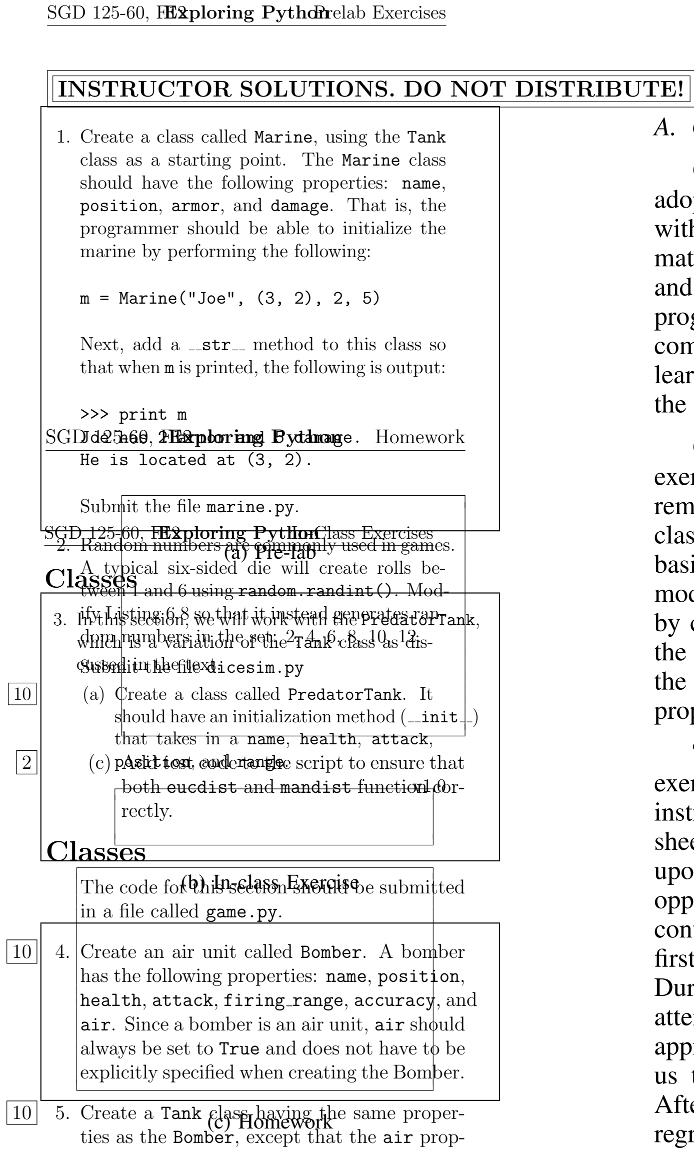

Fig. 1. A representative example of how class assignments carry from pre-lab to homework.

II. Course Syllabus

This 16-week course introduces artificial intelligence concepts with an applied focus in video game development and has been designed to be a part of a two-year community college program. The course is intended to be taught in a lab setting where each student has access to a computer workstation. Upon completion of the course, students should be able to understand the basic concepts, and implement algorithms, for AI in games.

The objective of the course was to teach computational thinking through game programming, so that students could relate theoretical classroom concepts to their existing experiences with playing video games [5]. A secondary objective was to design a modular course structure that can serve as a starting point for other community colleges. In this section, we discuss the specifics of the course format as well as the course topics. The class met once a week for 3 hours in the evening. However, the effective class time, after accounting for three 10-15 minute breaks as well as administrative overhead, was reduced to approximately two hours.

A. *Course Format*

Grounded in Revised Bloom's Taxonomy (RBT) [6], we adopted a just-in-time teaching approach [2] in our course, with some variations: we had less emphasis on web-based materials, integrated the classroom and laboratory sessions, and implemented blended learning by having computer programming tasks as the focal point for all activities. Students completed pre-lab exercises before class, completed active learning sheets in-class, and had a homework assessment on the related material after class.

Our pre-lab exercises were less exploratory. Instead, the exercises explicitly tasked students with surveying the text to remember and understand course material for the associated class session. Because of this, they were graded on a pass/fail basis. For example, the task in Fig. 1a. asks the students to modify an existing piece of code available in their textbook by changing a `Tank` to a `Marine`. To successfully complete the task, the student must rename the file, rename some of the properties, and change a single statement that prints these properties to the screen.

The majority of in-class time was spent completing exercises for the topic, with minimal lecturing from the course instructor [7]. Through the use of modified[2] active learning sheets [8], students completed in-class exercises that built upon the completed pre-lab exercises. Students were offered an opportunity to apply their pre-lab knowledge to new problem contexts, without introducing new material. Students would first attempt to solve the exercises without instructor assistance. During this time, we walked around the room to give individual attention to students as they solved the assigned problems. This approach was essentially an early-alert system that allowed us to quickly assess student understanding of the material. After 5-15 minutes, depending on exercise complexity, we regrouped as a class and together worked toward obtaining a correct solution. With the guidance of the instructor, students analyzed the problems to gain insight into the relationship between pre-lab and in-class material. Here, we provided the rationale for the problem solutions, analyzed tradeoffs and alternative approaches, and discussed how these materials might be applied to games they have played in the past. Continuing the previous example, for the task in Fig. 1b we instructed students to implement an initialization method based on their pre-lab, and performed the aforementioned tasks to explain how this method relates to the programming task as a whole.

After class, students were given a homework assignment that was a continuation of the class topics. The homeworks provided an opportunity to combine the concepts from class in a novel way and in more depth. Because of increased difficulty of homeworks, students were encouraged to work together, but had to submit work individually. Finalizing the ongoing example, for the task in Fig. 1c, we asked students to extend the behavior demonstrated in class by having them create unit types that support both air and ground modes. This required students to modify their existing Tank firing logic because of a constraint that Tanks can only fire on ground units (not shown).

[2]Instead of fill-in-the-blank type responses, our question prompts required students to supply short answers. This style was appropriate to our course format because we did not deliver active learning sheets within a normal lecture as Lau [8].

TABLE I. INDUSTRY VALIDATED SYLLABUS FOR A 16-WEEK SEMESTER AI IN GAMES COURSE

Module	Topic	Learning Objectives
1	Introducing Python	Basic Python syntax and semantics, such as numbers, strings, variables, conditionals, loops, and functions. The list, tuple, and dictionary data structures.
2	Exploring Python	Additional exercises on concepts from the previous module. Classes as a means to organize data. The game loop as building block for all games. Basic random number generation as a means for adding variation in games.
3	Introducing Pygame	Review of classes. Loading sprites and backgrounds; blitting (drawing) objects to the screen. Event handling and keyboard logic.
4-5	Numerical Python	Review of list operations, importing libraries. Converting lists and tuples to `NumPy` arrays. Fundamentals of Newtonian Physics, which include displacement, velocity, and acceleration. Vectors, including Cartesian coordinate systems, plotting, dot products, Euclidean distance, and vector normalization.
6	Movement Algorithms	Review of integer and floating point operations and subtle pitfalls. Additional practice on vector operations implemented using simplified Newtonian Physics model from the previous modules. Game loop updates for updating avatar position. Frame vs. time updates. Seek movement algorithm as a fundamental AI primitive.
7	Pathfinding I	Double-ended queues, and algorithmic costs and tradeoffs for list and double-ended queue operations. Data structures, e.g., stacks and queues implemented using double-ended queues. Static paths, as found older games, implemented through list rotations. Tile graphs as the basic building blocks of two-dimensional world representation.
8	Pathfinding II	Breath-first search implementation using nested lists as a world representation. A simplified edge finding function for locating adjacent nodes. Discussion of generalized search with explored and frontier lists, and choice of distance functions and their effects. Mathematical operations for quantization (translating graph nodes to pixel coordinates and back).
9	Decision Making I	Review of dictionaries and how they can be used to implement Blackboard architectures. Hard-coded decision trees as sequences of conditional statements. Five-state decision tree system involving AI that can fire on the opponent, seek the opponent, find ammo items, find health, and panic when it is out of ammo and low on health.
10	*Practical Midterm Exam*	
11	Decision Making II	Review of Manhattan distance. Multiple mechanisms (references) for accessing unique objects in the context of dictionaries. Visual comparison of decision trees and finite state machines (FSMs). Implementing FSMs in Python using object-oriented programming. Methods as a means to add behavior to classes. FSMs as a technique to modularize AI behavior. Implementation of a schoolyard game of tag through FSM behavior.
12	Learning I	Review of world representations and blackboard architectures. Review of random number generators as a means to emulate intelligence. Artificial stupidity; how games cheat to give the perception of intelligence (for example, fog of war). Implementing finite state machines in a hide and seek game setting.
13	Supporting Technologies I	Technologies that are not directly game AI, but help support games in general. Recasting AI algorithms and demonstrating applicability across domains. Finite state machines as an example of maintaining user states in a chat system. Event-based management in networks, as opposed to games, through the `Twisted` framework.
14	Supporting Technologies II	Continuation of previous module; modifying networking code to implement a text-based online game. Discussed the limitations of AI, and role and need for multiplayer games. The use of AI agents that can act as players.
15	Comprehensive Final Review	Wrap-up of course topics in an interview context. Main take aways and course highlights at a high level. Interviewing techniques for industry positions in entry-level game AI. Application of course topics to general programming careers.
16	*Practical Final Exam*	

Students were evaluated using a midterm and final exam, which had notable differences from evaluations most students were familiar with. To simulate industry settings, all exams were open-book and open-notes, and we allowed the use of the Internet. More importantly, all problems were programming exercises that required students to submit source code within the 3-hour time window. Thus, no multiple choice or fill-in-the-blank questions were employed. Students were notified in advance of the specific subject matter to be evaluated. In much the same way that in-class exercises were built on pre-lab exercises, the exams provided an opportunity to independently demonstrate learning from the in-class exercises. To our knowledge, this exam style is still not widely used in computer science; indeed, at the community college where this course was taught and evaluated, it was the first within the Information Systems department to implement these techniques.

Though many languages have been used for teaching introductory programming [9], we chose Python because of previous successes reported by four-year Universities and high schools, and we expected these reported benefits to apply equally well at the community college level [10], [11]. As presented by Grendel et al. [11], we also considered Python's minimal syntax, dynamic typing, expressive built-in types, and immediate feedback to be positive factors when considering its adoption. Most importantly, Python has an orthogonal design that allowed us to simplify the language, such that advanced language features, including decorators, list comprehensions, and operator overloading, were omitted from the course entirely.

To support game-specific features, the following additional libraries were required: Pygame,[3] for abstracting low-level game engine details (such as graphics, user input, and event management); NumPy,[4] for vector operators; and Twisted,[5] for event-driven networking support. Students used the built-in IDLE editor to write their Python programs, using simple `print` statements when debugging was necessary. All of the software used in the class is open source and therefore freely available to the students for use at home. In short, we offered a general-purpose programming language that was loosely coupled with the underlying game engine library so that the concepts learned in the course could easily transfer to other programming environments.

[3]http://www.pygame.org
[4]http://www.numpy.org/
[5]http://twistedmatrix.com/

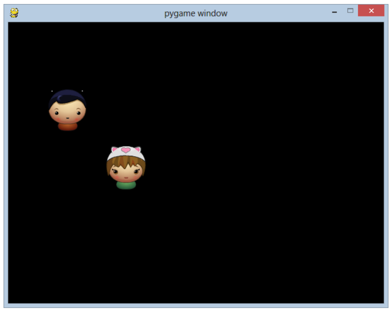

Fig. 2. Students experiment with avatar movement. The boy is controlled using the keyboard by the player and the girl is an AI agent.

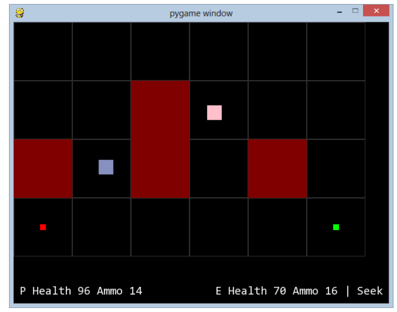

Fig. 3. Students implement a finite state machine in a tile-based world. Colored tiles are obstacles and hiding places for the player. Small red (bottom left) and green (bottom right) rectangles are ammo and health items, respectively, which provide opportunities for the AI to perform additional decision making.

B. Course Topics

The course used two textbooks. The first textbook was Python-specific and introduced the students to the Python programming language from a games perspective and the Pygame framework [12]. Throughout the course, this book was largely used as a reference. The second was an Artificial Intelligence (AI) textbook used in many four-year undergraduate programs [13]. Despite the fact that the AI text was not specifically designed for the community college level,[6] we hoped that its comprehensive coverage would allow students to continue pursuing their interests in game AI well after the completion of the class. As mentioned in Section II-A, class sessions assumed that students had read the text beforehand.

An overview of the topics can be found in Table I. We tried to strike a balance in course topics that satisfied the needs of the industry, but at the same time was appropriate for the capabilities of community college students. We presented traditional computer science algorithms through a game-focused lens. As one example, rather than offer a theoretical coverage of vectors as an abstract mathematical construct, we motivated the need for vector operations as a practical method to simplify AI movement in games programming. As another example, rather than directly cover the concepts of stacks and queues, we motivated the need for these data structures through their use in AI pathfinding, a staple of games. Throughout the course, we emphasized analyzing tradeoffs between different data structures, such as lists, tuples, and dictionaries. Nested lists were found to be most suited to representing a tile-based world; tuples were useful in representing coordinates; and dictionaries were useful in storing agent properties that needed to be accessed by a key (such as a player's health or ammo).

It was important to us that concepts in the course be cumulative because we felt that students could appreciate their efforts if they could tangibly see how their simpler implementations could be reused to develop more complex components. For example, students implemented tuples so that they could implement distance functions. Distance functions were used to implement seek behaviors, which were then used in their implementation of path finding, which is then used within finite state machines to move toward different goals, and so on. Concretely, we began with a simple environment devoid of obstacles and a world representation, as shown in Fig. 2. Students used this environment until Module 7: Pathfinding I (see Table I) as a platform for reinforcing mathematical foundations as well as developing their programming language skills. When the simpler environment representation became insufficient for expressing advanced concepts, students moved to a more complicated representation as shown in Fig. 3. The latter representation provided affordances for discussing more sophisticated topics that required a world model, and was used for the remainder of the course.

[6]The book assumes a moderate knowledge of mathematics. Additional class time may be required to cover these pre-requisites.

III. Methodology

Student data was collected anonymously in full accordance with research protocols at the authors' respective institutions. Students did not receive extra credit for participating in the study. The course consisted of $n = 18$ students (17 male, 1 female), but student data was discarded for students under the age of 18, and for students who did not consent to releasing their data. The course was offered as an elective, and students self-selected to enroll in the course, which is a potential bias.

To identify changes in student attitudes, students completed the Moskal's Attitudes Toward Computer Science survey [4], once immediately before the core AI component of the course and again at the end of the semester. The purpose of this qualitative instrument is to better understand factors that discourage students from pursuing degrees in computer science. The survey measures attitudes across five constructs: confidence, interest, gender, usefulness, and professional. Because of student demographics, the gender construct questions were removed from the survey. To score the survey results, the 4-point Likert-item survey responses are re-coded to a numerical scale which ranges from 1 to 4; negatively phrased questions were reverse coded such that a high score is always a positive attitude. The score for a construct is simply the sum of the responses for that construct.

To reflect on their own learning preferences, students also completed a Felder-Soloman Index of Learning Styles (ILS) questionnaire [3] at the end of the tenth class session. This is a 44-question instrument that can be used to assess preferences on four dimensions: active/reflective (ACT-REF), sensing/intuitive (SEN-INT), visual/verbal (VIS-VRB), and sequential/global (SEQ-GLO). The scoring methodology categorizes students for each of these dimensions ranging through, for example, Strongly Active, Moderately Active,

TABLE II. ATTITUDES TOWARD COMPUTER SCIENCE SURVEY

	Construct							
	Confidence $p = 0.362$		Interest $p = 0.011$		Usefulness $p = 0.172$		Professional $p = 0.037$	
Student	Pre	Post	Pre	Post	Pre	Post	Pre	Post
SA	28	29	36	40	24	24	16	16
SC	28	27	35	38	24	24	13	13
SD	28	29	35	37	21	24	7	16
SE	23	29	30	40	18	24	11	13
SF	20	16	18	22	18	18	10	12
SJ	23	26	27	38	22	24	11	11
SK	29	23	36	32	24	18	12	13
SL	29	29	29	32	22	23	14	12
SP	23	27	25	34	17	21	11	16
SQ	28	28	36	40	24	24	12	15

Balanced, Moderately Reflective, and Strongly Reflective. For this research, we compared the ILS distributions for each dimension against a typical four-year University CS1 program [14], to determine if statistically significant distributional differences exist between two-year and four-year populations.

To evaluate perceptions of the course, students completed a 13-question final evaluation consisting of 5-point Likert-type items. We provided this to the students directly before their final exam.

To validate if the course is relevant and useful to industry, we conducted four semi-structured, in-person interviews with game companies within the Raleigh, North Carolina area. The structure was as follows: a discussion about the course topics, the choice of Python as a programming language, and the blended learning approach of the class. The interviews were conducted over four months, and each session ranged from 1.5 to 3 hours. The first author was both the instructor and interviewer, which may have resulted in social desirability bias.

IV. STUDENT-CENTRIC RESULTS

In this section, we discuss the results of the Moskal's Attitudes Toward Computer Science survey [4], the Felder-Soloman Index of Learning Styles questionnaire [3], and the course evaluation.

A. Attitudes Toward Computer Science

Computer games have been cited as a motivational tool to teach Computer Science concepts [15]. Consequently, we were interested whether students who completed an Artificial Intelligence in Games course would have a positive increase in their attitudes toward Computer Science. Students completed Moskal's Attitudes Toward Computer Science instrument [4] directly before the AI component of the course, and again at the end of the semester. Students were randomly assigned a unique identifier, and the results for students who completed both pre-test and post-test surveys are shown in Table II. A Wilcoxon matched pairs signed-rank test was performed between the two trials, and constructs for students' interests in CS (W(10) = 25, p = 0.011) and students' beliefs about professionals in CS (W(10) = 49.5, p = 0.037) increased significantly.

Since students take many courses during a semester, it should be noted that there are several confounding factors that prevent us from attributing this affect to our course alone. There is also a survivorship bias, in that students who dropped the course before the final survey did not complete both surveys. It is indeed plausible that students who dropped the class had negative attitudinal changes. However, when taking into account the student evaluations, we believe that some component of these positive attitudinal changes were a result of our course.

TABLE III. INDEX OF LEARNING STYLES AGGREGATED SURVEY RESULTS, COMPARING OUR AI CLASS WITH A 4-YEAR CS1 CLASS

	Dimension (A-B)							
	ACT-REF $p = 0.234$		SEN-INT $p = 0.484$		VIS-VRB $p = 0.356$		SEQ-GLO $p = 0.054$	
Preference	AI	CS1	AI	CS1	AI	CS1	AI	CS1
Strong-A	1	13	0	24	4	64	0	8
Moderate-A	3	56	4	53	7	80	3	49
Balanced	7	123	6	101	1	70	6	139
Moderate-B	1	24	2	31	2	28	4	20
Strong-B	2	6	2	13	0	12	1	2

B. Index of Learning Styles

We hypothesized that one of the differences between community college students and traditional University students was that the two student populations have significantly different learning styles, and that these differences can be used to inform the pedagogical approaches in the class. To evaluate this hypothesis, we compared our results against a student population from an Introduction to Computer Science course at a four-year University [14]. Due to the small number of students in our AI class, Fisher's exact test was applied. These results are shown in Table III. We were unable to identify any statistical differences between the two populations, though SEQ-GLO appears to be on the threshold of significance. Thus, as with the CS1 population, a Shapiro-Wilk normality test reveals that, for all dimensions, we were unable to reject student populations as significantly different from normal (all $p > 0.05$). Consequently, our interpretation of this result is that pedagogical approaches that are explicitly based on ILS can potentially be applied with success in community colleges.

C. Student Evaluation

We had 18 students initially enroll, 4 of whom dropped before the final exam. One student did not complete the final evaluation. Though our reports reflect some level of survivorship bias, our course retention rate of 78% is comparable to the Simulation and Game Design program average retention rate (78%).

We expected a progression in student perception of difficulty, with the pre-lab exercises being easiest and the midterm exam being most difficult. Using the Wilcoxon matched pairs signed-rank test, we were unable to find any statistical significance to confirm this expectation. We believe that this is in part due to the small number of students. Qualitatively, we observe a monotonic increase in difficulty between the in-class exercises and the out-of-class homework. Our explanation for this is that students receive help during class from the instructor.

10 out of 13 students (77%) felt that the practical exam format was appropriate or very appropriate and that they would

TABLE IV. STUDENT EVALUATION AGGREGATED RESPONSES

Qn	Question Text	Scale	Likert-item Counts 1	2	3	4	5
Q1	The following question asks you to rate the difficulty of the course materials.	Very Difficult—Very Easy					
	How difficult were the questions for the pre-lab exercises?		–	5	8	–	–
	How difficult were the questions for the in-class exercises?		–	5	5	3	–
	How difficult were the homework assignments?		–	8	4	1	–
	How difficult was the midterm exam?		2	5	5	1	–
Q2	How often did you read the textbook material before coming to class?	Never—All of the Time	1	5	4	3	–
Q3	How often did filling out the in-class exercises cause you to miss important parts of the lecture?	Never—All of the Time	4	4	3	2	–
Q4	The midterm exam was a practical exam. How appropriate was this exam format for this course?	Very Inappropriate—Very Appropriate	–	1	2	4	6
Q5	If given the option, to what degree would you avoid or prefer this exam format for future exams?	Very Strongly Avoid—Very Strongly Prefer	–	–	3	5	5
Q6	During class, the instructor would go to each student to check their progress during in-class exercises. How useful were these one-on-one interactions with the instructor?	Very Useless—Very Useful	–	–	1	2	10
Q7	This course used a blended learning classroom approach. If given the option in your future classes, would you avoid or prefer classes that used this teaching style?	Very Strongly Avoid—Very Strongly Prefer	–	–	5	3	5
Q8	Please indicate your level of agreement with the following statements.	Strongly Disagree—Strongly Agree					
	The in-class exercises encouraged me to attend the lectures.		–	1	1	5	6
	The in-class exercises make the lectures interesting.		–	–	2	7	4
	The in-class exercises helped me better understand the lecture material.		–	1	1	3	8
	The in-class exercises helped me complete the homework.		–	–	2	5	6
	The assigned textbook was a useful resource in the class.		–	3	5	3	2
Q9	This course used the Python programming language for all programming activities. How difficult or easy was it to learn the Python language?	Very Difficult—Very Easy	1	3	4	4	1
Q10	For future programming tasks, how likely would you be to use Python as your preferred language?	Very Unlikely—Very Likely	–	2	3	4	4
Q11	How important do you feel the material in this class is in obtaining an entry-level game developer position in industry?	Not at all Important—Extremely Important	–	–	3	6	4
Q12	Compared to other classes that you have taken at this community college, how would you rate this course?	One of the Worst—One of the Best	–	–	3	1	9
Q13	Overall, how satisfied were you with this course?	Very Dissatisfied—Very Satisfied	–	–	3	3	7

prefer this exam format for future exams. More importantly, 8 out of 13 students (62%) strongly or very strongly preferred the blended learning approach to class. The other 5 out of 13 students (38%) were indifferent, and no students indicated that they would avoid this class format.

12 students (92%) found the one-on-one interactions with the instructor to be useful, despite having only a few minutes of interaction time with the instructor for each exercise. In our opinion, this is because the instructor could quickly steer otherwise perplexed students in the correct direction.

The department allows students to have up to 4 penalty-free absences before being dropped from the course. Of the 13 students who completed the course, 6 absences in total were recorded across all students, and 8 students had perfect attendance. 11 students (85%) agreed or strongly agreed that in-class exercises encouraged them to attend the lectures, reported that the exercises made the lectures interesting, and reported that the exercises helped them complete the homework. Thus, if students did not find class to be useful, we would have expected many more students to have absences.

10 students (77%) believed the class was very or extremely important in obtaining an entry-level game developer position, which shows that students perceive the course as being relevant. 9 students (69%) rated this course as one of the best they have taken at our community college. In general, 10 students (79%) were satisified or very satisfied with the course.

V. INDUSTRY COURSE EVALUATION RESULTS

The selected companies constitute what we believe to be a representative sampling from the diverse types of game studios in the marketplace: Redstorm (RS),[7] for traditional AAA game development; Vicious Cycle (VC),[8] for game engine design; Virtual Heroes (VH),[9] for serious research games; and Spark Plug Games (SP),[10] for mobile and independent game development. Programmers who directly worked with Artificial Intelligence in some capacity within their company evaluated our curriculum and contributed feedback for three measures: selection and ordering of topics, choice of Python as a programming language, and the use of blended learning.

With few exceptions, all four companies found the course topics and topic organization to be appropriate to the game industry. When we designed the course, we envisioned the sections on Supporting Technologies as optional, but all of the interviewed companies felt that this section was necessary to show how game programming concepts can transfer to other programming domains. However, VC felt that Supporting Technologies should only be a single class, using the gained class time on Learning in AI. RS suggested that students should implement a simple, but complete game (such as Asteroids or Pacman), rather than using prototype

[7]http://www.redstorm.com
[8]http://www.viciouscycleinc.com
[9]http://www.virtualheroes.com
[10]http://www.sparkpluggames.com

environments. Decision trees and finite state machines were considered to be an essential topic for all companies, but they differed on the importance of pathfinding. RS suggested that the topics of decision trees and pathfinding be reversed, since pathfinding is a relatively complex topic. Specifically, RS, VC, and VH indicated that all modern game engines support pathfinding, and that breadth-first search could be covered in less detail or abstracted entirely as a result. VC and VH also indicated that the concept of navigation meshes should be presented as an alternative to navigation points.

We were concerned that our course did not make use of an industry game engine, such as Unity.[11] However, the use of Python and Pygame was well-received by all companies. From our interviews, it was clear that companies are less interested in knowledge of particular tools and more interested in students' programming capabilities. For example, RS was interested in whether students understood the thought process behind programming and VH was similarly interested in students who have a base-level knowledge of programming. SP liked Python because it allowed students to focus on concepts, as opposed to focusing on language idiosyncrasies. In terms of entry-level opportunities, RS liked the use of Python because they considered scripting to be a stepping stone into other areas; their entry-level developers begin as scripters. VC entry-level hires also begin in a scripting or support role, and thus found Python to be appropriate. At VH, all entry-level hires start out as generalists, and at SP, their game programmers work on all aspects of the game. Thus, we conclude that teaching through Python is not a significant barrier to entering the game industry, and we recommend that community colleges examine their balance between tool-focused courses and concept courses.

All companies found the blended learning approach to the classroom to parallel the type of work performed in industry. RS liked the interactivity of the course, and how it built on concepts from first principles. VH felt that the course format accurately resembled the way that game programmers solve problems in industry. VC stated that having immediate feedback is valuable, and that the course offered several opportunities to practice debugging code — an essential skill. The practical midterm and final exam formats were also well-received. In general, companies preferred the problem-based learning format to lecture-based learning. In our interviews, we found that companies are interested in what projects students have completed more than the courses they've taken. In particular, SP liked that the course provided students with deliverables that could be discussed during interviews. VH also indicated that it was very important for students to have completed projects when applying for entry-level positions.

VI. Conclusion

While we have shown a positive increase in attitudes within the interest and professional constructs, we are unable to isolate these increases to our course alone. Future replications of this course may mitigate some of these confounding factors. The results of our final class evaluation demonstrate that by having a blended learning approach, no students are marginalized when compared with alternative classroom formats, but a significant number of students stand to have an improved experience. Finally, our industry interviews suggest that game companies prefer a blended learning approach to a traditional lecture because it more closely matches their industry practices.

[11] http://unity3d.com/

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An Agile Translation Process for Complex Innovations: an Industry/University Cooperative Research Center Case Study

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***Abstract*—The National Science Foundation Industry & University Cooperative Research Center (I/UCRC) program is intended to foster productive collaboration between industry organizations and academia. The focus of the I/UCRC research site herein is on the application of technology within the complex extended enterprise. The center's goal is to conduct research that is of interest to both the industry sponsor and the university partner, with the provision that the industry organization must provide major support to the center. In this paper, we describe the Agile Translation Process (ATP) for complex innovations that was developed at the center. The process meets the constraints of the academic calendar, the knowledge needs and the typical length of stay for a master's student, and the availability constraints of the students. At the same time, the process is designed to provide value to the industry sponsor. Specifically, it describes how the process meets the needs of technology consumers in industry seeking to derive tactical value through the funding of the center. In addition, we demonstrate how to derive research results for technology providers through subsequent activities. We also provide metrics from the center for a period of five years, which show, in particular, the benefit of using the ATP method over the last three years. These metrics provide insights on how to reconcile tactical industry needs with the long-term research and funding goals of academia, while understanding the innovations needed within complex contexts. This case study also provides insights on concurrently meeting the needs of all stakeholders – including industry clients, translational faculty members, adjunct faculty from partner companies, graduate students, and the center's affiliated research faculty – within the constraints of the academic calendar. By using an agile translation process and a set of expanded performance metrics, the center effectively applies research to bring innovation to its industry partners.**

Keywords—collaboration, design, innovation, performance metrics, services science, technology management

I. Innovations for Complex Enterprise Systems

Beginning in early 2004, we looked at hiring patterns within the Information Technology (IT) industry and noticed several emerging trends, including the fact that a significant portion of IT complexity began shifting from *technology development* to *technology use*. These trends are shown through several factors. First, enterprise IT departments became brokers of cloud, social, mobile and information services [1]. Second, there was a significant interest in converting data from these services into actionable intelligence - the *big data opportunity* [2]. Third, hiring by the technology consuming industry overtook that of the technology producing industry. Fourth, budgets for IT maintenance were ballooning due to an increase in the number of technologies needed to manage complex IT service workflows. Thus, the overall focus of the Center's research became the growing gap between technology consumers (government, industry, etc.) and technology providers (including academia). Hence, the Center experimented with alternatives to make the translational process viable within academia.

In this paper, we describe what we term the Agile Translation Process. This process was developed to meet the needs of the student within the constraints of an academic program while meeting the needs of industry, by deriving tactical value through the utilization of the Center as a research partner. Furthermore, we show how to derive *research* results through subsequent activities. Lastly, we provide metrics from the Center for a period of five years. These metrics provide insights on reconciling tactical industry needs with the long-term research and funding goals of academia.

From an industry-university collaboration perspective, we can also ask related questions. How do we as academics and engineers help increase innovation, and diffusion of new ideas? How do we apply the rigor of the latest research to design solutions? How do we show that designed solutions provide value within the context of a complex enterprise? And, finally, how do we overcome any impediments to come up with a cost-effective industry-university capability to accomplish these goals? This case study provides approaches to these questions using the Agile Translation Process that concurrently meets industry-university stakeholder needs. These approaches include: the sharing, use, creation of knowledge and feedback; resourcing of translational projects related to complex systems; and protection of intellectual property while conducting projects.

The context of this study is a specific National Science Foundation Industry/University Cooperative Research Center (I/UCRC) for Experimental Research in Computer Systems (CERCS). This is a multi-university center with

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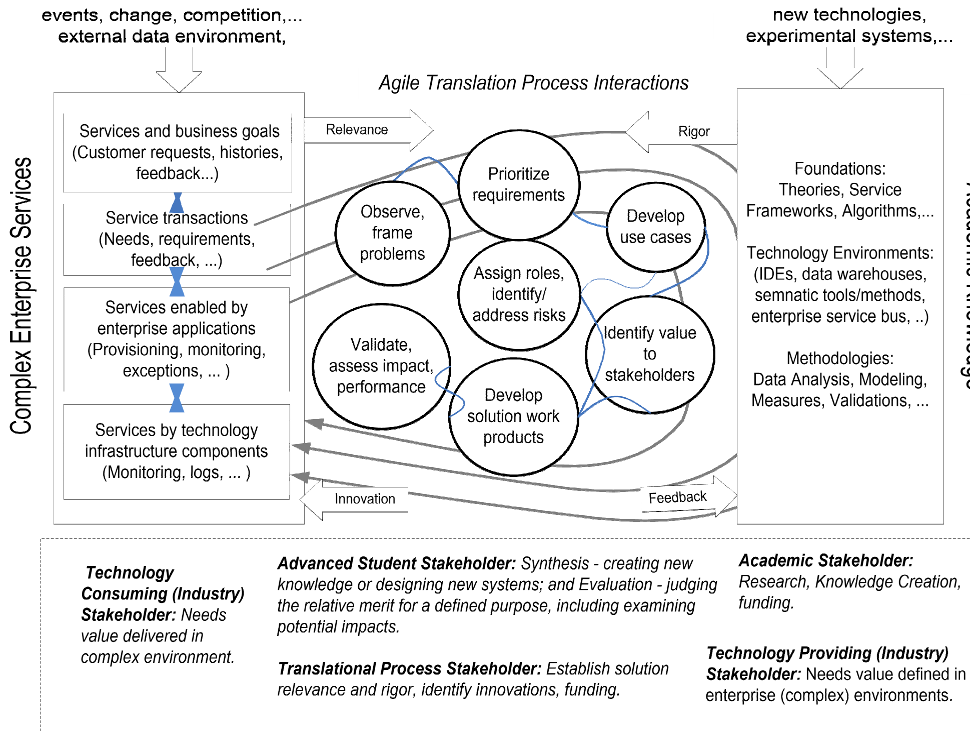

Fig. 1: The contexts of Complex Enterprise Services on the left and Academic Knowledge on the right. The Agile Translational Process (ATP) resources by advanced experiential learning, cycles between Descriptive and Normative research activities as illustrated.

CERCS at Georgia Tech researching technology: hardware, communications and system-level software, and applications. Complementary to this, the CERCS research site at The Ohio State University, the Center for Enterprise Transformation and Innovation (CETI) studies the applications of technology for innovation. The center's goal is to conduct research that is of interest to both the industry and the university, with the provision that the industry organization must provide major support to the center [3]. The simple center structure also provides for the protection and sharing of intellectual property through the Bayh–Dole Act. By emphasizing experimental methods, CERCS promotes the creation of knowledge through the design, implementation, and measurement of large-scale technology and systems.

The specific focus of this case study is the CETI research site and its application of technologies within the extended enterprise.

II. Design Related Concepts

Before presenting our case and performance data, we cover related concepts.

A. Context for Design

It is well established that engineering design requires an understanding of the context for the correct framing of the problem, as well as interdisciplinary approaches to solution development [4]. For example, architectural design is viewed as its own integrated field of study, and compared to other engineering disciplines; it is multi-disciplined since the field seeks integration of electrical, plumbing, lighting and other systems within an overall building design. Capture of contextual knowledge as *design patterns* was also first introduced by the architect Christopher Alexander [5, 6] as a way of making hitherto tacit knowledge explicit. Design patterns were adopted by software engineers, leading to many framework technologies that have improved the development of software. However, far less has been done in integrating interdisciplinary frameworks related to complex enterprise services within the graduate software and systems engineering curricula.

Recent NSF workshops have also looked at the process of introducing design thinking into the engineering curriculum [7, 8]. In addition, advocates of grounded theory provide a systematic methodology in the social sciences involving the discovery of theory through the analysis of data captured in the field [9]. It is mainly used in qualitative research, but is also applicable to quantitative data. These ideas and methods carry forward to bridging the gap between technology consumption (left of Fig. 1) and technology development (right of Fig. 1). Finally, related to technology, engineering research continues to focus primarily on normative theories related to technology while business, such as management information systems, and healthcare focus more on descriptive or operational aspects, leaving a gap to be bridged as described by Christensen [10]. To address this, *design science* [11] emphasizes the need for the information systems researcher to bridge the gap between existing knowledge and the context of use. This is captured in Fig. 1 as the Agile Translation Process (ATP) Interactions discussed later.

B. Complex Enterprise Service Systems

Complex enterprise service systems refer to intra- and inter-enterprise services that collectively enable a business goal. As in [12, 13], we view these as networks (a value chain, supply chain, service value networks) with nodes as agents (humans, organizations, software and hardware) creating, communicating, and consuming information.

C. Living Laboratory

A living laboratory, or sandbox, is an environment that replicates the complexity of real-world enterprise environments. Given the importance of field-based research in innovation, these environments allow problem framing and experimentation to occur as in the real world. This works well if this synthetic environment itself can be embedded in real-world organizations with safeguards in place for privacy and security concerns.

D. Translational Role

While there are many variations across universities, we have kept the role definitions below intentionally simple to make a point. Today the center acts in a translational role to conduct translational activities that are not explicitly identified within universities and their engineering colleges. This role is well recognized in medical schools; within engineering this is often filled in an ad-hoc fashion by appointments that do not fit the translational role and performance requirements. According to Duderstadt, "[t]he strong research focus of many engineering schools has led to a cadre of strong engineering scientists, quite capable of generating new knowledge but relatively inexperienced in applying this knowledge in professional practice" [14].

We illustrate this issue below using the term *role* to identify responsibilities. For a translational role, these responsibilities include: demonstrating the value of research in practice and developing descriptive theories; providing related experiential education in solution-driven contexts and applying research theories and methodological rigor where applicable; providing feedback and identifying intellectual property; developing industry relationships and making interpersonal connections needed for field research. It is insightful to contrast this with the typical academic roles at the other end of the spectrum: developing research theories; providing related education of principles, methods and tools; providing academic administrative services; and developing relationships with federal and industrial research and development labs. Because of the *applied research* component of the translational faculty role, we also distinguish the translational role from the roles of adjunct lecturer and clinical faculty typically filled by professionals from industry to augment teaching resources.

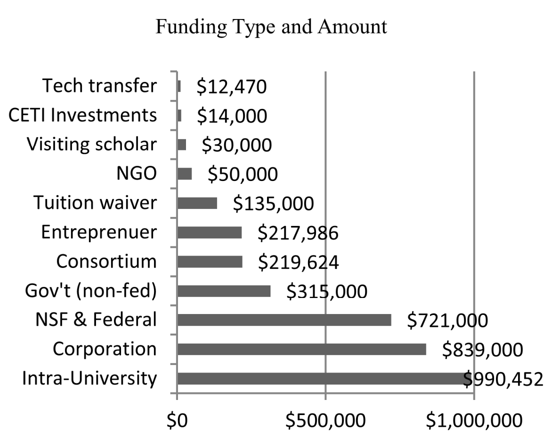

Fig. 2: Funding types and amounts. Total amount is approximately $3.25 million.

III. Agile Translational Processes (ATP)

CETI uses the precise notion of an *Interaction* to bridge technology-consumer context and technology-provider knowledge as illustrated in Fig. 2.

A. Interaction-based Translation Methodology

For the purpose of measurement, we consider the unit of activity to be an Interaction that takes place between consumers and providers. Each Interaction is at the request of a consumer (e.g. a sponsor, student, or academic collaborator) and is provisioned with resources by the center to provide work products of value to the consumer. The request can ask for any type of Interaction, for example: requirements analysis, a project, experiential education, or thesis research. We take the average duration of an Interaction to be an academic term.

Also it is important to note that an Interaction may fall outside the primary I/UCRC mission and be a secondary Interaction. The variation in types of sponsors of Interactions is illustrated in Fig. 2. For example, a project Interaction with the Agriculture department to visualize the transmission of disease may be funded by another federal grant that is not counted as I/UCRC membership revenue for reporting, and is thus a secondary Interaction.

However this type of secondary Interaction would not have happened without the existence of the center and its relevance to sustainability. We therefore list secondary Interactions here to identify the full benefit of the I/UCRC, which is often outside the main / measured intent. We also list secondary Interactions here to identify potential opportunities to establish a sustainable translational center beyond the duration of the I/UCRC. Also, it is important to note that the concept of an Interaction is similar to the previous I/UCRC evaluation methodology followed using *critical events or incidents* in the life of the center from the perspective of the director [15]. The goal of that study was to study management relationships *across* centers. On the other hand, the goal of this study is to analyze events and resulting Interactions *within* a single center.

Agile software engineering bridges customer needs and provider tasks, especially when requirements are uncertain.

From the center perspective, the benefits of combining *agile* and *translation* include: a prescriptive process that is responsive to industry sponsors; an expanded set of internal performance measures across industry engagements; and collaborative resourcing for experiential learning. Thus, by focusing on the details with ATP at the boundary of industry and university, we begin to examine opportunities for increasing the rate of bidirectional idea diffusion.

The ATP is illustrated in the center of Fig. 1. Each Interaction is aligned to academic increments. It consists of the following steps, based on [16]:

1. *Process satisfaction:* Measured by rapid delivery of useful work products, in the midst of changing requirements, even late in development. Work products (see center of Fig. 1) delivered frequently.
2. *Project work products:* Acceptance by the sponsor is the principal measure of progress towards an innovation. This means the sponsor reviews the work products based on value to organization.
3. *Self-organizing teams:* Small teams of one to five students are asked to be responsive to the sponsor. There is regular adaptation to changing circumstances.
4. *Standup presentations:* Made to the sponsor; reviewed by translational faculty.
5. *Sustain development at a constant pace:* For graduate research associates and interns this starts at 20 hours per week, less so for capstone students. Close, weekly cooperation between sponsors and student developers with face-to-face conversations is expected.

Some unique aspects of ATP are important to note here. Industry sponsors approve all work products based on achieving a translational goal; thus the work products are of value to an industry process or product. Each work product contributes incrementally to a final innovation.

A typical master's student is available *only* for four increments; during their first semester, they are taking their mandated core courses. Useful value must result as below:

- Increment 1 (Spring) consists of on boarding in the field with mentoring by professionals, with instruction delivered as an advanced project-oriented course using an enterprise context and curriculum assets. Here, second year group members mentor the first year group members in each team. The course serves to provide needed background on different sponsor companies.
- Increment 2 (Summer) is where students are embedded as industry interns in the enterprise. Enterprise data gathering, model development, and initial problem formulation are the foci of this increment.
- Increment 3 (Fall) sees problem abstraction and solution synthesis along with project deliverables. Thesis research and hypothesis development begin.
- Increment 4 (Spring) consists of analysis and thesis writing for the student, who must defense their research and hypothesis at the end of the increment.

B. Project environment

The environment includes weekly activity tracking, which is kept private to the student and faculty advisor, and a project environment with blogging for team collaboration.

IV. Center Performance and Stakeholder Benefits

The following data are both for primary and secondary Interactions from April, 2007 to March, 2013. These data provide insights into: the primary and secondary Interaction outcomes that are measured from an engineering research perspective in academia; the need for additional translational measures to address translation; and ways the I/UCRC-type structure could provide sustainable translational research.

Over the five-year period CETI has had 85 Sponsors ranging from Fortune 500 companies to small- and medium-sized enterprises. These industry organizations are both technology-using and technology-providing companies, as well as both local and international. Included in the sponsors are other departments across the university and Capstone sponsors. Capstone course projects do not initially involve significant dollar amounts. The center has over fifty master's and doctoral students at any given time. In addition, over five years the center has provided 3,000 students at the undergraduate and graduate levels with experiential learning that generated tuition revenue.

A. Interaction Performance and Related Stakeholder Benefits

The Interaction framework and standard ATP structure presented above allows us now to explicitly state CETI performance, which is discussed next.

1) Interaction Outcomes: As mentioned, all center execution is measured in a standard way as increment-long Interactions. A primary or secondary Interaction can be of different types, can have different types of consumers, providers, sponsors, or resourcing, and can have different outcomes. Outcome types are classified as follows: Academic outcomes and innovation outcomes.

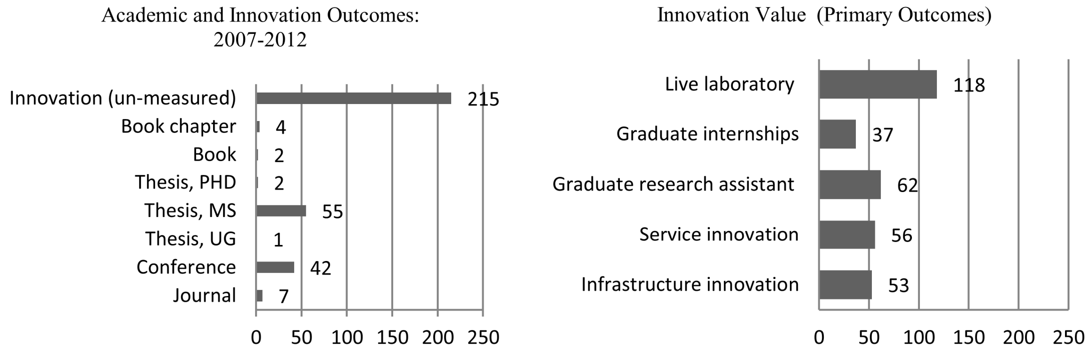

Fig. 3: Overall Interaction outcomes: (a) academic and (b) translational.

Academic outcomes, which are measured for individual researchers, include: journal and conference publications, undergraduate, Masters, and doctoral theses, books, and book chapters. Innovation outcomes, which are typically unmeasured for individual researchers, include: workforce impact, project reports, curriculum assets, software assets, and data assets. As shown in Fig. 3, there were both academic and translational Interactions. There were 113 academic outcomes and 215 innovation outcomes related to projects which are identified in greater detail in Fig. 3(b)Fig. 3. All reported work products were sponsored by consumer or provider stakeholders (see related graphs in Fig. 4).

The center's technology consumers and providers have specific innovation value tied to one or more of the following: Technology Infrastructure, Service Delivery, or Workforce. The rationale related to Workforce innovation is that, through graduate research assistantships and graduate internships, the live laboratory curriculum assets are indirectly used to achieve skills that will diffuse results to industry.

2) Interaction Funding Types: This refers to any organization type that provides funds, including: industry, the government, academic or non-governmental organizations, the university (in terms of fee waivers), visiting scholars, technology transfers, internal CETI funding, intra-university (i.e. other departments within the university). Note that the funds for an Interaction might be from a source that is different from the problem sponsor for an Interaction. For example, a capstone class may provision an Interaction for an entrepreneur, but funds are by tuition. Incidentally, this is the only type of funds not counted in the overall number in Fig. 2. Also, the university support in terms of fee waivers was instrumental in making this program successful.

The overall funds directed to the center are given in Fig. 2. From an NSF perspective, note that the funding from other departments, labeled Intra-OSU, is the highest due to the high level of interdisciplinary collaboration in the center. Also, an I/UCRC brand has far greater impact in fostering and resourcing collaboration than the amount reported as direct I/UCRC funding which is less than a third of the total amount.

3) Interaction Domains: Described in Fig. 4, the sponsor's domain could be a Technology Consumer (in government, finance & insurance etc.), or as a Technology Provider interested in complex system aspects classified as one of: service delivery (e.g. applications of mobile, sensor technologies); technology infrastructure improvement (e.g. applications of cloud computing, Hadoop, etc.); or semantic enterprise architectures and services.

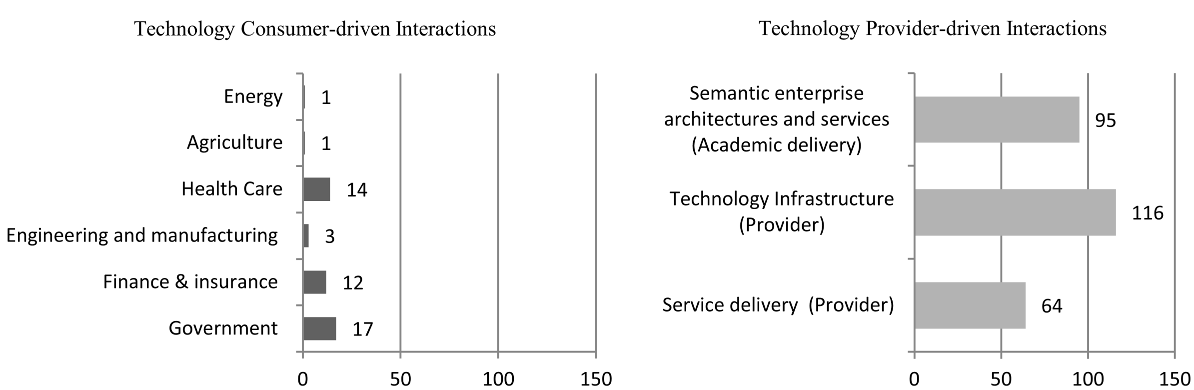

Fig. 4: Interactions and domains of technology providers and technology consumers.

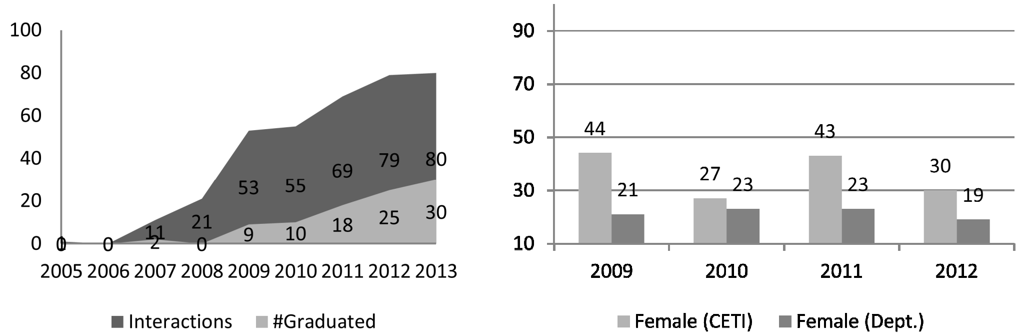

Fig. 5: (a) Advanced student beneficiary numbers (the number of graduate students) and related Interactions. (b) Female students within the CETI sub-population vs. female students within the at-large departmental population.

4) Interaction Resourcing to Achieve Translation Outcomes: Graduate students implement the Interactions using the ATP steps of problem framing, synthesis, and analysis. These are measured as the final project report and work products accepted by the sponsor, a published research paper or thesis, and usable living laboratory curriculum assets, such as case studies that introduce the contextual challenges of problem solving. In addition, the ATP conforms to the students' availability and academic interests and addresses their knowledge gaps. The students also get two to three increments of funding. The knowledge applied is often interdisciplinary. They learn that research ideas may or may not provide value within a complex system whose improvement depends on many factors. The students also learn that the most critical aspects must be identified first, meaning that they must be agile.

5) Interactions versus Graduates: The number of graduate student beneficiaries is related to the Interactions needed to achieve this number in Fig. 5. This provides an idea of the resource intensive nature of advanced experiential learning and the demands on the translational role. While projects were sponsored by industry from the very inception of CETI, we began to link projects and industry sponsorships to the academic increments (e.g. a semester or quarter) and the students' own availabilities and skills only in the third year. Coincidentally, in 2008, the Center's home Department started accepting master's students, thus providing a pool of industry-headed talent with an interest in innovation (see the large increase in Fig. 5. CETI graduates were a fifth of all Masters level graduates over the period. We also note that significant number of female students joined CETI (see in Fig. 5(b)).

6) Interdisciplinary collaboration: As noted earlier, the greatest funding type (Fig. 2) is intra-university funding. This represents over forty faculty from fifteen departments – including public policy, medicine, business, and design – across the university that were actively involved in supervising specific Interactions. Often faculty members started with sponsoring a capstone project, then moved the project to an externally funded grant.

V. Conclusions

The presented case is related to an Agile Translation Process implemented specifically in the CETI I/UCRC research site. The data show that it is possible to impact innovation and research and advance experiential learning in a way that is concurrently beneficial to all stakeholders. We show here how to build a translational structure at the boundary of industry and university through alignment of existing resources. This includes provisioning work through experiential learning courses and funding advanced graduate students. These students, under the guidance of translational faculty, learn how to correctly frame problems, synthesize solutions, and evaluate results in the context of complex enterprise service systems. Such problem-based experience can be time consuming and resource intensive. To overcome the challenges and make this possible, we draw upon agile development principles to address: the translational processes at the boundary of industry and university; the academic calendar constraints; and the needs of stakeholders and challenges.

Acknowledgment

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Bringing Adjunct Engineering Faculty into the Classroom: Opportunities for Enhancing the Practice

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Abstract- **The paper reports on a success story of an adjunct, a practitioner with excellent credentials, who "teamed-up" with a "full-time" faculty, in an attempt to bring-in the "practice" to 4th year students in a *geotechnical/foundation engineering* class. The paper sheds light on this experience, and focuses on the contribution and effectiveness of the adjunct in: course planning, delivery of "practice-related" material, organizing activities and adjunct's ability in engaging students, in and outside the classroom. The positive outcome of this experience has lead other faculty members to follow the same path, i.e., by searching for practitioners - as adjunct faculty- to assist in bringing the practice into the classroom, in partnership with "full-time" faculty**.

Keywords—adjunct faculty, partnership with full-time faculty, bringing the practice into classroom.

THE PROS AND CONS OF ADJUNCTS

There are many reasons for employing adjunct faculty, including: unanticipated increase in enrollment, the start up of new programs, the need for specific expertise, and the replacement of an "on-leave" faculty, are some of the reasons that may necessitate making temporary arrangements to ensure coverage of instruction. Unfortunately, department heads, administrators, and most faculty members, look upon hiring an adjunct faculty as a "stop-gap" measure. Not only that, but there are those skeptics, who are vehemently against employing adjuncts on the grounds that: i) they do not have the teaching skills, ii) are not familiar with rules and regulations that control the day to day academic operations, iii) lack organization skills, iv) do not possess the self-confidence, v) do not have the enthusiasm in comparison to full-time colleagues, and vi) often lack familiarity and depth of insight with course material. Simultaneously, however, there is a growing recognition of the potential contributions that adjuncts and other part-time faculty could make in the teaching arena, provided a thorough search for "the right type" of an adjunct is carried out through proper channels.

Although no firm guidelines on how to search and identify candidates for an adjunct position are available at present; the most common starting point is the unsolicited applications from individuals in industry and consulting firms, seeking part-time work as adjuncts. The motivation often is to supplement their income. There are those that like to do it for other reasons such as: exposure to the academic environment and an interest in working with students, to gain experience in presentation and delivery methods, to take time-out from their daily schedule, or as a stepping stone into a full-time teaching position. In addition, full-time faculty may recommend colleagues, they have known through professional societies or other domains, who may have expressed an interest in working with students. .Some adjuncts could offer linkages for the development of industrial affiliate programs, co-op activities, summer training, and employment opportunities for new graduates. They may also provide ideas for senior design projects, topics for graduate theses, or render help in the establishment of collaborative research programs.

The academic systems in place today have not been fair to adjuncts, in general. The author has known of many "full-time" adjuncts that have been mistreated despite their proven records of being very good teachers.

They are often marginalized by the tenure system, in the sense that their efforts and contributions to the academic process are undervalued [1]. As pointed out by Gosink and Streveler [1], there are ways for recognizing the contributions of adjuncts. Their suggestions have included the following:

- Look into the feasibility and/or the legal aspects of offering 3-5 year contracts to those who have demonstrated their abilities as good teachers.
- Accord appropriate titles, awards & citations, to adjuncts with proven teaching skills, on par with regular faculty.
- Encourage new recruits to take courses towards a degree, or acquire new knowledge, including teaching skills. This is usually done on campus at no cost to the department.
- Encourage experienced instructors to teach new courses to widen their scope and increase their versatility; thus help them get out of "a rut" by developing new potentials.
- Allow those with experience to serve on various academic committees and assign them to undergraduate advising, as is the case with regular faculty.

In summary, if care, recognition, and fair treatment are accorded to adjuncts, their morale, loyalty to the college, as well as their teaching effectiveness, would improve markedly.

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REPORTING ON THE EXPERIENCE

At one of the International Universities, a course, *Foundation Engineering*, introduces students to the fundamental concepts and applications of foundation analysis and design with emphasis on methods and applications in the arid and semi-arid soils of the Country in contention, and the Region in general. The prerequisite, *Geotechnical Engineering I*, exposes students to the basics of soil mechanics, including: theoretical background, relevant techniques, and selected applications. The author has always been of the opinion that certain subjects, including *Foundation Engineering*, should be instructed by qualified practitioners; but, if not feasible, then practitioners should be involved in the instructional process, possibly as guest speakers. To proceed with the idea of bringing the practitioner to the classroom, a preliminary plan was drawn, and a search for an expert, preferably with teaching experience, commenced as soon as formal approval was secured. An announcement was dispatched to companies in the Region describing the position, qualifications, and employment-related conditions. It was also stipulated, that the appointment is for one year, renewable for longer periods, depending on outcome & feedback from students and faculty.

The search led to a candidate that had the desired qualifications, and was willing to accept the position, but had no prior teaching experience. However, his skills in lecturing and delivery of teaching materials were put to the test by having him present a seminar on a subject of his choice. Attendees' overall impression was positive; and on that basis, he joined the department as a part-time adjunct faculty. The candidate, a registered professional engineer with experience that stretches over a ten-year period; was particularly suited for the position because of: i) his knowledge and familiarity with the soils and geology of the Region; ii) his direct involvement with the practice in the locale; and iii) being in charge of the geotechnical section in his consulting firm, facilitated getting the right kind of information such as: soil data, case studies, exposure to equipment in-use, and relevant testing procedures. Most important, he was excited, eager and looking forward to bringing-in his experience to the classroom. Initially, different alternatives, on how to proceed with the instruction of *Foundation Engineering*, and in particular, the role/contribution of the adjunct to the process, emerged. The *alternative* agreed upon – and preferred by the adjunct and the full-time instructor - was to work jointly in terms of: planning course material, delivery of subject matter, organizing in-class and out of class activities, and in testing and evaluation It was understood that the adoption of this *alternative* meant that both instructors would be present in the classroom, at the same time, and actively involved in the instructional process: delivering the material in a coordinated manner and engaging students through questions and answers. Both instructors were willing to "do their level best", and pledged to put in the effort required to guarantee success.

In the section that follows, we examine relevant aspects that pertain to: *the role of the adjunct faculty* in this endeavor.

THE ROLE OF THE ADJUNCT FACULTY

In general, *Foundation Engineering* went well and was almost on target! In retrospect, proper planning that preceded course delivery had a lot to do with the success achieved. In all fairness, adjunct's eagerness, commitments, and efforts were instrumental in meeting set goals, and declared objectives, i.e., "bring the practice into the classroom".

On the ***planning*** side, and after a careful review of the syllabus, the adjunct was able to generate the material (design procedures in use, relevant construction and constructability issues, prevalent soil conditions, lessons learned, typical foundation behavior and potential problems in the locale, and a great deal of relevant case studies, statistics, presumptive bearing capacity values, etc.). He was also able to sort it out, stream line it, and diffuse it within the general course outline so that it supplements the various topics as specified in the course chronology. His selections of *case histories* were: relevant, concise, derived from the locale, and addressed timely issues and concerns. He and his colleagues at work were the proponents of the selected *cases.* They were responsible for data acquisition, analysis, the write-up, and the final recommendations. The three selected *field trips* were also based on adjunct's recommendation, who prepared a write-up for each, explaining what would be observed, and how do field observations relate to the specifics in the syllabus

Another aspect that had been planned and fully implemented was ***to cater to different learning styles*** [2]. To promote effective learning, within the context of varied learning styles, the instructors grouped the students, devised activities and tasks that brought the students closer together, and made sure that joint tasks were consistent with course objectives. Therefore, an attempt to create an ***active learning*** environment was pursued in this experiment, despite the fact that traditional teaching methods were dominant and practiced on a wide scale. *Active learning* implies class participation, i.e., the students, the instructors, and the teaching material are intertwined through preconceived learning/teaching activities [3]. Research has shown that what students tend to remember is highly correlated with their level of involvement [4, 5]. This is to say: the higher the level of students' involvement, the greater is their comprehension and the higher is their retention.

On the ***Delivery*** side, the adjunct was always on time, physically present in class with the full-time faculty, the entire semester, ready to contribute and/or express his views at the appropriate moment. He made good use of his "lap top", and often resorted to "Xeroxed" handouts to reduce students' note-taking during the lecture. When his turn came to deliver his part, he was courteous, considerate, and spoke slowly and clearly. His main contribution in every session was to supplement the subject matter, with relevant examples derived from the Region, focusing primarily on the "practice" or the practical side of the topic on hand. For example, when *settlements of shallow foundations* was the theme under consideration; he showed: *settlement plates* being installed and fully operational; an example of the discrepancy between *measured* and *calculated* settlements; guidelines for *tolerable* settlement based on local *building code*; and presented *allowable bearing pressures* in sandy soil based on settlement consideration. He presented valid points and commented on the specifics of the day during the *pause* periods; led the discussion at the end of the session, and answered questions even when improperly phrased! The three case studies he chose to present, during the latter part of the course, were valuable, relevant, and well received. He was extremely helpful during office hours; and the rapport he initiated with students, he was able to sustain throughout the semester. His contributions to the experience can be highlighted as follows:

- His foresight, effort, an abilities as a practicing engineer did enrich the course, made it more relevant, and brought "real" problems into the class room;
- Drawing on his experience as a practicing engineer in the locale, provided students with first-hand information of local soils and their behavior in supporting foundations;
- His ways of responding to questions, engaging students, and encouraging them to come forward with their questions and comments, promoted confidence and community amongst the students;
- The presence of the adjunct faculty in class, side by side with the full-time faculty member, broke the monotony often experienced in traditional lecture room setting, and was instrumental in creating a class room environment, that resembled a professional engineering forum.

. After *Foundation Engineering* was over, and the final course grade was out, a "questionnaire" was sent to those who enrolled in the class seeking their opinions, evaluations, and any comment(s) they may wish to offer. Twenty six out of a total of 30 students returned the "questionnaire" on time! The opinions expressed and comments made were, by and large, positive to say the least. After regrouping, and rephrasing to correct the English language; some of the comments offered by the ex- students, could be summarized as follows:

- The adjunct was easy to approach every time and every where, and was always helpful,
- His input into the course has dramatically improved students' understanding of the material, enlivened the experience, and made the course more meaningful,
- Many students felt that the adjunct was eminently qualified to teach *Foundation Engineering by* himself, should the need arise. On the other hand, many argued that it could not have been delivered as effectively, had it not been for both instructors working together,
- Some students expressed their desire to see similar arrangement be implemented in other courses; with particular reference to design &construction type courses,
- The field trips, planned and conducted by the adjunct, were described as: very useful, particularly in developing an awareness of how soil exploration work is performed.

The experience reported on here was repeated several times; and a number of minor changes, mostly in sequencing teaching material, were since introduced. The experience has gained momentum, and has since been applied to other engineering courses in the same institution.

SUMMARY AND CONCLUDING REMARKS

Properly selected adjunct faculty can enrich an engineering program by bringing their practical experience and introducing relevant practical applications to the classroom. Adjunct faculty members can also provide important linkages for developing joint programs between industry and academic departments, and employment opportunities for graduates. Nevertheless, the position today of adjunct faculty, in most engineering colleges, is tenuous, often marginalized by the tenure system, and their presence on campus is considered as temporary; until replaced by a "full-time" faculty member. The adjuncts, by and large, are extremely capable and in all likelihood, do what we, the "full-time" faculty, could never do, i.e., bring the practical experience into the classroom!

Another arena for the adjunct, who possesses a proven record of practical experience in a specific area, is to "team-up" with a "full-time" faculty, in an attempt to bring in the practical side of the subject into the classroom. This means that two members ("full-time" faculty and the adjunct) share in teaching the class. There are many possibilities on how to "intertwine" teaching material, and merge teaching activities.

This paper reports on a success story of such a merger in a *geotechnical/foundation* class. The success achieved was attributed, in large measure, to proper coordination that preceded course delivery. In this exercise, an experienced practitioner was sought out to supplement the regular lectures offered in an elective course to 4th year civil engineering students. In addition to the practice-related activities brought into the lecture hall; case histories were also introduced by the practitioner, as well as pre-selected field trips, focusing on soil exploration and relevant monitoring and testing procedures.

Students' evaluations, their views, comments and overall impressions (during-and at the end of the course) have been very encouraging to say the least! The positive outcome of this experience has lead other faculty members to follow the same path by searching for practitioners-as adjunct faculty- to assist in bringing-in the practice into the classroom.

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Investigating the Attributes and Expectations of Engineering Ph.D.s Working in Industry

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***Abstract*— Many engineering Ph.D.s are finding career opportunities in industry. Despite the increase in number of Ph.D. engineers working in industry, there is little research on what it takes to be a successful engineering Ph.D. in industry. This study explores the characteristics, and expectations of engineering Ph.D.s by interviewing ten engineering Ph.D.s working in industry. These preliminary findings reveal that responsibilities of engineering Ph.D.s in industry include more than research and development. Among other things, engineering Ph.D.s that work in this sector are expected to communicate effectively and teach others. The characteristics that engineering Ph.D.s need to possess to be successful in industry are also discussed.**

***Keywords*— engineering Ph.D.; industry; attributes; expectations**

I. Introduction

In the past few years, there has been a steady increase in the percentage of engineering Ph.D.s working in industry. According to National Science Board statistics, in 1999, 60.6% of engineering doctorate holders worked in industry (classified as "Profit" companies) [1]. In 2008, this percentage increased to 66% [2]. On the other hand, the percentage of engineering Ph.D.s working in the education sector (including 2-year, 4-year, and precollege institutions) has declined from 31% to 26.6% in the same period [1, 2]. Since 1983, the annual growth rate for employment of engineering Ph.D.s in academia has been declining. The growth rate for employment of engineering Ph.D.s in academia for years of 1983-1993, 1993-2003 and 2003-2008, was 2.54%, 1.95%, and 1.43%, respectively [3]. It is likely that this trend will continue, at least in some foreseeable future, due to the limited number of positions in academia [4] and industry's desire to hire more highly-skilled professionals or recipients of doctoral degrees to help them grow, to compete, and to innovate in this globalized world [5,6].

Since the number of academic positions available to engineering Ph.D.s is lower than the overall demand for such positions and since the majority of engineering Ph.D. graduates will obtain jobs in industry, it is important to investigate the attributes and roles of engineering Ph.D.s in industry. Examining the expectations and important attributes (i.e., knowledge, skills, and characteristics) that engineering Ph.D.s need to possess to work in industry is necessary in order to help future Ph.D.s understand and/or prepare for industrial careers. Moreover, limited empirical studies have been conducted about engineering Ph.D.s in industry. Therefore, this study aims to identify and to examine the important attributes and expectations of engineering Ph.D.s working in industry through a qualitative study.

II. Research Method

A. Data Collection

The data for this study is drawn from interviews within a National Science Foundation project, "An examination of graduate education's role in preparing engineering students for careers in academia and industry". One of the project's goals was to identify the skills, knowledge, and attributes engineering graduate students must have if they are to be successful in academia and industrial careers. To achieve this goal, researchers conducted one-on-one semi structured interviews with 40 engineering Ph.D.s working in industry and academia. All participants were classified according to the employment sector in which they had worked: academia only (17), industry only (10), industry first and then academia (9), and academia first and then industry (4). A 16-item interview protocol was used to examine engineering Ph.D.s' roles and expectations within their work settings, their views on important characteristic and attributes that Ph.D. engineers should possess, their motivations for obtaining a Ph.D.; their perspectives on the added value of getting a Ph.D., their experiences in a doctoral program, and recommendations for doctoral education.

The present study examined ten industry engineering Ph.D.s' responses to the two questions within the 16-item interview protocol. Participants included seven male and three female engineers with five to twenty-five years of experience in industry. In these two questions, participants were asked to identify the most important attributes and characteristics an engineering Ph.D. should possess to be successful in industry and to discuss the expectations of engineering Ph.D.s in their work environment. The insights garnered from this study can help to ensure that graduate schools are preparing its doctoral engineering students to possess the desired attributes and are prepared to meet the expectations of employers for engineering Ph.D. holders.

B. Data Analysis

Members of the research team conducted all ten interviews. The interviews were recorded and later transcribed by an external transcriber. Members of the research team used Atlas.ti, a software program using in qualitative research, to analyze the transcripts. An open coding and constant comparative method were used to study the views of the respondents [7]. In the first phase of data analysis, two transcripts were randomly selected, and each researcher assigned a word (or code) next to a segment(s) of text that best matched the essence of the response. This process involved reading the data multiple times and making memos about phrases and ideas that stood out. All

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members individually identified and recorded the codes using the software. During research meetings, the team engaged in an auditing process. The team members then discussed the appropriateness of the code assigned to segments of the participants' responses. Codes that were agreed upon among all researchers were recorded in a separate document, which later became the codebook for the study. The research team members were assigned two additional transcripts to analyze. This led to more discussion and the addition of new codes and/or a refinement of existing codes in the codebook (e.g., clarifying existing code definitions and coding rules, including code examples, and indicating when and when not use a code).

In the second phase of the data analysis, inter-rater reliability (IRR) tests were conducted. IRR tests ensure that researchers independently agree on the data sections to be coded and codes to be assigned. One measure of IRR is percent agreement – which is the overall extent to which the individual coders assigned codes that were consistent with they coded the team agree upon during the auditing process [8]. To conduct the IRR analysis in this study, four transcripts were randomly selected. The only restriction on this selection was that the four employment classifications of interest in the larger study (academia only, industry only, industry-to-academia, academia-to-industry) needed to be represented among the four transcripts for the IRR analysis. Responses to the 16 interview questions were randomly selected from the four transcripts and combined to form a "mixed-transcript". The researchers used the final version of the codebook to code individually the mixed transcript. The process involved researchers selecting the codes that they felt best fit the quotes.

The first round of IRR analysis resulted in 75% overall agreement for the responses to the 16 questions. Percent agreement was calculated on an individual basis and across coders. Individual percent agreement was based on the extent to which the codes a researcher's code matched the codes that were determined during an auditing process. Each coder's overall percent agreement was also calculated. The 75% overall agreement is an average of the individual percent agreement values. Although fair coding agreement existed among the researchers, there were three interview questions where all of the coders had a low (less than 75%) percent agreement. The low percent agreement occurred when there were multiple ideas in a sentence or a paragraph and researchers failed to assign all of the codes reflected in the response. Therefore, the research team conducted another round of IRR for these three questions. A different mixed-transcript was generated and used to minimize bias. The IRR for the three questions resulted in overall percent agreement of 79%.

From here, each researcher was assigned a set of interview questions to code across all transcripts. For example, one researcher was responsible for coding all 40 participants' responses to interview questions 1-4. Since the individual researcher was responsible for a set of codes that belonged to their set of interview questions, the coding process was more efficient and accurate. The preliminary findings of this study will be presented in the next section. This will include insights on the responsibilities, expectations, and characteristics of engineering Ph.D.s in industry.

III. Preliminary Findings

A. *The day-to-day responsibilities of an engineering Ph.D.*

During the interviews, engineering Ph.D.s in industry offered in-depth accounts of their work. Industry engineers' work included research-related tasks such as creating new tools to stimulate certain manufacturing processes, developing new techniques to include a new feature in an existing material, investigating faults in an assembly plan, or running experiments and testing hypothesis. Many of the participants mentioned that there is no such thing as a typical workweek; their work was filled with variety. Not all of their day-to-day tasks were research-related. Other examples of tasks included commercializing and keeping valuable projects active within the organization; protecting intellectual property (e.g., dealing with patents, trade secrets, copyrights, non-disclosure agreements, and trade development agreements); managing engineering personnel within the organization; interacting with internal (e.g., engineers, technicians, high level management) and external stakeholders (e.g., customers, and business, engineering, and manufacturing leaders); and developing curricula and teaching classes to improve engineering practice in the company. These findings, which vary by corporation, provide a glimpse of other responsibilities beyond research and development (R&D) for engineering Ph.D. holders who work in industry.

B. *Expectations of others for engineering Ph.D. holders*

There was agreement on what is expected of engineering Ph.D. holders who pursue careers in the industry sector. Many participants emphasized that engineering Ph.D.s are expected to communicate in many ways –speaking, writing, and presenting. The majority of the participants had regular meetings with senior management and customers to provide progress reports on current projects. In these meetings, engineers must be able to communicate ideas or procedures effectively and clearly to technical and non-technical audiences. Furthermore, the participants strongly emphasized that oral communication encompass more than presentations but also involves the vital collaboration between engineers and other stakeholders such that meaningful exchanges can occur (in both directions).

Engineering Ph.D. holders are also expected to demonstrate strong technical skills, innovation skills, leadership skills, and problem-solving skills and to provide hands-on support to their colleagues. Innovation skills include coming up with different and new ideas that the company can pursue. Leadership skills include collaborating with a diverse team of people and delivering a project on time within budget. Problem solving skills include the ability to break down problems, to ask the right questions, to find intermediate steps, and to develop sound hypotheses to reach solutions. Moreover, doctorate-holding engineers, with their in-depth technical knowledge, are expected to teach and to develop technical competencies in others. Furthermore, Ph.D. engineers are expected to be able to see the "big picture", which means that they need to possess understandings of how their work will impact the company and the community at large.

C. Characteristics of engineering Ph.D. holders

Characteristics identified by engineering Ph.D. holders in industry included being curious, adaptable, flexible, able to think ahead and broadly, able to and/or willing to learn new knowledge, and ethical. Participants highlighted that these characteristics are necessary to complete the responsibilities of an engineering Ph.D. holder in industry. Participants discussed being curious and willing to learn new knowledge as important characteristics that are useful when transforming theory into practical products that can drive and deliver upon a corporation's needs. Furthermore, participants asserted that the ability to use tools to predict possible outcomes and implications at a corporation are very important characteristics. They said similar things about the importance of being able to determine how research results provide valuable findings for the company regarding what to pursue in the future. Finally, integrity was identified as the most important characteristic an engineering Ph.D. holder should possess. One participant's relates to engineers' interactions with customers and stakeholders. Engineering Ph.D. holders are expected to report findings to relevant stakeholders. In this reporting process, it is essential to present both the successes and failures of their work, to provide a complete picture of this work, and to discuss next steps for moving forward.

IV. Discussion

A preliminary analysis of the results shows that engineering Ph.D. holders. in industry are expected to be resourceful, to commercialize products, to communicate with internal and external stakeholders, and to engage in business practices. Key characteristics of engineering Ph.D. holders include leadership skills, integrity, being adaptable to a work environment, being willing to acquire deep and broad knowledge, and possessing abilities to think ahead.

The findings from the study contribute to the literature in a number of ways. First, this study did not restrict participants to Ph.D. holders in industry who were only conducting research. Unlike previous research that examined Ph.D.s holders whose primary work role was research [9], this study included any engineering Ph.D. holder working in industry, regardless of role. This sampling criterion provided unbiased views and wider understandings of engineers' roles and expectations in industry. Second, unlike studies that examined the characteristics of the workplace and workers thorough pre-defined variables [9,10], this exploratory study investigated the nature of responsibilities, expectations and characteristics of engineering Ph.D. holders, thereby capturing the comprehensive picture of working engineers' characteristics in industry. Finally, this study explored Ph.D. holders from industry whose discipline was in engineering, hence adding value to the small body of literature that currently consists on research on Ph.D.s in the life and physical science disciplines only [9,10].

V. Implications and future work

The findings of this study present a description of what it is like to be an engineering Ph.D. in industry. Such insights are useful to engineering Ph.D.s that are considering career paths in this employment sector. Additionally, this study has the potential to reveal how graduate schools can collaborate with companies to educate future engineering Ph.D. students who possess the attributes and skills identified in this study. As part of the future work, more interview transcripts will be analyzed to continue to build and to identify important abilities for engineering Ph.D.s across specific engineering disciplines (i.e., mechanical, chemical, and electrical), across various career stages (i.e., early-career or late-career), and across different employment sectors (i.e., industry, academia, government). Furthermore, an assessment tool that measures the important attributes to work in industry (as identified by the interviewees) for engineering Ph.D.s will be developed. This assessment can inform present and future engineers of their current strengths and weaknesses in the needed attributes for a career in industry.

Acknowledgment

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Grading by Experience Points: An Example from Computer Ethics

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***Abstract*—In most of education, courses are graded based on percentages—a certain percentage is required for each letter grade. Students often see this as a negative, in which they can only lose points, not gain points, and put their class average at risk with each new assignment. This contrasts with the world of online gaming, where they gain "experience points" from each new activity, and their score monotonically increases toward a desired goal. In Fall 2012, the lead author switched to grading by experience points in his Ethics in Computing class. Students earned points for a variety of activities, mainly performing ethical analyses of various issues related to computing, and participating in debates on ethics-related topics. The students appreciated the ability to earn extra points by performing extra activities. But they were less likely to complete analyses after signing up to do them than were students in a traditionally-graded class. At semester's end, the number of peer reviews increased, as students strove to top off their point total. The grade distribution was bimodal, with clusters at both ends (A+ and F). Students' greatest concern was rapid grading turnaround, so they would know where they stood in the class at all times.**

Keywords—gamification, experience points, XP, computer ethics, assessment *(key words)*

I. Introduction

In most of education, courses are graded based on percentages—a certain percentage is required for each letter grade. Students often see this as a negative, in which they can only lose points, not gain points, and each new assignment puts their class average at risk. This contrasts with the world of online gaming, where one only gains, never loses, "experience points" from each new activity, causing their score to increase monotonically toward a desired goal.

In the last two or three years, several instructors have moved to grading by experience points (XP). The strategy was showcased by Lee Sheldon in his 2012 book, *The Multiplayer Classroom: Designing Coursework as a Game* [1]. It offers a way to motivate students in almost any course, without the need to design actual games to teach different units of the course material. It seemed appropriate for our Ethics in Computing course, which is not always a favorite among our technically oriented students. We thought it might boost the level of student interest and engagement.

II. Motivation

The motivation for using experience points stems from a number of shortcomings of more traditional, percentage-based grading schemes. In such schemes, a finite number of potential points are set at the outset of the course, and students strive to obtain 100% of the potential points. Because the number of points is fixed, it can be difficult for students to recover after poor performance on a single, heavily-weighted assignment.

When assignments are weighted heavily, students are under intense pressure to perform well [9] on them. An unintended corollary is to incentivize behavior that does not adequately promote learning [4]. To gain insight into how students are prioritizing their time and energy, listen to questions that students ask about assignments, e.g., How many pages should the essay be? Or, will the exam be mostly multiple choice or mostly essay? The guiding principle from this insight is that *high-stakes assessment incentivizes performance over learning*.

Gamification [3] is used in business and education to reward positive behavior. In the context of the classroom, gamification would be used to incentivize student actions associated with learning. By setting a goal and allowing students to choose their own way to reach that goal, it allows students more agency in the tasks they perform. The hope is that because they define their own tasks, they will choose those those in which they take a personal interest, rather than performing them simply "for the grade." One of the simplest ways to gamify a course is to grade it by a monotonically increasing number of *experience points*, rather than weights and percentages for each assignment.

The principal detriment of percentage-based grading is that it is difficult for students to recover from mistakes. In the event of failure, experience points are more forgiving than percentages. This is desirable, since failure can serve as an excellent learning experience. While percentage grades equate success with near-perfect performance, experience points can reward deep and thorough learning.

In addition to reducing the pressure on students, points can also be used to reward socially positive activities that not only advance the learning of the individual, but also improve the learning experience for the rest of the class [5]. Students can be awarded points for holding study sessions, office hours, or participating in peer reviews. In this way, students help with the logistics of the course, improve the experience for their peers, and absorb the positive message that teaching others is a valid approach to demonstrating mastery of course material. One manifestation of peer teaching in computer science is pair programming, which is often used to facilitate a transfer of skills between students [2].

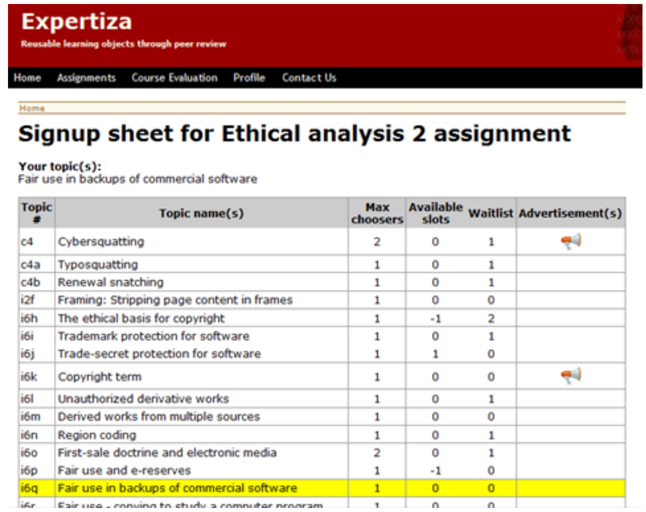
III. Implementation

Our Ethics in Computing course is a one-hour course required for all Computer Science students. Students were awarded points for each activity in the class:

- weekly quizzes over the reading material for the class (each worth 50 points maximum),
- ethical analyses (done alone or in pairs, each worth 400 points maximum),
- peer reviews of other students' ethical analyses (each worth 50 points maximum),
- evaluations of one's partners' contribution to an ethical analysis (each worth 50 points), and
- in-class debates (each worth 200 points maximum).

Except for partner evaluations, all activities were graded in some way, and the students' points were scaled by the grade they received. For example, if they scored 80% on a weekly quiz, they earned $50 \times 80\% = 40$ points. For evaluating their partner, they received the full 50 points automatically. This provided an incentive to do the ethical analyses in pairs, since one could earn an easy 50 points just by filling out the partner survey. Some students asked if teams of more than two would be allowed. We decided that students could work in larger teams, but regardless of how many were on a team, the maximum score earned by all team members would be 400 x 2 = 800. So each student on a 3-member team could earn only 800/3 = 266 2/3 points, even if (s)he got a perfect score on the analysis. Of course, they could earn 100 more points for evaluating both of their partners, but even so, the maximum point total was less than for a solo or 2-member analysis. Only 6 out of 174 analyses during the semester were written by 3-member teams; all the rest had solo or pair authors.

The course Web site specified grading thresholds like this: "To get an A in the class requires 2600 points; a B requires 2300 points, etc." The meaning of "etc." was intentionally left vague because this was the instructor's first time grading by experience points, and he wanted the flexibility to adjust cutoffs if necessary to achieve a "reasonable" grade distribution. In any case, if students needed to earn extra points to reach their desired grade, they would merely need to perform additional activities, like analyzing more issues, or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Reusable learning objects through peer review
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Signup sheet for Ethical analysis 2 assignment

Your topic(s):
Fair use in backups of commercial software

Topic #	Topic name(s)	Max choosers	Available slots	Waitlist	Advertisement(s)
c4	Cybersquatting	2	0	1	
c4a	Typosquatting	1	0	1	
c4b	Renewal snatching	1	0	1	
i2f	Framing: Stripping page content in frames	1	0	0	
i6h	The ethical basis for copyright	1	-1	2	
i6i	Trademark protection for software	1	0	1	
i6j	Trade-secret protection for software	1	1	0	
i6k	Copyright term	1	0	0	
i6l	Unauthorized derivative works	1	0	1	
i6m	Derived works from multiple sources	1	0	0	
i6n	Region coding	1	0	1	
i6o	First-sale doctrine and electronic media	2	0	1	
i6p	Fair use and e-reserves	1	-1	0	
i6q	Fair use in backups of commercial software	1	0	0	
i6r	Fair use - copying to study a computer program	1	0	0	

Fig. 1. Signup sheet for ethical-analysis topics

reviewing analyses done by other students. The A threshold was set so that students who (i) took all the weekly quizzes, (ii) did three ethical analyses during the semester, (iii) and two reviews per analysis, and (iv) participated in two debates, and received an average of 93% on all their work, would collect just enough points for an A. However, students were permitted to do as many as six analyses (there were six two-week analysis rounds during the semester), and also to participate in extra debates if space was available. They could thus "make up for" poor performance on other assignments, or for missing those assignments altogether. In effect, all work was treated as if it was "extra credit," counting for a particular number of points. No one needed special permission to do extra work.

Ethical analyses were reviewed by a combination of peer review and instructor/TA review. The process is similar to the practice that we earlier described for writing sections for a student-authored wiki textbook [8]. Using our Expertiza system [6,7], students first select a topic from a list presented by the instructor. Students are allowed to sign up individually (Figure 1) or in pairs, but usually, only one student or team will be allowed to sign up for each topic. This is to ensure that all the topics will chosen by someone. Students then write up their work in a Google doc (ultimately to be included in a Google site) and submit the link to Expertiza. Other students review it using a rubric that asks them to comment and rate approximately ten aspects of the work. The student authors then have an opportunity to respond to their reviewers (also using a rubric). Based upon reviewers' comments, they revise their work. Their final submission is again assessed by their peer reviewers. The instructor and TA review the work and assign the final grade, but are often influenced by the reports of peer reviewers.

To give students an incentive to do careful reviews, the instructor and TA "metareviewed" the reviews done by the students. We looked over all the reviews done by the student during a particular round of ethical analyses, and scored the student's *average* review on a scale from 1– to 3+. (This was faster than assigning a score to each review.) The 1– to 3+ scale was translated to points (1– = 10 points; 3+ = 50 points), and the student was awarded this many experience points for each review done in this round (Figure 2).

1=vacuous, 3=good, 2=in between												
David	# rev	qual	points	Ed	# rev	qual	points	Shea	# rev	qual	points	
Student 1	8	2	240	Student 28	1	2	30	Student 57	0			
Student 2	6	2	180	Student 29				Student 58	4	3-	160	
Student 3	2	2	60	Student 30				Student 59	0			
Student 4	2	2+	70	Student 31	2	3–	80	Student 60	7	3+	350	
Student 5				Student 32				Student 61	0			
Student 6	2	3-	80	Student 33	1	3	45	Student 62	0			
Student 7	1	2+	35	Student 34				Student 63	0			
Student 8				Student 35	7	2	210	Student 64	0			
Student 9	1	2+	35	Student 36	15	2	450	Student 65	9	2+	315	
Student 10	3	2	90	Student 37				Student 66	0			
Student 11	2	2	60	Student 38				Student 67	6	2+	210	
Student 12	1	2	30	Student 39				Student 68	1	3-	40	scale for reviewing:
Student 13	1	1	15	Student 40				Student 69	0			4 or 3+: 50 points
Student 14	3	1+	60	Student 41	1	1+	20	Student 70	0			3: 45 points
Student 15				Student 42	13	1	195	Student 71	27	2-	675	3–: 40 points
Student 16				Student 43	2	2	60	Student 72	0			2+: 35 points
Student 17	4	3-	160	Student 44	10	2–	250	Student 73	0			2: 30 points
Student 18	1	1+	20	Student 45	9	3–	360	Student 74	9	2+	315	2–: 25 points
Student 19	6	1	90	Student 46	10	3+	500	Student 75	2	3	90	1+: 20 points
Student 20	9	1+	180	Student 47	4	2+	140					1: 15 points
Student 21	13	1	195	Student 48	2	2+	70					1–: 10 points

Fig. 2. Metareview scores assigned by instructor and TA

IV. Results

As it turned out, the most common grade in the course was A+. The A+ threshold was set at 97/93 of the A threshold, or 2712 points (typical university cutoffs are 97 for an A+, 93 for an A). More than 1/4 of the students (21 out of 77) received an A+. Some of them were very excited about the course. Five students wrote the maximum 6 ethical analyses, and five of these 6 earned an A+ in the course. Of the A+ students, 8 of them participated in at least 3 debates (one took part in 4 debates). These students accumulated 2782 to 3694 experience points. However, there was more than one path to an A+. One of our A+ students wrote only one analysis and received almost 60% of his points for reviewing.

The second most common grade in the course would have been F—if we had extrapolated the grading scale linearly (2600 for an A, 2300 for a B, 2000 for a C, 1700 for a D). Fifteen students accumulated fewer than 1600 XP, with totals that ranged from 152 to 1586. Figure 3 shows the grades that would have been awarded without any "curve." To avoid failing a large number of students (in an ethics course nonetheless!), we loosened the scale so that only 1600 points were needed for a C and 900 for a D. With these cutoffs, there were only 5 Fs. But this meant that an A required nearly three times as many points as a D; on Sheldon's scale [1], by contrast, an A can be earned with only 50% more points than a D.

The idea that grading was based just on points meant that we could not really require students to complete any course activity. According to the syllabus, all students were compelled to participate in two debates. However, there was no way to enforce this requirement, since students could instead earn points for writing or reviewing extra ethical analyses. Even among the A+ students, 7 of them failed to do

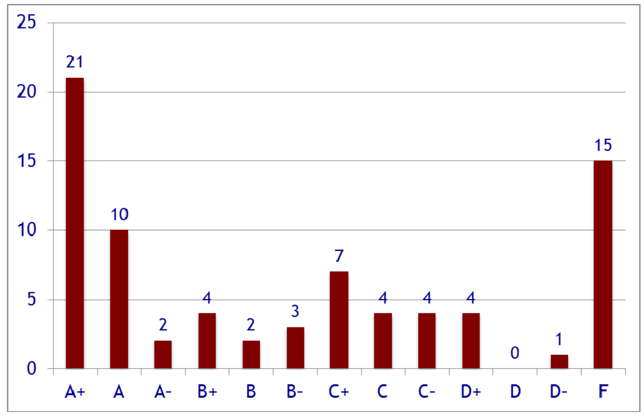
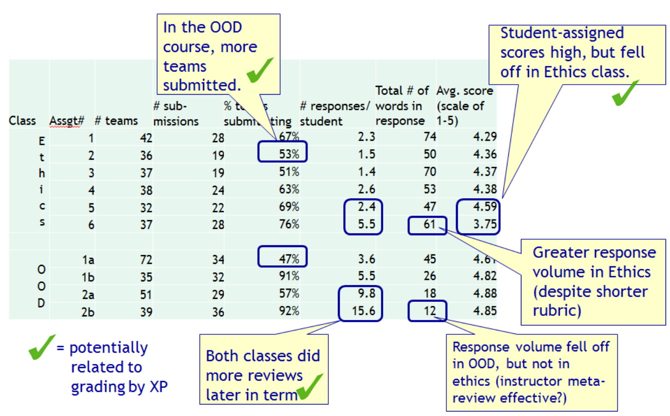


Fig. 3. Grade distribution with unadjusted grading scale

two debates; one of them didn't do any. In future semesters, we will consider making debates an achievement that all students must attain in order to pass the course.

Figure 4 compares the results in the ethics course with the results in the author's other Fall 2012 course, a course in object-oriented design, which was not graded by experience points. The column marked "% of teams submitting" refers to the percentage of teams that chose a topic and then followed through with a submission. In the ethics class, about 2/3 of the teams submitted an analysis of their chosen topic in the first round of ethical analyses. This percentage declined slightly in the next few rounds, then rose as the end of the course approached and opportunities for procrastination evaporated. In the OOD course, students were required to submit a wiki chapter for either assignment 1a or 1b, and again for either 2a or 2b. The percentage actually submitting in the OOD class was lower than the ethics course in the "a" rounds, but much higher in the "b" rounds. This may be a manifestation of the fact that the ethics students feel less pressure to do any particular assignment, since there are always other ways to earn points. This is especially true early in the semester, when the other opportunities are numerous.

Now look at the row titled, "# responses/student". This is the number of reviews done per student for the submissions in



Class	Assgt#	# teams	# sub-missions	% t[illegible]s submi[illegible]ting	# responses/ student	Total # of words in response	Avg. score (scale of 1-5)
Ethics	1	42	28	67%	2.3	74	4.29
	2	36	19	53%	1.5	50	4.36
	3	37	19	51%	1.4	70	4.37
	4	38	24	63%	2.6	53	4.38
	5	32	22	69%	2.4	47	4.59
	6	37	28	76%	5.5	61	3.75
OOD	1a	72	34	47%	3.6	45	4.6[illegible]
	1b	35	32	91%	5.5	26	4.82
	2a	51	29	57%	9.8	18	4.88
	2b	39	36	92%	15.6	12	4.85

Fig. 4. Comparison of peer reviewing in ethics and another course

the different rounds. Note that it rises in both classes as the end of the semester approaches. This is probably a consequence of the fact that students in the OOD class could earn extra credit for doing extra reviews (though there was a cap on the amount of extra credit that could be earned in this way). Thus, students in both classes were incentivized by earning extra points for extra reviews, and this inducement seemed to grow as the semester wound down and the other opportunities for earning credit dried up.

The next column tells how many words of prose were included in reviews submitted by the students. Note that this is much higher in the ethics class than in the OOD class. However, the OOD class was using a much more detailed rubric than the ethics class (18 criteria vs. 6). Thus, it took reviewers longer to rate the OOD submissions on the required criteria, which seemed to subtract from the energy that the student reviewers invested in writing prose. It is probably also true that student authors derived more guidance from the more detailed rubric, so prose comments were somewhat less necessary.

The volume of prose comments falls off sharply toward the end of the semester in the OOD class, but not in the ethics class. This is likely due to the fact that students (rather than instructors) were serving as metareviewers in the OOD class. Students tend to be much less demanding of the reviewers that they rate than the instructor/TA would be. This suggests that instructor/TA metareviewing served to "keep the ethics students honest," doing reviews that were just as careful at the end of the semester as at the beginning.

On the other hand, when one looks at the average score assigned by the reviewers (on a Likert scale of 1 to 5), it falls off sharply at the end of the semester in the ethics class, but not in the OOD class. This suggests that perhaps the quality of ethical analyses fell at the end, with students attempting to earn points via quantity rather than quality of submitted work. However, if one compares the average score awarded (by the instructor and TA) to analyses in round 6 (75.3) with the average score in round 5 (76.2), there isn't much difference. So it's not clear that quality did fall. Of course, one would hope to see quality increase from one round to the next, but we didn't see that happen.

A. Student Responses

Students were surveyed on their reaction to the review process and grading by experience points. Results are shown in Table 1. Students were most positive (4.02 on a Likert scale of 1 to 5) on having the chance to do extra work to achieve the grade they desired. They were least positive (2.11 on a scale of 5) on the grading process giving them a clear indication of where they stood. As one student put it,

> "I believe this system could really work..the problem was this semester is that the grading was unacceptably late. I can't even describe how infuriating this was as a student. I didn't even start knowing what my XP points were until mid November."

TABLE I. RESULTS FROM STUDENT SURVEY

Survey Question (Likert scale of 1 = strongly disagree to 5 = strongly agree)	**Average** (*n* = 44)
1. I had trouble understanding what was expected of me in writing an ethical analysis.	3.36
2. I put a lot of effort into writing my ethical analyses for the Ethics in Computing	3.83
3. The material I read in order to write my ethical analyses gave me new insight into the topic I was writing on.	3.57
4. The ethical analyses I wrote would be credible entries for an undergraduate textbook	2.81
5. I am proud of my contributions to the Ethics site.	3.34
6. Having students write analyses for an ethics Web site in a course like CSC 379 is a good idea.	3.05
7. I clearly understood what was expected of me in reviewing an ethical analysis.	2.95
8. The analyses I read that were authored by other students gave me new insight into the material they covered.	3.21
9. I read the content of the ethical analyses more critically than I read the content of other textbooks I have used.	2.98
10. I often questioned the information and ideas in the ethical analyses I read..	3.29
11. I tried to decide if I agreed with the ethical analyses when I read them.	3.76
12. When I read the ethical analyses I considered what other opinions and ideas might exist on the topic.	3.67
13. As I read, I often thought about my own ideas and opinions on the topic.	3.83
14. I looked to see if the claims made in the ethical analsyes were well supported.	3.57
15. When I read the ethical analyses, I often thought about information that seemed to be missing or what else could be included.	3.48
16. The reviews I received helped me to improve my work.	2.95
17. The scores assigned by the reviewers were fair.	3.07
18. There was too much rating required for this class.	3.55
19. I had trouble determining how to carry out the assigned activities in Expertiza.	3.33
20. Grading by experience points (XP) motivated me to work more on this course.	2.83
21. Grading by XP motivated me to write more than the required number of ethical analyses.	3.40
22. Grading by XP gave me a clearer idea of where I stood in the course"	2.11
23. I appreciated being able to do more work to earn the extra points that I needed to achieve a certain grade	4.02

This can be attributed to two factors, one logistical and one inherent to the review process. Early in the semester, the course staff *was* slow in posting grades. Ethical Analysis 1 grades were not finalized until after Ethical Analysis 2 was due. In part, this reflects the large amount of work required to write up the topics (52 topics for rounds 1 and 2). It should get easier in the future; next time, we can use a revision of this year's topic descriptions. However, it also reflects the time needed to take the submissions through the required rounds of review. The final review deadline was 11 days after submission, and final grading/metareviewing could not start until after that deadline. In later rounds, we caught up and were posting final grades within a week of the final review deadline.

Complaints about the speed of grading were the most frequent prose comment (10 out of 44 respondents). Next most frequent (8 respondents) were favorable reactions to grading by XP:

> "I think it is an interesting and novel idea. Perhaps the greatest benefit is I could participate in as many debates, ethical analyses, and reviews available and not be required to perform any one task. This allowed me to strengthen my skills in an area of my choosing. However, I did have to spend some time deciphering the allocation and accumulation of my experience points."

We thought our grading scheme was simple, but not all students agreed. The third most frequent comment (6 respondents) said it was hard to figure out:

> "Grading by XP gave me no idea about where in the class I stood or how well I was doing the entire semester. I still have no idea how well I've done this semester because the system was so convoluted and hard to figure out."

Some students (4 respondents) thought the course was too much work:

> "Also please assign less work for a 1 credit hour course, its not helpful to have a course that counts for so little of my time take up so much of it. A passing grade for this course should be out of 1600 not 2600 by my estimate of the workload appropriate for a 1-hour course."

Two students thought the system rewarded quantity, not quality:

> "Grading by XP encourages quantity of work, not quality. I didn't care if i got a C on an assignment, because if I got enough C's I would have well over an A."

V. Conclusion

In 2012, we switched to grading by experience points in our Ethics in Computing course. The course has often been plagued by low attendance. We wanted an approach that would make students delve into the very relevant and often very interesting issues of law, public policy, and personal morality. The change was successful in many respects. It did motivate a large number of students to go beyond what was required. Nearly a quarter of the class earned a grade of A+. These students, by and large, wrote more ethical analyses, and participated in more debates, than any student had in previous classes. Some of them told us how much they enjoyed the debates. Students in the 77-member class submitted a total of 174 ethical analyses, on about 150 different topics. This, too, is more topics than we had been able to cover in any previous running of the class.

On the other hand, a significant fraction of the students thought that the class was too much work for one credit. Many students did less than was expected. Even after curving, 10 students received Ds or Fs. This too was a much higher number than in previous semesters. Activity rose markedly near the end of the semester, as student strove to earn the points that they needed for the next higher grade. However, the quality of the ethical analyses was not as high as desired. This may indicate that many students thought it was better to write many analyses, rather than write a fewer number of good analyses. On the other hand, the quality of peer reviews remained high, probably reflecting the effort that the instructor and TA were investing in assessing the reviews and rewarding good quality.

The most important lesson learned is that speed of feedback is critical in motivating students. The peer-review process makes it difficult to finalize grades quickly. But scores should be recorded almost immediately after the final review deadline. Students need a single location where they can go to view the number of points they have accumulated thus far. There is ample opportunity for us to improve the ethical analyses by (i) using good analyses from this semester as examples for later students, and (ii) assigning some students to improve this semester's analyses in specific ways identified by the instructor. As time goes along, the analyses should only get better. This will show the students what a good analysis looks like, and motivate them to do work of similar quality.

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A Qualitative Study Exploring Students' Engineering Ethical Reflections and Their Use in Instrument Validation

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***Abstract*— The development of ethical awareness and ethical reasoning is a critical part of engineering education. Appropriate assessments are needed to determine if the educational interventions are effective in developing these skills. Although there are measures to assess general moral reasoning (e.g., DIT2), they do not take into consideration the peculiarities of handling ethical situations in engineering rather than ethical situations in general. In addition, because most undergraduates learn to apply ethical reasoning to engineering through design courses that are taught in teams, it is important to understand the team ethical climate. To address this need, our research team is developing instruments to assess both individual moral reasoning and team ethical climate in an engineering context. As part of the validation efforts, we have conducted individual interviews and team observations to triangulate data from other sources and aid in data interpretation. In this work-in-progress research paper we present an overview of the instruments and our qualitative study design including our interview protocol and analysis approach. At the FIE conference, we will present initial findings from the analyses and discuss how these results are being used to validate and/or modify both the individual engineering ethical reasoning and team climate instruments being developed.**

***Keywords*— engineering ethics; assessment; qualitative study**

I. Introduction

The need for understanding and enhancing engineering students' ethical development has been the subject of numerous publications and has been embedded in ABET criteria. Engineers in today's global society are interacting with ever more of the world's peoples and cultures. These interactions are introducing greater social and ethical complexity to the profession than has been incorporated previously and are raising the importance of practicing engineers becoming capable ethical decision makers and contributors to ethical team climates. As engineering educators, we are responsible for helping to develop these ethical decision-making and productive team climate skills in our students so they might transfer them into the profession.

Although measures such as the Defining Issues Test, Version 2 (DIT2) have been designed to assess general moral development [1], they do not address the peculiarities of handling ethical situations in engineering. In addition, because most undergraduates learn to apply ethical reasoning to engineering through design courses that are taught in teams, knowledge of the interaction between individual ethical development and the team climate, as well as individual and team factors, is vital to design effective learning environments. To address these needs, we are collaborating with three other universities, Illinois Institute of Technology (IIT), Lehigh University, and Michigan Technological University (MTU), to develop instruments that reliably and validly measure individual ethical reasoning (Engineering Ethical Reasoning Instrument or EERI) and team ethical climate (Team Ethical Climate Survey, or TECS), from which we will study multilevel effects of both the individual and team data using hierarchical linear modeling (HLM). This study has been approved by the university's Institutional Review Board (IRB).

As part of the validation efforts of both the EERI and the TECS, we have been conducting individual interviews and team observations at each of the four partner institutions. The interview and observational data not only supplement self-report measures by aiding in data interpretation and suggesting further areas of study but also triangulate data from other sources to contribute to instrument validation [2]. The four university partners all have undergraduate engineering programs with multidisciplinary teams which were the focus of the study: the IPRO program at IIT, the Integrated Product Design (IPD) at Lehigh University, the Enterprise Program at MTU, and the EPICS program at Purdue University.

After conducting a total of 57 interviews and numerous observations within the four programs, we have begun analysis of the interview data using a typological analysis approach [3-4]. In this work-in-progress research paper we present an overview of the instruments and our qualitative study design including our interview protocol and analysis approach.

II. Description of Instruments

In the sections below, we provide an overview of the instruments, including a description of their structure and their underlying foundations. We also describe current statistical validation approaches.

A. *Engineering Ethical Reasoning Instrument (EERI)*

Similar to the DIT2, the EERI uses three fundamental schemas which are based on Kohlberg's moral development phases (originally called "stages") in which individuals increase in ethical decision making from purely self-centered responses to dilemmas to (ideally) highly empathic and contextually oriented choices [5-7] as a foundation to measure ethical development in an engineering context. These schema are: pre-conventional (focusing on personal interest and encompassing Kohlberg's stages 2 and 3), conventional

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(emphasizing maintaining norms, stage 4), and post-conventional thinking (displaying agile perspective-taking, ability to appeal to ideals that are shareable and non-exclusive, and expectations for full reciprocity between laws and the individual, stages 5 and 6).

The EERI has been developed over the course of several years and undergone a number of changes in scenario construction and in item and scale development [8]. We began with eight scenarios, and we are using six of those in its current form. These scenarios involve dilemmas that students might reasonably expect to encounter on a student project team. Similar to the DIT2, students are asked explicitly what action they would take in the given situation. An example scenario with the decision question is as follows:

Your student design team has designed a new Soap Box Derby car that allows children with physical and cognitive disabilities to race by allowing an adult to ride in a backseat and maintain full control of the car. Based on suggestions from the adults, you have added spring tension to the child's steering wheel in front in order to simulate the feeling of driving and make the child's experience more realistic and fun. The child will not have the ability to control the car, only the illusion of control. Before the first test run with an adult and a 14-year-old child onboard you hear the child's parent tell the child to "be careful" and to "drive safely." The parent turns to you, explains that because of a cognitive disability the child likely won't understand the difference anyway, and asks you to tell the child that the front steering wheel is actually functional. The request that you lie to the child would take advantage of the child's disability and it creates the possibility that the child would feel responsible if they were to lose the race or have an accident. Would you lie to the child? __Yes __Can't decide __No

Following their recording of their individual decision, students are next asked to rate the importance of a series of items in making their decision. In its current form, students rate 14 items in terms of importance with five response alternatives: great, much, some, little, or no. The instructions for the ranking of students' top 4 items were: "Consider the 14 issues you rated above and rank which issues are the most important." This rating and ranking process follows the format of the DIT2. Therefore, like the DIT2, it is the ranked items that determine individual students' ethical reasoning schema phase ("score").

A number of statistical analyses of the EERI are being conducted to determine if there is a correlation with year and major, as well as other external measures such as the DIT2 and peer evaluation data. The statistical measures are also being utilized to inform the reduction of the instrument, if possible, to contain only four or five scenarios with 12 items each.

B. *Team Ethical Climate Survey (TECS)*

The TECS is a new instrument adapted from Victor and Cullen's team Ethical Climate Questionnaire (ECQ) [9] for the student project context. The ECQ consists of five scales: caring, law and code, rules, instrumental, and independence. The TECS also includes items intended to measure the caring, law and code, and rules dimensions, as well as exploring dimensions of friendship, personal morality, self-interest, team interest, shared ethics model, interdisciplinary ethics, rule-orientation, and how the team responds under pressure. In the TECS, students are asked to respond to 59 items as they relate to their project team in the Enterprise, EPICS, IPD or IPRO program using a Likert scale (Strongly Disagree-Disagree-Neither Agree nor Disagree, Agree, Strongly Agree).

Validation of the TECS includes item and factor analyses. In addition, scoring methods are being developed to provide scores for the individual scales, as well as an overall score.

III. USE OF INTERVIEWS AND OBSERVATIONS IN VALIDATION

In addition to the quantitative validation efforts, we have conducted observation and interviews at the four collaborative university programs. Our semi-structured interviews provide access to unanticipated aspects of ethical decision making and team ethical climate by enabling participants to add comments that explain their experiences and/or that they believe are relevant but may not be requested directly in a structured interview. These comments provide access to team members' meaning and sense making of ethical processes. These processes include the point at which individuals or teams consider possible ethical challenges through engineering team members' resolution and explanations of ethical decisions. Furthermore, observational data provide access to details of team processes that may not be expressed in, or consciously processed enough for, more traditional interviews.

A. *Interview and Observation Protocol*

The interview protocol was developed to probe aspects from both the EERI and the TECS. Therefore, it includes questions that elicit information about how the participant prioritizes issues related to both their individual and team decision-making. We also explore general team processes and the student's perceived role to provide context on how the individual operates within the team. Overarching questions that are explored include:

- How would you characterize your team interactions as a whole?
- What is important to or valued by your team? What are your team's priorities?
- What is your role on the team? Do you feel like you belong? Are your viewpoints listened to?
- How and when are decisions made by your team? Who was involved in those decisions?
- Do you feel as though any of these decisions or your team work involved ethical considerations?
- How do you define ethics? How do you make ethical decisions?
- Does your team seem concerned about professional codes and/or rules/laws?
- Does your team share a common understanding of "right and wrong"?

Observations of team meetings were also made in order to provide context for the interviewer and help identify participants for the interviews. Observations were guided by a general observation protocol, with other interesting interactions being noted where appropriate. Several examples of the observation protocol include:

- What seems most important to the team at this time? What did you observe that made you answer in the way you did?
- Were there decisions made during team meetings? What were the decisions about? Who made the decisions?
- Did you observe interactions or language centered on how a decision or design aspect might affect individual team members?
- Did you observe interactions or language that centered on how team processes and deliverables align with moral or ethical stances that are up for discussion, shared and malleable, and/or act as appeals to ideals for human existence?

IV. Analysis and Conclusion

After conducting a total of 57 interviews and numerous observations within the four multi-disciplinary programs, we have begun analysis of the interview data using a typological analysis approach [3-4]. Initial codes were generated from the TECS scales (e.g., friendship, rules, shared ethical model) and the schema of the EERI (e.g., personal interest, maintaining norms, post-conventional). As the researchers analyze this interview data, any themes or ideas that seem prevalent across respondents will be considered and additional codes will be added throughout the analysis. We will compare and contrast findings emerging from data with interdisciplinary research to uncover regular patterns of discourse (messages and interactions), team norms for ethical decision making procedures, and other aspects that are part of team processes. In addition, we will review the participant's TECS and EERI instrument responses to how well they align with their scores on the instruments. We will also determine if the there are aspects of the experiences which are not currently reflected in the EERI and TECS. At the FIE conference, we will present preliminary results of our analysis and how it has informed our validation of and/or changes to the instruments.

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Ethics in Engineering Education: A Literature Review

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***Abstract*— Engineering Ethics is an important topic to be developed in engineering education curriculum. Despite its importance, ethics is not much investigated in engineering education as compared to other disciplines, in particular medicine or biology education. In this paper, a comprehensive review of engineering ethics is provided. The review covers three main topics: 1) Attributes of ethical engineers, 2) Content, logistics and pedagogy of engineering ethics, and 3) Assessment of engineering ethics. A particular focus is given to the Defining Issues Test (DIT) and the Engineering and Science Issues Test (ESIT) that is considered a promising instrument to assess moral judgment development of science and engineering students. Final remarks will conclude the paper.**

Keywords*— *Engineering Ethics, Ethics Assessment, Ethics Pedagogy

I. Introduction And Definitions

Recent advances in engineering complexity requires engineering graduates who are able to handle interrelated technical, social, human, and complex issues [1]–[2]. The engineering profession mission requires the engineer to contribute to human welfare by reshaping the social, economic and legal contexts [3]–[4]. Hence, engineering profession is not only about the application of technical knowledge, but it is also about the application of technical knowledge in an ethical manner. Engineering ethics is taught to engineering students as a practical academic discipline that deals with real life situations, whereas an engineer's responsibilities are more complex than ever. Therefore, the professional responsibilities are introduced through these ethics to prepare the students for real life ethical dilemmas [5]. Ermer and VanderLeest [6] define engineering ethics in accordance to Martin and Schinzinger [7] as "the study of the moral problems confronted by individuals and organizations involved in engineering". Another definition of engineering ethics was proposed by Li and Fu [8] as a field which "*consists of the responsibilities and rights of those engaged in engineering, and also their desirable ideals and personal commitments*". They add, ethics "*is the study of the decisions, policies, and values that are morally desirable in engineering practice and research*".

Engineering ethics education plays a significant role in the formation and reshaping of the engineer's ethics. Possible objectives for ethical instruction in engineering education have been reported in the literature. Newberry [1] in accordance to [9] highlighted some of these objectives as follows: "i) stimulate the ethical imagination of students, ii) help students recognize ethical issues, iii) help students analyze key ethical concepts and principles, iv) help students deal with ambiguity, v) encourage students to take ethics seriously, vi) increase student sensitivity to ethical issues, vii) increase student knowledge of relevant standards, viii) improve ethical judgment, and ix) increase ethical will-power".

II. Attributes of an Ethical Engineer

The engineering profession positions the engineer in numerous ambiguous or conflicting situations of various types; a common example is facing ethical dilemmas. In order to tackle ethical dilemmas, the engineer should possess the necessary ethical skills and attributes. Li and Fu [8] highlighted a set of skills an ethical engineer should hold present in [10]. An ethical engineer should have the skill to: define ethics issues, identify relevant socio technical systems, understand different perspectives, identify and recognize value conflicts, identify constraints, identify and assess decisions (in terms of: barriers, consequences and defensibility), engage in ethical reasoned negotiations and finally, revise plans/actions/options.

Reasoning and critical judgment skills are essential for engineers while handling ethical situations. Steneck [11] highlighted that engineers should posses ethical reasoning skills, and should be able to understand the interrelation between technology and society.

Another ethical engineer's profile and set of ethical attributes were suggested by Devon [12]; these are: competency, cognizance, democratic information flows, democratic product design and development teams, a service orientation, diversity, cooperativeness, creativity and project management skills. These attributes act as guidelines for the engagement process of the engineer with other individuals. The understanding and application of such eliminates the reliance on individual ethics. Competency includes the engineer's realization of a product that achieves the goals of money making, protection of infrastructure and the protection of the country. An important attribute is cognizance, i.e. an engineer should have a full understanding of the implications of the decisions and designs they propose. Open democratic information flows includes the respect flowing between the participants while sharing information.

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Development teams and product design processes must be aimed towards achieving technology of the people, for the people and by the people. An ethical engineer should value diversity and avoid stereotyping. Cooperativeness is essential and without such cooperation the productivity of an unsafe product or decisions becomes a potential risk. New creative innovative ideas are demanded by an ethical engineer. Finally, an ethical engineer should possess project management skills. Knowing what expertise and duties are required, and knowing how to assign and manage them is necessary.

A significant portion of the skills and attributes of an ethical engineer are related to morality. Several moral models have been conducted. The paper proposed by Illingworth [13] in reference to [14] summarized the Four Component Model (FCM) of Morality:

1) *Moral sensitivity (interpreting the situation as moral).*
2) *Moral judgment (judging which of the available actions are most justified).*
3) *Moral motivation (prioritizing the moral over other significant concerns).*
4) *Moral character (being able to construct and implement actions that service the moral choice)*

Based on the literature review conducted in this area [8], [10]-[14]; an optimum model of the ethical engineer was created.

An ethical engineer should have the skills to identify an ethical dilemma and all the constraints related to such dilemma. He/she should communicate effectively with other team members to assess barriers and any possible consequences. Negotiation skills are required when team members decide upon a final ethical decision. Skills of reasoning and understanding of the relationship between both engineering and the society, and technology and society are also essential. Understanding also includes the understanding of different diverse perspectives. An ethical engineer should be competent and service oriented. The identification and recognition of value conflicts is necessary. The exchange of information between colleagues in a democratic form is also a required skill. Part of being an ethical engineer is related to moral sensitivity, judgment, motivation and character. Being creative and having strong project management skills is a must for an ethical engineer. Finally, an ethical engineer should have the skill to revise plans/actions/options.

III. Mechanisms of the Provision of Engineering Ethics Education

Several concerns were raised regarding the engineering ethics education; does it really influence the ethical skills as planned, what is the most suitable and effective approach to teach ethics. Numerous research studies were conducted in this field [3], [5], [8]–[9], [11], [13], [18]–[19]. Stand-alone ethics courses are the most common mechanism, but the introduction of engineering ethics in technical courses is highly recommended [9]. Throughout this review, the delivery methods noticed revolved around three main methods: 1- standalone courses, 2- embedded courses, and 3- team taught courses.

A. Standalone Courses Approach

As suggested by Li and Fu[8]; a standalone course is an independent course usually taught by one professor, not necessarily a professional in ethics. It is also easy to select what topics should be covered. Engineering ethics can be conducted through: standalone ethics courses within engineering or standalone ethics courses from outside engineering [1], [5], [18]. Stephan [5] suggested some "Credit-Hour-Friendly ways of teaching ethics" that were such as "Politics and Ethics of Engineering". A disadvantage of such approach is that it overcrowds the engineering curriculum which is already crowded [20].

B. Embedded Courses Approach

An embedded approach includes the introduction of ethics in different engineering core courses. This is accomplished by incorporating an ethical component or module into actual engineering courses [8]. It includes the integration of ethics content in all technical courses [1], [5], [18]. A series of contextualized activates are used to perform the integration of ethics into the engineering curriculum. This integration is considered an advantage for such approach [20]. An example of an integrative course that includes both technical and non-technical ethics mentioned in [5] was adopted in Drexel School. To further emphasize on the "across curriculum/embedded" approach, the College of Engineering at the University of Michigan adopted this approach for teaching engineering ethics along with the issues of communication, teamwork and environment [11]. The high dependency of the course on the willingness of the faculty member to address ethics decisions in his/her course is considered are the main disadvantage of such approach [8].

C. Team Teaching Approach

Team teaching approach delivers a course which is taught by a team of multidisciplinary professors [21]–[22]. Such approach gives the students that advantage of learning form the diverse expertise of both the engineering professors and the philosophy professors. The main difficulty of such approach is related to finding highly motivated and qualified engineering professors to deliver such course [8].

Some examples of the approaches used to teach engineering ethics in the undergraduate level are: "Segments in Introduction to engineering courses, Segments in Senior Seminars, Segments in Capstone Design Courses, Pervasive Approach, Integrated Humanities Courses, and Stand-alone Courses" [15]. A new approach for teaching engineering ethics is expected to include guidance by experts in making ethical decisions, harmonizing the ethics with the engineering curriculum and finally strongly demonstrating that ethics is an integral component in all engineering practices [19].

IV. Pedagogy

Several researches have been made to define the paramount methods to deliver the curriculum of engineering ethics. The review conducted resulted in numerous delivery approaches such as case studies, ccollaborative/challenge games and role plays, debates and group discussions, presentations, codes of ethics, online instruction, multimedia packages, videos and simulation, and traditional teaching methods [3], [8]–[9], [16], [23]–[30].

A. Case Studies

The best method to teach engineering ethics as mentioned in [9] is by using several case studies, e.g. disasters cases. The cases used are cases which are more likely to be encountered in real life situations. Using case studies provides a framework which engages the students in problem solving themes; they also can become a platform for peer to peer learning and experiences exchange. During such cases, the students train their moral imagination as a result of the holistic effect the case approach has [16]. Case studies force students to draw the line between acceptable and unacceptable actions and behaviors [9]. Involving students in case studies strengthens their ethical reasoning skills [23]. Such method provides the exchange of experiences between students and faculty [16]. Some examples of utilized case studies are: Challenger launch decision, BART case [8]; The Hyatt Kansas walkway collapse, West Gate Bridge, and the Thredbo disaster [23].

B. *Collaborative/Challenge Games and Role Plays in Ethics Education*

Practical understanding of ethical issues, specially the concept of responsibility, can be attained by designing collaborative games [26]. Skills of negotiation, strategic planning, public speaking, and evidence presenting are some of the skills games provide the students with. The "Engineering Ethics Challenge Game" as mentioned by Carpenter [27] involves a large number of ethical cases. Students get involved in without losing interest or feeling bored. Teamwork skills, ethical reasoning and problem solving skills are developed during such game. Such games provide an excellent chance for group discussions and emphasize on teamwork and collaboration between students [8]. Lloyd and de Poel [26] highlighted that games with their competitive environments provide students an informative experience in the management of open ended situations.

C. *Debates and Group Discussions*

An approach to improve the engineering ethics education is to involve the engineers in debates that aim to develop the uses of technology [3]. Such debates improve the ethical reasoning skills of students and the exchange of information and opinions. Debates focus on the idea of respecting other opposing opinions. While debating, students have the chance to fully analyze an ethical situation from all its aspects, i.e. design, technical and statistical considerations [24].

D. *Utilization of Online Instruction*

Loui [28] suggested that online educational technologies used in teaching engineering ethics have many benefits over traditional educational technologies. It opens the space for communication between students with each other and between the students and instructors [30]. Archiving of class sessions is one main advantage of such method. Access via the Internet to course resources is possible by this type of instruction [28].

E. *Utilization of Codes of Ethics*

Schmaltz [24] highlighted that the introduction to existing codes of ethics will increase the students level of knowledge and comprehension. Implicit social contract between society and professionals is also achieved. Being aware of the codes of ethics helps the students understand the professional societies role [23]. Stern and Russell [29] suggested a module to teach engineering ethics more effectively. In this module, students work on developing their own code-of ethics; Once developed, they compare them to established codes by engineering societies.

F. *Other Methods and Approaches*

Multimedia packages, videos and simulation provide an interactive learning framework for students [8]. The use of presentations as a method to teach engineering ethics is recommended by Bowden [23]. During presentations, students with their peers have the chance to discuss their viewpoints and draw conclusions. Group work and cooperation among students is achieved when preparing and giving presentations [28]–[29]. Traditional Methods including exams, reports, quizzes, assignments, etc. are still used in which analytical skills are used and measured [24]. The previous methods are summarized in the table below.

TABLE I. ENGINEERING ETHICS INSTRUCTIONAL METHODS AND OUTCOMES

Instructional Method	Expected Outcome
Case Studies	• Strengthen the ethical reasoning [23] • Engagement in life time ethical concerns [23] • Encountering of real life situations [9]. • Drawing the line between acceptable and unacceptable actions and behaviors [9]. • Engage students in problem solving themes [16]. • Exchange of experiences [16]. • Awareness of harmful practices [24] • Demonstration of ethical issues [25].
Collaborative/Challenge Games and Role Plays	• Practical understanding of ethical issues (responsibility) [26] • Teamwork [27]. • Ethical reasoning [27]. • Negotiation, strategic planning, public speaking, and evidence presenting [26]. • Group discussion [8]..
Debates and Group Discussions	• Exchange opinions and respect others opinion [3]. • Improve the ethical reasoning skills • Analyze ethical situations from all its aspects [24].
Presentations	• Discuss viewpoints and draw conclusions [23]. • Cooperation among students [28].. • Groupwork [29]..
Traditional Methods (Exams, reports, quizzes, assignments, etc)	• Application of analytical skills [24]. • Groupwork [29]..
Codes of Ethics	• Increase the level of knowledge and comprehension [24].. • Understand the professional societies role [23] • Understanding of class-wide codes of engineering ethics [29].
Online instruction	• Communication [28] ,[30]. • Production of documents, drawings, and other artifacts [28] • Train the students moral imagination [16]. • Prompt Feedback [28] • Archiving of class sessions [28]. • Management of open ended situations [26] • Access via the Internet to special resources [28]..
Multimedia packages, videos and simulation	• Interactive framework [8].

In this section, an overview of the most common methods of engineering ethics instruction has been provided. The next section provides more details on the contents deployed in these methods. Examples of where these methods are applied are also mentioned.

V. CONTENT

The content of the curriculum must provide the knowledge and skills the future engineer needs to face the ethical challenges of today's world [8]. It should increase student's knowledge of relevant ethical standards. The curriculum must be designed improve the ethical judgment and ethical willpower of students [9]. The main ethical issues taught in US engineering schools are enumerated in [23]: Public safety and welfare, risk and informed consent, health and environment, representation of data, whistle-blowing issues, conflict of interest, accountability to clients, plagiarism or giving due credit, quality control, confidentiality, gift giving and bribes, employee relations and discrimination. Many methods of teaching engineering ethics were reviewed in the previous chapter. This section focuses on the content of two main engineering ethics educational pedagogies, online instructions and games/role plays.

A. Online Instruction

Instruction using the internet (web-based instruction) bridges cultural gaps and distances between both students and instructors [31]. Several reviews have been made and the following are three examples of applied web-based instruction [11], [30], [32]. Simulator for Engineering Ethics Education (SEEE):

As reviewed from Chung and Alfred [30], the SEEE is an online interactive simulator for engineering ethics education. The students are placed in scenarios which involve several ethical dilemmas, where they have to solve in a first perspective manner. During the first perspective scenarios, the students are obliged to perform an action rather than only observing the situation. The action includes playing the role of an agent and making serious decisions regarding the collection of more evidence, raising of ethical issues, and finally how to best support their ethical concerns**.**

The SEEE has four modes of operation:

a) Instructional mode: "fundamental information about engineering ethics, rules of practice, and professional obligations."

b) Training mode: "specific scenario segments involving the recognition and response to the engineering ethics subjects presented in the instructional mode."

c) Scenario mode: "complete first person perspective scenarios involving different types of possible engineering ethics situations."

d) Evaluation mode: "provide users with an objective means of assessing the level of the user's knowledge."

Comparison was made between the SEEE method and the "conventional web based engineering ethics education resource". A 32% improvement in instructional effectiveness was noticed compared to the conventional web resources [30]

1) Responsible Engineering Forum (REF@UM):

The forum was developed by the University of Michigan, it aimed to engage engineering faculty members in the teaching of engineering ethics in engineering classes. The structure of the REF@UM website is as follows:

a) Main content: divided into four sections (4 levels of ethics introductory courses)

b) Course sections: resources specifically designed to support teaching at each of the four levels (readings, links to other sites, interactive materials, and assignments)

c) Separate, password-protected section: materials specifically for faculty

d) Additional links: to locate other ethics sites, career information, professional societies, codes, journals, and case studies [11].

2) Websites for ethical engagement

A website developed by Imperial College London for the purpose of ethics engagement.

The website was developed in the form of an online ethics advisor. The three main aspects are:

a) A search tool: from which the user can get statistics and specific references to codes of conducts to ethical questions or problems.

b) A polling element: so that users can give their view on ethical matters.

c) A forum: for people to discuss any ethical issues they may have.

B. Games/Role Plays

Skills of negotiation, strategic planning, public speaking, and evidence presenting are some of the skills games provide the students with. These games with their competitive environments provide students an informative experience in the management of open ended situations [26]. The Engineering Ethics Challenge and the Delta Design Game are examples of these games.

1) Engineering Ethics Challenge (EEC):

University of South Florida developed the EEC to encourage teamwork, experience exchange and responses to ethical dilemmas. The EEC game includes questions based on ethical situations. A typical class is divided into 6 groups. Each group has a name. Ethical situations are assigned for each group. Each group develops EEC questions based on these situations. They also develop multiple choice responses. The responses are formulated in a PowerPoint presentation. To begin, a group presents their questions and several responses to all the class. The rest of the groups are asked to discuss the question and choose one of the responses. An expert, usually the class moderator, is given the scoring of the responses made by the remaining groups. The performance of the presenting group is criticized based on their presentation skills, communication skills, their understanding of the codes of ethics and the clarity of their responses. Based on this critique, the playing group makes their move on the EEC board and another group makes their presentation. The group which moves the furthest is the winning group [27].

2) Delta Design Game (DDG):

The Delft University of Technology developed such game to train students for a full design process including all types of ethical dilemmas. In this game a group of multidisciplinary designers work together to design and construct a building which is suitable and at the same time attractive for inhabitants of DeltaP company. This game is used mostly in business sectors. The same idea can be applied with the undergraduate students in which seven groups each consisting of 4 to 6 students. The game is played for almost 3 hours where students propose solutions and start discussing their proposals. Judgments are made concerning the trust of the "rule of thumb" guidelines given. Several conflicts will arise during the game and the students will try to come up with the optimum solution to solve these conflicts [26].

Developing an engineering ethics education approach and applying it is not enough. An assessment of the developed approaches must be constructed to assess the effectiveness of the engineering ethics educational treatment. The following section covers the assessment instruments used to evaluate the effectiveness of ethics educational approaches.

VI. Assessment

Several research studies have tried to examine the effectiveness of ethics education offered for engineering students in higher education institutes. As an example on existing attempts is a recent large-scale study covering engineering undergraduate students from 18 higher education institutes in the U.S [33]. The study aimed to provide descriptive data to aid the process of identifying ethics education practices that most effectively promote ethical development of engineering undergraduates. The data was collected using two main tools; the first is the "Student Engineering Ethical Development (SEED)" survey which was developed by the research team [33]. The survey included 152 items targeting the following measurements: Students' characteristics, ethics related curricular and co-curricular experiences, two constructs of ethical development, which are knowledge of ethics and ethical behavior. The second tool utilized was the Defining Issues Test Version 2 (DIT-2), which is a well-established test used to assess moral judgment/reasoning development [34]. The study has shown that the DIT-2 results are consistent with national norms of DIT-2 measurements. In addition, the authors pointed out that students' knowledge of ethics was 'surprisingly low' [33].

Other studies attempted to use DIT-2 to measure engineering students' moral judgment. A study conducted by May and Luth has utilized DIT-2 in assessing engineering students' moral judgment. They planned this study to investigate the impact of ethics education on enhancing a number of ethical outcomes [35]. Moreover, the authors of the study developed a survey to measure the five remaining outcomes which are: Students' knowledge of responsible conduct of research (RCR) and four positive psychological outcomes including: perspective-taking, moral efficacy, moral courage, and moral meaningfulness. The DIT-2 and survey were conducted in a pre- and post-test experiment design. A main result reported by the authors is that no significant difference was found in students' moral judgment measured by DIT-2 before and after exposure to an ethics course [35]. Drake and others [36] also used DIT-2 to test and compare the effectiveness of two approaches to ethics education by relying on measuring development of moral reasoning in engineering students. The experiment was conducted following a pre- and post-test with a control group experiment design. The experimental group was composed of engineering students where some are exposed to a full course on ethics education and others are exposed to a course with a module on ethics during the semester. As with the previous study, no significant difference was detected in moral reasoning of engineering students before and after exposure to ethics education [36].

Referring back to the discussed studies it can be noticed that moral judgment/reasoning has been widely examined in studies that attempted to measure effectiveness of ethics education for engineering students. Such studies have utilized the well-know DIT test to measure moral reasoning of students. A brief discussion on DIT and DIT-2 test is provided next.

A. DIT-2

The DIT-2 is the second version of the DIT that is widely used to measure individuals' moral reasoning [36]. Moral judgment can be described as "the ability to apply general moral principles to particular situations" [37] it is widely recognized as an important element of ethics education [1], [9], [37]–[38]. The validity of the DIT test has been established by 30 years of testing by many measures, one measure is its sensitivity to the effect of educational interventions [36], [14], [39] cited in [37]. Developers of DIT-2 have provided significant theoretical refinement of the framework underlying the DIT allowing for a more accurate test of moral judgment [37]. The DIT-2 assumes that three moral schemas may be active in the individual's mind in the same time [40] which are; preconventional that can be described as personal narrow interest, conventional characterized as appeal to duty and maintenance of existing social order and postconventional which includes the search for moral ideals and how the ideal social order must be [40]. The test consists of a set of 5 moral dilemmas in social context [33], each stated in one paragraph. Each dilemma is followed by twelve questions corresponding to "different ways to judge what is important for making a decision about the dilemma" [33]. Participants are required to state the importance of each question in taking the decision, and then rank the four most important questions. Reading the test dilemmas and the DIT questions activate moral schemas [40]. When the participant encounters a test question that activates a preferred schema and makes sense, that question is rated and ranked as being of high importance in formulating the moral decision. On the other hand, encountering a question that does not make sense or does not activate a preferred schema, the question receives a low rating [40].

B. DIT-2 in engineering context and the ESIT

Developers of the DIT-2 and other experts in ethics education have identified the usefulness and need for profession-specific assessment tools [41]–[42]. Similar suggestions were reported by Drake et al. [36] deploying the DIT-2 to measure moral reasoning. Based on the test results, no significant difference was detected in moral reasoning of engineering students before and after exposure to a stand-alone ethics course. Similarly, a recent study [35] has found that measuring moral judgment using DIT-2, moral reasoning did not increase as a function of the ethics education conditions. Drake et al. [36] suggested that a general measure of moral judgment such as DIT-2 may not reflect the discipline-specific judgment needed in professional settings such as the case with engineering practice. In a follow up study [37], researchers have hypothesized that these results are due to the fact that DIT-2 tests engineering and science students on general dilemmas that student may not relate to. Borenstein et al. [37] were encouraged to develop The Engineering and Science Issues Test (ESIT) that was designed to follow the structure of DIT-2. A major difference is that the dilemmas in ESIT are drawn from engineering and science contexts rather than a general social context [37]. Such test is assumed to be more sensitive to the impact of professional ethics education on engineering and science students. ESIT was tested by administration to engineering students before and after exposure to a stand-alone course of ethics education. Results have demonstrated significant development in moral reasoning measured by the ESIT due to ethics instruction [37]. The ESIT seems to be a promising tool to measure moral reasoning development for engineering students as pointed out by [35].

VII. Barriers/Constraints that Impede the Effectiveness of Engineering Ethics Education

Integrating engineering ethics into the technical courses of the engineering curriculum is faced by several difficulties and oppositions [43]. Difficulties and oppositions are produced by the teaching faculty, students, the engineering ethics curricula and other constraints. The fact that engineering ethics includes many areas related to attitudes, values and behavior makes it uncomfortable for many engineering faculty members to teach, especially that some of these values have religious overtones [6]. Also, faculty members feel that they don't have formal training in ethics [43] and they don't possess the background skills and education for teaching ethics [1]. These non-supportive attitudes highly affect the success of ethics delivery to students.

Students identify engineering ethics as a non-quantified area of study, i.e. subjective. They perceive it as the softer side of engineering which in their opinion is less interesting [6]. In addition, concrete and specific concepts are preferred by many engineering students over general and abstract concepts taught in engineering ethics [6]. "Philosophy is not practical" is a common pre-concept the engineering students have. Since engineering ethics is related to philosophy (from the students point of view) they believe that engineering ethics is little useful for the engineering field [6]. What's most difficult is the emotional engagement of the students. Newberry [1] reports that the students end of year surveys returned that the ethics course is the least interesting, least useful, most trivial. They also mentioned that ethics is irrelevant, it is common sense, waste of time and effort when studied. This is considered as a main barrier.

Engineering ethics curricula also impede the effectiveness of the engineering ethics education. Engineering ethics is somehow difficult to integrate with the technical engineering topics [6]. In addition, the engineering curriculum is already overcrowded and there is not enough time to include ethics in [43] [44]. The issue of crowded engineering curriculum has been also a barrier to include other topics and activities for another set of essential skills, such as entrepreneurship [45][46], research based learning [47], meaningful mathematics [48], experiential and project based learning approaches [49] [50], continuous assessment and effective feedback provision [51][52], etc. Other constraints related to time, money, role complexity and potentially conflicting interests and commitments are also noted [43].

VIII. CONCLUSION

The paper at hand aimed to demonstrate the results of an extensive literature review on engineering ethics and engineering ethics education. It revealed the importance of engineering ethics in the engineering profession. Pedagogical approaches along with the content of these approaches were reviewed ranging from regular, well-established approaches to the more modern approaches utilizing web and computerised resources. Several assessment methods were reviewed and documented. Most of these assessment methods utilized the well-established DIT-2 to measure moral reasoning of students as moral reasoning is a major element targeted by ethics education. The DIT-2 has shown questionable results in assessment of engineering ethics education as it assesses students' moral reasoning in general contexts that may have not been influenced by the engineering ethics education. Thus, the need for a contextualized assessment instrument for the engineering specific settings is noted and resulted in the development of instruments such as the ESIT which has shown promising results. The paper also highlighted barriers impeding the effectiveness of engineering ethics education.

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Using scaffolded, integrated, and reflexive analysis (SIRA) of cases in a cyber-enabled learning infrastructure to develop moral reasoning in engineering students

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***Abstract*— Each year thousands of new engineers join the workforce and face novel issues raised by radical technological advances. Concurrently, changing societal responses to new technologies introduce novel conflicts in research and development that challenge the scope of established professional codes of ethics. These issues create a critical demand for new approaches for developing moral reasoning for ethical decision-making. Our multidisciplinary team of engineering, communication, and ethics educators has developed and tested a novel pedagogical framework of Scaffolded, Integrated, and Reflexive Analysis (SIRA) of ethics cases to enhance development of moral reasoning that extends beyond case-based analyses. Implemented as a series of two-week cyber-enabled learning modules, with cases from several engineering disciplines, this theory-based, data-driven, cyber-enabled framework for ethics education has applicability across a broad spectrum of disciplines and provides engineering educators with limited ethics training a tested framework and set of resources and modules to adapt and use in their own disciplines. In this paper, we discuss our work in progress on the SIRA framework, its implementation, and our assessment of changes in moral reasoning and student satisfaction when utilizing this model.**

***Keywords*— engineering ethics; moral reasoning; principlism; reflexivity; scaffold; cyber-enabled learning modules**

I. Introduction

Rapid technological advances, coupled with evolving societal and environmental challenges, introduce unprecedented ethical issues for engineers. This dynamic landscape creates a critical need for ethics education that provides engineers with the conceptual tools to understand and resolve emerging ethical problems not yet addressed in professional codes. To address this need our multidisciplinary team of researchers in engineering, philosophy, communication, and engineering education has developed a novel pedagogical framework to develop moral reasoning in engineering students. Implemented as a series of 2-week cyber-enabled learning modules with cases from several engineering disciplines, this theory-based, data-driven framework has broad applicability and provides engineering educators with limited ethics training a tested framework and set of resources to adapt for use in their disciplines. In this paper we introduce this *SIRA framework*, and discuss its development, assessment, and implementation in a cyber-enabled context.

II. The SIRA Framework

Our novel pedagogical framework involves a coherent approach that is scaffolded, integrated, and includes reflexive analysis (SIRA) of ethics cases to provide effective development of moral reasoning. Grounded in the ethical principlism familiar in medical ethics [1], the framework challenges students to use higher-level reasoning in their analysis of ethical issues through structured learning modules that invite and facilitate integrated dialogue and reflexive and reflective analysis about professional codes of ethics and moral principles. Called *Reflexive Principlism*, this approach uses four core moral principles – autonomy, non-maleficence, beneficence, and justice – as a guiding framework for moral decision-making within engineering ethics, and serves as a backdrop against which to evaluate codes of ethics [1]. Integrated within this framework are well-storied narratives, high levels of interactivity using moderated discussions and facilitated debates, and cases with complex content [e.g., 2,3] implemented on an established learning cyber-infrastructure. The core elements of the approach are discussed below.

A. Scaffolded Learning

Scaffolding refers to the tools and resources provided to the learner to support the developmental learning process [4], supporting the learner in the early stages of complex problem solving by providing high levels of structure, and becoming less prevalent as the learner develops skill and confidence [5]. Hard scaffolds are consistent structures such as glossaries, expert information, and textual guides designed with anticipated obstacles to learning in mind. Soft scaffolds are "dynamic, situation-specific" types of support provided by instructors and are tailored to individual needs [6].

B. Integrated Method

We extend the principlist approach [1,7] by using an integrated method to appeal to the core principles throughout the learning modules. Principlism provides guiding moral principles that are independent of particular situations, and has individuals apply them *in situ* and *reflected* against the details of specific contexts. The principlist approach pushes beyond

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application of codes to a richer level of reasoning regarding value assumptions in specific contexts [1]. Each integrated module includes a case study of an ethical issue in an engineering context involving a variety of stakeholder perspectives, including the subjective (self), the imagined (role play), actual persons (stories), professional (codes), and experts (reporting). Grounded in this approach and each specific case, the pedagogical framework leads students through: (a) identification of relevant facts and stakeholders, contextual issues, core ethical principles and moral assumptions; (b) reflexive analysis comparing ethical principles and professional codes; and (c) analysis of key ethical elements using critical thinking, prioritization, and justification of the four principles to arrive at a defensible decision.

C. *Reflexivity Analysis*

The goal of strengthening moral reasoning is enhanced when we situate engineering ethics within a reflexive process involving the analysis of the relationships and conflicts between value claims. Reflexivity analysis is guided by a set of questions developed to encourage analysis of applicability, relevance, and repercussions within each SIRA module. For instance, students are asked how they specify and prioritize principles in the context of each case, as a means of encouraging reflection on the principles of the particular case. This iterative analysis parallels an engineering design process and can be readily adopted by engineers. Reflexive analysis deepens the disciplinary discourse but also facilitates the applicability of ethics and moral reasoning into emerging fields of engineering. It helps engineering ethics fulfill a role as a proactive or "preventative" ethic [8] guiding the profession, while helping developing engineers gain deeper insights into the practice of moral reasoning.

III. Cyber-Enabled Learning Modules

The pilot course was developed and delivered in a hybrid format integrating live classroom interactions with a set of online learning modules delivered on a sophisticated cyber-infrastructure for global engineering education, GlobalHUB (globalhub.org). We piloted four SIRA modules and a meta-module on reflexive principlism, in a graduate engineering ethics course with in-class and online students (N=20) which fulfilled a mandatory ethics requirement. Four cases were tested from several engineering contexts. Two were previously published, including a disaster (*Hyatt Regency Skywalk Collapse*) [9] and a design case (*Engineering Pediatric Heart Valves*) [10]. The other two were developed for the course and included developing technology (*Diagnostic Device Development*) and a recent environmental disaster (*BP Deepwater Horizon Oil Spill*).

Each SIRA module was designed to be completed in a two-week timeframe, progressing students through a series of six structured learning stages including: (a) establishing knowledge; (b) perspective taking; (c) compare and contrast; (d) inducing conflict; (e) decision-making and justification; and (f) reflection and reflexivity (see Table 1). In each stage we specified the type and form of content to be delivered, and the form of learning activities required to facilitate educational goals. The degree of scaffolding provided was gradually reduced, progressing from high in the first two stages to low in the final two stages. For example, early in the module students were specifically instructed to make decisions using the four principles; in later modules, these prompts were faded.

IV. The Learning Testbed and Research Methods

To assess the efficacy of this framework, we examined the relationship between students' participation in and experience of the online learning module and their development of moral reasoning and satisfaction with ethics education. The fundamental questions addressed by this research are:

(1) What is the impact of a SIRA approach on the development of students' moral reasoning, and their satisfaction and engagement with engineering ethics education?

(2) What characteristics of the SIRA approach contribute to change in moral reasoning ability, and to student satisfaction and engagement?

We take a mixed-methods approach [11], and gather both quantitative and qualitative data. In this first year, we analyzed the efficacy of the course modules, and the change in two primary measures: moral reasoning and student satisfaction and engagement. In a process of concurrent triangulation [11], surveys, observation of class sessions, focus groups, and semi-structured structured interviews were used to evaluate moral reasoning development, student satisfaction and engagement, the use and success of scaffolding/resources, and the efficacy of the course module structure. In the following we discuss the instruments and measures.

A. *Moral Reasoning Development*

To evaluate the impact of the learning module on the development of moral reasoning two assessment tools were administered using a pre- and post-test strategy at the beginning and end of the course: the well-validated Defining Issues Test (DIT2) [12], and the novel Ethical Reasoning Instrument (ERI). The latter was developed to measure moral reasoning in the context of engineering [13]. Both instruments provide quantitative measures of change in students' moral reasoning as a result of participation in the SIRA modules. We also assessed a variety of artifacts submitted by students during the course, and used reflective analysis to assess changes in students' moral reasoning abilities.

B. *Satisfaction and Engagement*

To assess the impact of the SIRA modules on student satisfaction and engagement with ethics education, an additional survey was administered at the beginning and end of the course. The survey was derived from published scales from the SEED survey [14], which has been validated with over 3000 engineering students at 18 institutions nationwide.

C. *Course Efficacy*

Student views regarding the efficacy of specific elements of the course modules were captured from (a) written responses to meta-reflection questions at the conclusion of each module, (b) a survey administered midpoint and at the end of the course, and (c) from semi-structured interviews at the conclusion of the course. Questions in these assessment instruments included ones such as: "*Which elements of the*

TABLE I. STRUCTURE OF SIRA MODULES

Learning Type: *(time allotted)*	**Establishing Knowledge** *(1 day)*	**Perspective Taking** *(2 days)*	**Compare and Contrast** *(3 days)*	**Inducing Conflict** *(1 day)*	**Decision-making and Justification** *(2 days)*	**Reflection and Reflexivity** *(3 days)*
Type of Content:	Scenario, facts, and expert info about emerging technology	Stakeholder perspectives	Comparing perspectives	Common ethical principles	Debate with justification; Opinion by technical ethicist	Meta-reflection on ethics and process
Form of Content:	Multimedia -video and text (multiple perspectives)	Responsive writing / Journaling	Multimedia responses in text, voice, video	Expert ethicist's presentation (video, slides, or text)	Live web-video conferences & Recorded statement	Multimedia responses in text, voice, video
Learning Activity:	Narrative	Reflection	Moderated Discussion	Listening / Reading	Facilitated Debate	Meta-reflection
Scaffolding	High / *hard*	High / *hard*	Medium / *soft*	Medium / *hard*	Low / *soft*	Low / *soft*

module were most important to your development of moral reasoning?" and "*How and where did your thinking about ethics change in this process*?" The midpoint survey data were used to adjust the scaffolding, content, and staging of the modules to optimize student access and comprehension. At the conclusion of the course, we conducted semi-structured interviews to probe additional aspects of student participation, and elicit dimensions of the modules that were significant to the learning process or to engagement. The interview data also assisted in interpretation of quantitative data, and provided contextual seeds to revise questions in subsequent instruments.

V. FUTURE RESEARCH AND DEVELOPMENT

Building upon theory and research in ethics, engineering education, and communication, these highly interactive and modularized learning modules for engineering ethics have broad implication for being embedded into a wide variety of courses and curricula across disciplines, and at undergraduate, graduate, and post-graduate levels. Through our use and development of measures to assess the efficacy of ethics education, we are building evidence of effectiveness of the principlist approach in engineering ethics education contexts. In addition, we provide resources for engineering educators including materials, case studies, research instruments, and a research-tested framework for cyber-enabled learning that has applicability to graduate, undergraduate, and professional ethics education needs around the world.

In the next phase of the project, we will embed the SIRA modules in an online ethics course for students around the globe through Purdue's NeXT and GlobalHUB environments. Sixty first-year graduate students will be recruited and offered 1-credit of graduate level coursework in Ethics for completing a four-module series. Their progress will be measured against a comparison group of students enrolled in a graduate ethics course that does not employ the SIRA framework. Four additional modules will be developed and tested to bring the total number of deliverable SIRA modules to eight, covering a broad range of cases related to emerging technologies in multiple disciplines including Biomedical, Materials Science, and Mechanical Engineering. Concurrent to this continuing development of course modules and cyber infrastructure, we will continue assessing the efficacy of the SIRA learning environment for developing moral reasoning skills, to iteratively test and refine our framework.

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Development of a Classification Scheme for "Introduction to Engineering" Courses

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***Abstract* — "Introduction to Engineering" courses are often designed from scratch and can become a grab-bag of unrelated topics. They are often designed by instructors to cover what they feel is important. Therefore, while they may be *prerequisites* to second-year courses, first-year engineering programs are not necessarily *integrated* into the curriculum. Further, since they are often designed with little consideration for existing models, overall outcomes and content may vary widely. The results include an issue of course developers "reinventing the wheel" as successful models are not adequately disseminated.**

Results of multiple methods of investigation are presented. An analysis of syllabi for Introduction to Engineering courses identified course learning objectives, and these objectives were grouped to establish an initial classification scheme. A workshop in which objectives were discussed was held at a national conference and a separate draft classification scheme was proposed. A concurrent effort uses a Delphi procedure to define and categorize expected outcomes in first-year courses. Survey data from the Delphi study has been collected toward a single, final classification scheme.

This paper will present results of the first two components of the study and the initial high level classification scheme identified as the Delphi analysis begins.

Keywords—classification scheme; first-year; introduction to engineering

I. Methodology

This project involves a study and the development of a classification scheme for courses meant to introduce engineering to first-year engineering students. Such courses are typically entitled "Introduction to Engineering" or similar; yet, this course title can describe fundamentally different courses. For instance, an introduction course with weekly presentations from different departments is fundamentally different than one with an outcome to cover programming fundamentals. With the various nuances and contrasts in the content of "Introduction to Engineering" courses between universities, these classes should be classified differently. The problem is exacerbated by a lack of definition of first year models. For example, a developer may know what they want in a course, but how do they find a course with similar outcomes with nothing more than "first-year engineering" as a description?

Prior research in the first year of engineering has focused on an understanding of student success directly related to coursework [1], innovative curriculum design [2,3,4,5], and specific necessary components of the first year including a solid foundation in math [6]. Brannan and Wankat [7] looked at different components in the first year, including introductory courses. Little research to classify various first year engineering courses is available, although establishing a common framework seems to be a necessary step toward informing curricular reform and program development.

Three separate methodologies were used to develop the classification scheme.

A. Analysis of syllabi

In an effort to identify common concepts and student learning objectives, an Internet search of web sites from universities, colleges and programs was conducted for courses entitled "Introduction to Engineering", "Engineering 1", or courses with similar titles. A team of undergraduate research assistants was tasked with executing this Internet search and summarizing results in cooperation with the principal investigator during the 2012 spring semester. Researchers used common search engines to search for "introduction to engineering" and similar terms. When such a course was identified, an additional search for the course syllabus was completed. Each syllabus found was reviewed to ensure that the course was meant to apply as a common engineering course rather than a technically oriented, discipline specific course: for example, delineating between "Introduction to Engineering" and "Introduction to Electrical Engineering." The Introduction courses may contain significant technical content (such as MATLAB programming), but must be either intended for students in multiple disciplines or have an interdisciplinary focus to be included in the analysis. Further, courses were not to be general orientation courses geared strictly toward understanding the culture of a university or a general introduction to university life – although again, these topics may appear in a course meant to introduce engineering. Finally, courses were not to be those that might introduce engineering to non-engineering majors, such as a "How Things Work" survey course. To be considered, a course must be presented to an interdisciplinary population of first-year engineering students and not meant as only an orientation course.

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The team identified 28 syllabi that met the criteria. Each team member was assigned to review 14 (half of the syllabi), thereby reviewing each syllabus twice. As the intent was to develop an exhaustive list of all course outcomes, each specified course outcome along with other course outcomes that could be gleaned from the course description were listed. For example, one syllabus described a significant project to design a robot, yet no course outcome similar to "discover robots" was specified. This was considered as a (potential) course outcome from this course.

Team members listed each outcome from each syllabus. The team developed a mind-map or concept map by grouping similar outcomes using post-it notes on a whiteboard. In the event of similar outcomes (for example, Programming in C++ and Computer Programming), group consensus was reached to determine whether the outcomes were identical. If judged to be identical, or for cases of absolutely identical outcomes, a count was maintained. The final scheme evolved from this concept map.

The intent of this initial search was to develop a framework to guide formation of initial questions for and analysis of results for the upcoming Delphi study.

B. Analysis of results of workshop discussion

A workshop for informal discussion of establishing the classification scheme took place at the Frontiers in Education conference in Seattle, WA in October 2012. A Catalyzing Collaborative Conversations (CCC) session was designed and organized jointly by Directors of First Year Engineering programs at Ohio Northern University and Virginia Tech. The session offered an opportunity to convene a community with a common interest in first-year engineering education, and establish a set of existing and desired course outcomes for Introduction courses as a group. The guided, informal discussion offers the opportunity for participants to submit their ideas; the collective ideas of the group then guided conversation toward the development or discovery of other ideas generated through the group discussion.

Approximately 24 attendees were seated in groups of 6; each group was tasked with having a discussion around a set of guiding questions distributed at the beginning of the workshop. Each group had a designated recorder to capture results. While the initial intent was to allow a fixed time for small group discussion, then to bring the groups together and have a culminating discussion among the full group, the leaders opted to allow the conversations to conclude naturally, or to continue to (and past) the scheduled end of the session.

The set of guiding questions for each group included:

- What are the objectives of the first-year engineering programs?
- Why isn't there a common set of objectives for the first year engineering courses?
- What would we consider to be the best practices for first year engineering program?
  For example, should we teach Matlab/Excel rather that introducing students to the disciplines?
- If students were so successful in High School, why is there so much emphasis on success?
  What do we mean by success?
- Are there any of these objectives that are hard to assess? How might we assess them?
  Is there anything that we think should be a best practice that isn't because it is too difficult to assess?

Results were collected from the recorder of each group. These results were analyzed by the team of researchers, then a similar mind-mapping process was employed to develop a concept map from the written comments of the reporters from each group. Again, the research team came to consensus on any outcomes judged to be similar or identical.

As in the case of the scheme from the search of online syllabi, results of this analysis were used as the framework toward the development of the initial round of questions for the Delphi study.

C. Delphi study

The Delphi procedure was employed to engage a group of participants with a common interest to develop shared images based on three rounds of question development and information, with iterative feedback [9,10,11,12].

The initial invitations to participate came from a list generated by a steering committee of faculty in first-year engineering programs, e-mail invitations to the listserve of the First-Year Program Division of ASEE, email invitations to all participants in the 2012 First-Year Engineering Experiences conference, and targeted e-mail requests sent to a variety of universities with first-year engineering programs identified through ASEE and through recent literature. Given a potentially large quantity of information from each round of surveys and the eventual expected duplication of responses, a target of approximately 35 participants was selected [11,12]. Thirty seven participants submitted their interest in participating and 31 participants completed the initial round of data collection.

The Delphi procedure is administered online. Questions for the initial round consist of those initially developed by the steering committee and refined from results of the first two phases of the project. The goal of the first round is a collection of all possible outcomes found in an Introduction to Engineering course.

The second round includes asking participants to examine a draft of a scheme developed from responses to the first round and the first two preliminary schemes to ensure that all outcomes were captured. Participants were directed to a website with the scheme available for review, then to a survey site to record answers. Feedback from round two served to develop a final proposed classification scheme. The advantage of the Delphi method for these first rounds is the elimination of 'groupthink', where participants fail to fully participate or modify their responses based on the perceived majority opinions found in a group.

In the third round, participants received final proposed classification scheme generated by all prior work and asked to use the scheme to analyze their courses, and asked to comment.

As round three was completed, it appeared that consensus had been reached and only minor modification to the proposed scheme was necessary.

Results of all three methods are used to define the final classification scheme which is planned for final testing and discussion at a culminating workshop during the 2013 First-Year Engineering Experience conference.

II. RESULTS

A. Analysis of Syllabi

A total of 28 syllabi were found online that fully met the specific criteria. A diverse set of institutions were represented: community colleges, private and public universities, and large research-based institutions. Each individual syllabus was inspected to cull student learning objectives and/or course objectives, whether expressly listed or found in a descriptive summary of the course objectives. Course objectives were listed and categorized.

A complete concept map was generated by grouping related outcomes, eliminating exact duplicated (judged by a consensus among the research team), and specifying the relationship among the outcomes. As a concept map was developed, main factors (i.e., Professional Skills) and subfactors (i.e., Tech Comm) emerged from the cloud of individual course objectives. The classification of the course objectives found in the examined syllabi is shown in figure 1. Figure 1 shows the scheme to a subfactor level; in other words, "Tech Comm" includes individual objectives such as effective public speaking, effective report writing, poster and/or web page design, etc. that are not shown in this figure.

Objectives were found to group into four main categories:

- engineering skills,
- professional skills,
- orientation to the university / course / program, and
- orientation to the profession.

It is important to note that there is often not a clear delineation of objectives: for example, one objective specifically mentioned in a syllabus "prepare the student as a person including preparation toward their chosen field" may best represent an objective under orientation to the programs of the university or toward the profession. The analysis of the syllabi is intended to support the Delphi study, so further, specific classification of objectives where a subcategory was not immediately evident was not overly analyzed in this part of the project.

It should also be noted that the order in which the subcategories appear is significant: outcomes appearing most often in syllabi appear first (leftmost) and toward the right in descending order. For example, most if not all of the syllabi expressly listed teaming or teamwork among the course objectives; those that didn't expressly list them had group projects described in the syllabus. Fewest (but at least two) syllabi mentioned "global responsibility" (or similar). Since the goal was to collect as many outcomes as could appear in an introduction class, it is not important to what extent these courses instruct students in effective teamwork; rather, the appearance of group projects in a course description indicates that the potential for instruction on effective teaming exists.

B. Analysis of results of workshop discussion

Similar analysis was done based on the answers to the initial question in the Catalyzing Collaborative Conversations workshop: "What are the objectives of the first-year engineering programs?" This question generated most of the conversation, and most comments were listed under this item in the notes from each recorder. Discussion on the other questions typically drifted back to addressing this first question, or became a discussion of objectives that should ideally be (but may not currently be) included, all of which contribute to the goal of the data collection in this case.

Other discussion during the workshop critiqued the set of questions themselves. For example, "Are there any of these objectives that are hard to assess? How might we assess them?" was discussed for its merit as a valid question rather than discussing answers. The consensus was objectives that *should* be included but were *not* were such because of a lack of time or a lack of defining how to include those objectives rather than their ability to be assessed.

A similar mind mapping process was used to generate a concept map from data from reporter notes from each group. Individual team members reviewed the entire set of 18 pages of notes from the reporters from each small group. Individual outcomes were grouped to form main factors and subfactors. Again, specific objectives that may be most appropriate to more than one subcategory were assigned to one of the appropriate subcategories rather than an extended analysis of which would be best, since the goal is to capture all of the objectives mentioned within the group.

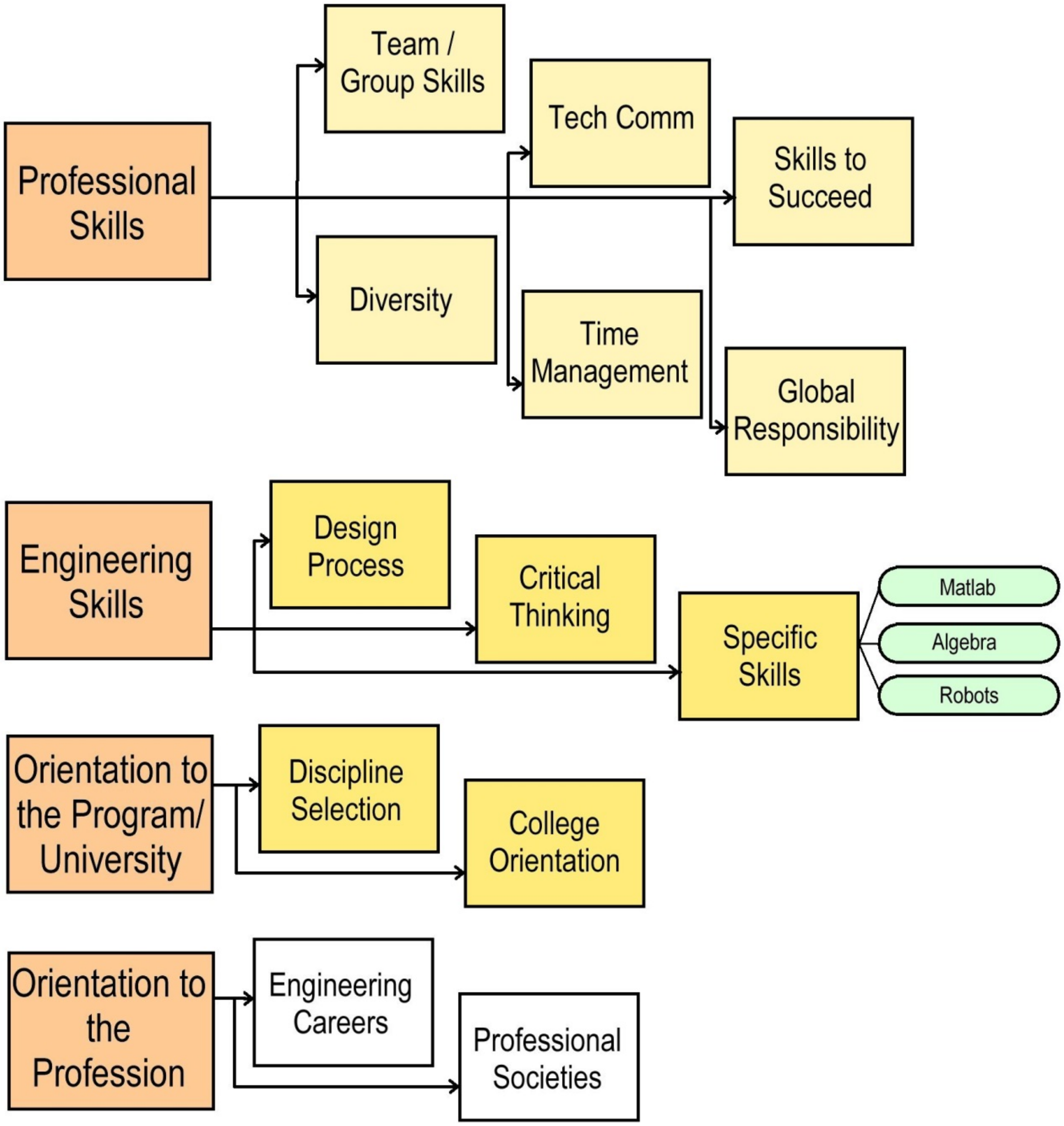

Figure 1: Draft of classification based on examined syllabi at the main factor and subfactor level

Figure 2 shows the concept map of objectives mentioned in the group discussions. Objectives were classified into similar themes as the analysis of syllabi. All subfactors included more than one objective, or objectives mentioned more than once in group discussions (according to reporters' paperwork).

Items are categorized from most often to least often mentioned, but always mentioned more than once. The exception is when any specific technical or discipline specific engineering skills were mentioned; these were included for the sake of comparison.

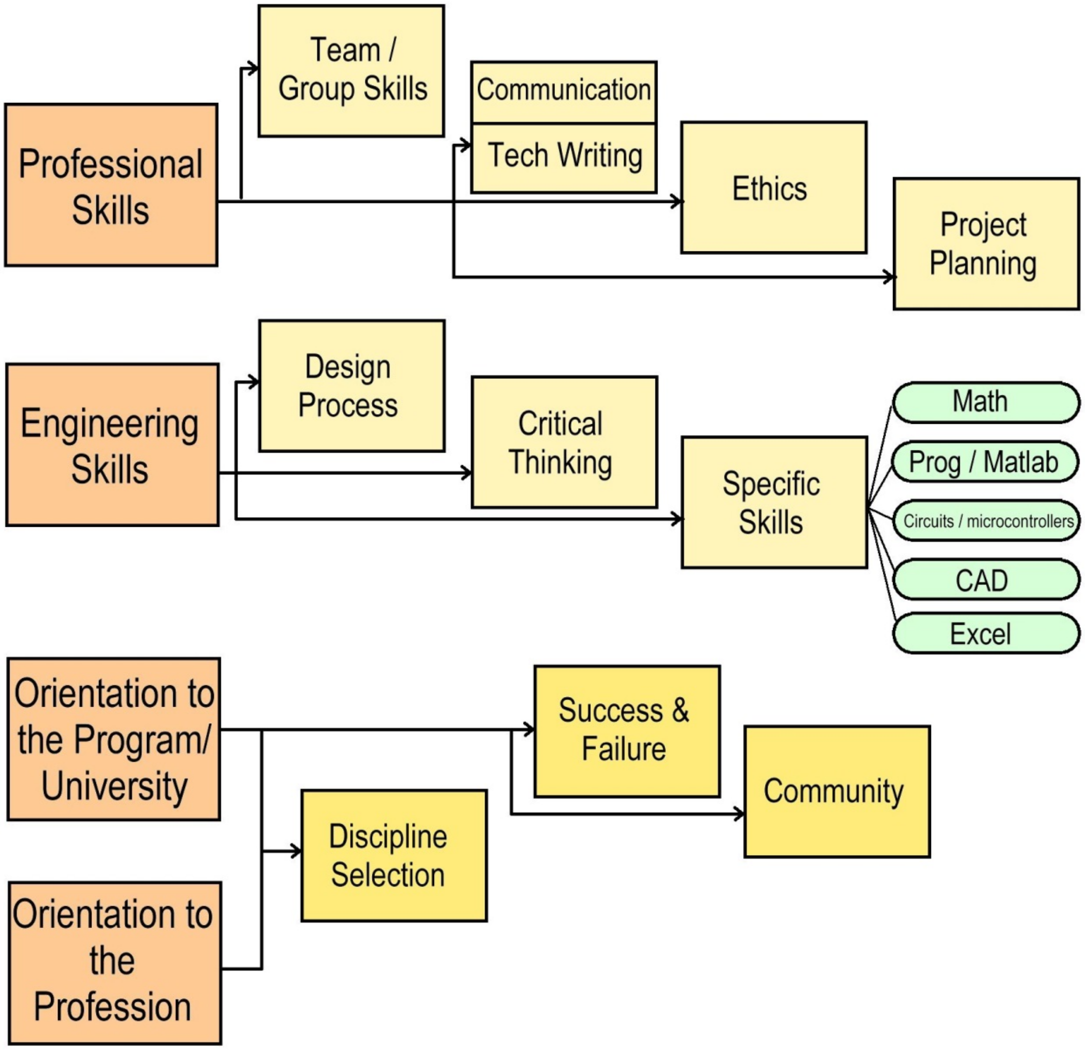

Figure 2: Draft of classification from CCC workshop at the main factor and subfactor level

III. Discussion

The same main categories emerged from both analyses. However, interesting and key differences emerge from objectives classified beneath each of these categories.

A. Engineering Skills

The specific objectives under the engineering skills heading showed the least difference between the two activities. The only difference was in specific engineering technical skills listed where the group discussion generated more examples of specific skills within a course. This is easily attributable to the dynamics of the group discussion and the occasional lack of specifying specific technical skills on course syllabi.

B. Professional Skills

Teaming skills and communication were mentioned in most if not all syllabi and group discussion. Given that these are often the most cited characteristics from employers and specifically cited in ABET criteria, this is to be expected.

From here, the most often cited objectives from participants in the CCC workshop were a consideration of engineering ethics and project planning, neither of which appeared in the analysis of syllabi. The lack of 'ethics' appearance in course syllabi is somewhat surprising. It is possible – and remains to be investigated – whether, for example, "project planning" and "time management" are meant to be included in the same category.

With more specific objectives mentioned and a more rich and thorough description of these objectives in the CCC discussion, a separation between technical writing and verbal (or other non-verbal) communication rather than a more generic "Communication" objective found in syllabi was introduced. Rather than focus on the validity of delineating different types of technical communication, further analysis was left for the Delphi study.

C. Orientation

The discussion seemed to go in two distinct directions: orientation to the university's engineering program and orientation to the disciplines to the profession in general. There is an inherent difficulty in defining the intended meaning of "orientation" objectives from course syllabi.

A discussion of including failure and success from both an engineering and orientation / integration context also emerged from the CCC discussion. Indeed, while research and discussion of the importance of incorporating "failure" into engineering plans of study, this only appeared specifically as a course objective in one syllabus.

This is an excellent example of a topic that is often discussed as one that "should be included" but often does not appear as a specified objective.

IV. Delphi Study

The initial round of the Delphi study featured the following question set based on input from both rounds of data collection thus far:

> When answering the following questions, please answer them within the framework of Introduction to Engineering / First-Year Engineering course(s). Do not consider other required courses within the first year. For example, please do not consider math, science or general education courses.
>
> - What topics are included (please list) in first-year engineering courses at your institution?
> - Are there topics that are not, but should be included in first-year engineering courses at your institution? Please list:
>   - (please do not duplicate answers from the previous question)
> - What are (please list) the expected student outcomes in first-year engineering courses at your institution?
> - What other student outcomes should be included in first-year engineering courses? Please list:
>   - (please do not duplicate answers from the previous question)

Of the 37 participants who originally indicated interest, 31 completed round 1. Results of this round were used in combination with the results of the analysis of syllabi and workshop to establish a proposed list of all objectives that currently exist or should exist within the Introduction courses. This list was published on a website, and participants were asked to review and comment on the list. The second round asked:

> After reviewing the proposed classification scheme / concept map, are all course outcomes in your existing course AND all outcomes that should be in an Introduction to Engineering course included in the diagram? If not, please list any that are missing.

Of the 31 who completed the initial Delphi round, 24 completed rounds 1 and 2.

A. Preliminary Delphi results

As anticipated, the open ended nature of the initial round of Delphi questions along with the inclusion of outcomes that "should be, but are not included" led to a more varied and complete picture of all possible outcomes included in Introduction to Engineering courses.

The highest level of the classification scheme is shown in figure 3. Eight of the nine highest level categories map directly to the four main categories from the prior two analyses. Pedagogy became the subject of conversation in the second round of the Delphi process.

Initial discussion pointed out that "pedagogy" drifted away from the intent classifying outcomes, as pedagogical methods implemented in the course are certainly not the same as student outcomes; therefore, "pedagogy" was removed entirely from the scheme.

B. Completion of the Delphi processand final classification scheme

The final round of the Delphi process will result in a complete classification scheme that is tested on each "Introduction to Engineering" course coordinated and/or taught by each participant. Once tested, the classification scheme will be presented at a culminating workshop in conjunction with the 2013 First Year Engineering Experience (FYEE) workshop. This workshop will involve discussion and additional testing (in which participants will use the scheme to classify their courses).

V. Future Work

The classification scheme gives a means to definitively classify an Introduction to Engineering course. While this is inherently useful for transfer credit and defining outcomes which can be expected in future classes, it also can indicate where gaps in assessment exist. Defining a student outcome that may be an integral part of a course implies that the outcome should be assessable. In cases where there is no assessment mechanism, one or more may need to be developed. This is expected to provide opportunities for further research, and is on the agenda for the FYEE workshop.

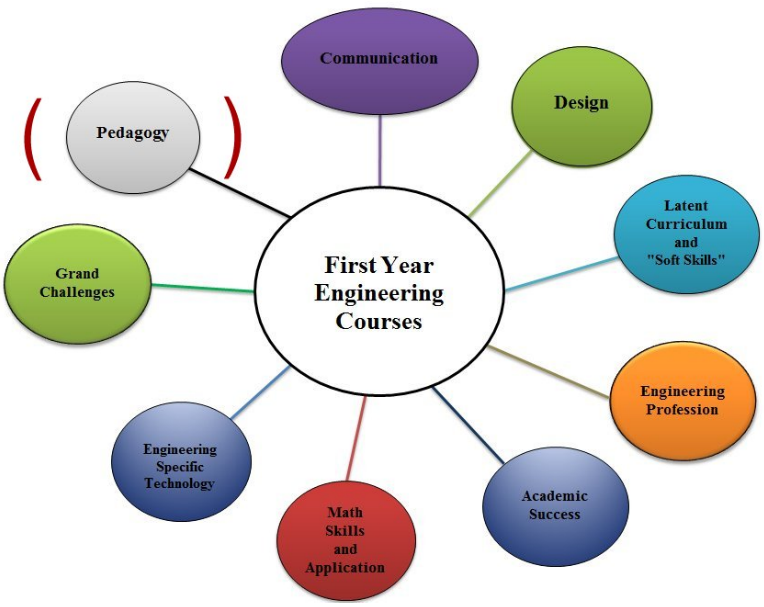

Figure 3: Top level of Classification Scheme from Delphi Method (Pedagogy was originally included but has been removed)

VI. CONCLUSION

A classification scheme is emerging from a study in which three different methods were used to collect course objectives from "Introduction to Engineering" courses. The final classification scheme will be useful to definitively define these courses within programs, especially as programs evolve. Further, the scheme will be useful when evaluating transfer credit and may have value in evaluating proposals for funding for research involving the first year of study in engineering.

Results thus far seem to indicate that course objectives can be grouped into eight major categories: Design, Latent Curriculum (soft skills), Engineering Professionalism, Academic Success, Math Skills, Engineering Specific Technology, Communication, and Grand Challenges, with any related outcomes or objectives defined as subcategories.

The final development of the classification scheme is expected to lead to future research into defining a naming convention (for example, "design focused") that could allow developers and researchers to use a common set of terms to describe different courses. Further research into using the scheme to define gaps in assessment of course outcomes is also expected.

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A Survey on the Mathematical Emphasis in Brazilian Computer Science Curricula

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***Abstract*—A recurring question raised by professors and undergraduate students involves the distribution of basic and practical — or professional — courses. Some authors defend a curriculum with more basic courses, such as mathematics, physics and chemistry, in order to create a solid foundation. Moreover, there is a growth of academic exchange programs all around the world, which require a common learning core.**

Since 1960, the importance of mathematics in Computer Science (CS) undergraduate curricula has been decreasing, particularly, because new fields in CS have risen and they were assimilated in the curricula. Despite its of reduction, mathematics still has its role in CS's curricula.

The goal of this paper is to analyze the amount of the courses related to mathematics in different CS undergraduate curricula. In this work is analyzed the lecture hour load dedicated to mathematics courses on eleven Brazilian CS undergraduate programs: The Federal Universities of Ceará, Minas Gerais, Campina Grande, Pernambuco, Rio de Janeiro, Rio Grande do Sul and Santa Catarina, State Universities of São Paulo (two programs) and Campinas and the Pontifical Catholic University of Rio Grande do Sul. These programs were selected among others due their 5-stars rating in the Guia do Estudante 2012 Ranking, published by Editora Abril.

To allow this comparison, a definition was established of what was considered to be a lecture hour of mathematics. For a reference point, such programs were compared with two reference curricula in the area: The Brazilian Computer Society curriculum (SBC) and the Computer Science Curriculum 2008 made by the IEEE Computer Society and Association for Computing Machinery (ACM) joint task force.

The curricula presented in the official websites of the selected universities in 2012 were analyzed and it was possible to conclude that more than half of the programs don't achieve the minimum amount of mathematics study hours necessary during undergraduate studies according to IEEE/ACM's or SBC's reference curricula.

I. Introduction

The recent growth of different higher education courses have resulted in a worsening of the identity crisis inside the university. Since its creation in the late thirteenth century [1], its function varied with the political context of the local society, basically presenting values related to national issues. Still, persisted the existence of two orthogonal trends, the one which states that the university mission should be to fix the current problems of society, and the one which states that its main task is to be a beacon, glimpsing the future. The present difficulty is that there are some undergraduate programs that follow the first trend and consequently aim immediate employability by focusing on technical knowledge and others that follow the second trend, valuing the academic knowledge and being more interested in graduating professionals able to deal with problems that still don't exist.

According to Renato Janine, Brazilian philosopher, there is a certain knowledge which is volatile, usually the technical one, which should be taught by companies. Furthermore, it's better that, in their educational period, the young deal with what's perennial, by giving them a solid foundation, than with details in constant change [2].

Universities should provide the necessary cultural and professional foundations so that, after graduating, a person may be able to adapt to different standards used by companies in the practice of the profession whose qualification was obtained. Therefore, the university should not bother to teach different types of procedures established in the labor market or teach techniques to deal only with some particular problems of the profession. In face of a rapidly changing world, where new challenges appear in an ever increasing rate, it should rather prepare students to learn by themselves how to deal with any problem or types of procedures at any time, whether present or future.

After all, procedures may vary not only across companies, but also change over time. Thus, the trained professional would not be prepared for the future and could only adapt to companies that could handle certain problems and only dominate some specific techniques. One can easily notice this fact through the rapid evolution of software, which requires a constant learning of their manipulation, generating in some cases a disposal of knowledge previously used.

Therefore, it is evident that theory and fundamentals are essential for this type of education and can not be *replaced* by just technical or practical knowledge. After all, foundations give the ability to tackle a given problem and use different approaches or reasoning to solve it. This issue has greater impact on technology-intensive undergraduate programs, such as engineering, a field where professional associations govern

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the exercise of the profession.

On the other side, practice has also an important role in the learning process. It allows students to apply concepts in real problems and thus reach conclusions which strengthen and sediment their knowledge of the area. This is particularly true for areas like Computer Science, which need to balance theory derived from algorithms and graph theory with programming, for example. As [3] states, one desirable characteristic of graduates is the appreciation of the interplay between theory and practice. "A fundamental aspect of computer science is the balance between theory and practice and the essential link between them. Graduates of a computer science program must understand not only the theoretical underpinnings of the discipline but also how that theory influences practice."

One of the common points, located in virtually every course curriculum that deal with technology are the contents of mathematics. Those, which in most cases have only a basic level of depth, precisely fit the definition that Renato Janine presented for tasks to be developed within the university. According to Anthony Ralston, mathematics develops the mind and "improves students' learning skills." [4]

Moreover, both Ralston, Kelemen et al [5], are emphatic in noting that the way mathematics is offered in undergraduate programs in American universities, more specifically the Bachelor in Computer Science (BSc CS), influences on student learning.

An important fact detected by several of the studied previous works ([4], [6]) is that an analysis of the reference curriculum provided by the IEEE and Association for Computing Machinery (ACM) joint task-force [7] [3] indicates that the role of mathematics has been decreasing gradually since at least the 1960s, although at a lower rate today.

This scenario is considered bad, because for Computer Science / Software Engineering students, in particular, mathematics is important because the logical reasoning inherent in any mathematical thinking is very similar to logical thinking necessary in software development [4]. In developing and implementing software projects, the graduate needs to develop effective ways to solve computational problems and the amount of mathematics used in daily life of a programmer usually increases when the structures are built using a more formal language. [4]

According to [5], "Computer Science students should be able to model 'real world' problems precisely using mathematics and using structures like arrays, linked lists, trees, finite graphs and matrices. They should be able to design and analyze algorithms that transform such structures [...], understand the nature of a mathematical model and relate mathematical models to areas of real problems [...]. Strategies for solving problems such as divide-and-conquer and backtracking are also essential."

This paper aims to fill a need from university faculty who want, for example, to reform their curriculum. By presenting an updated overview of how much math is studied in various well ranked Brazilian curricula it is possible to make better decisions. The consolidated information is then compared with standards in the academia, allowing a broad and weighted view of the current math education reality in Brazilian CS undergraduate programs.

II. Methodology

This paper makes a comparative study of different Brazilian Computer Science programs through a quantitative comparison of the number of lecture hours in the area of mathematics both in absolute and in relative values to the total hours required for graduation. The main goal is to identify whether the selected programs have more or less emphasis on mathematics compared with two reference curricula in the area, the Brazilian Computer Society Reference Curriculum (SBC) [8] and the Computer Science Curriculum 2008 (CS2008) made by the IEEE Computer Society and ACM joint task force [3].

It is important to point out that a quantitative assessment of the hour load allows an objective classification of studided programs; on the other hand, may be less effective in analyzing the different facets that mathematics is presented in CS programs, such as the emphasis of a particular program in the area of continuous (Calculus) or discrete mathematics (Algebra, set theory etc).

The task of isolating covered topics or areas in different curricula — such as mathematics in this paper —, for comparison purposes is, on one hand, very important as it enables objective analysis; on the other hand, is difficult to be done as different curricula have their own peculiarities. This is one of the challenges faced by accreditation organizations such as the European Network for Accreditation of Engineering Education (ENAEE), Accreditation Board for Engineering and Technology, Inc. (ABET) and the Asociación Iberoamericana de Instituciones de Enseñanza de la Ingeniería (ASIBEI). All of them are responsible for certifying that different Engineering curricula satisfy a common body of knowledge in order to facilitate students exchanges.

For this paper, are considered math disciplines those that address the areas of Calculus, Linear Algebra, Vectors, Geometry, Algebra, Proof Techniques, Counting, Probability, Statistics and Set Theory. These subjects are usually taught by the universities mathematics departments. A difficulty is that in some cases the names of the courses, or their syllabi, do not represent what is actually taught. All curricular material was read and classifications were created to select what in fact can be identified as mathematics.

The eleven Brazilian CS undergraduate programs studied were selected among others due to their 5-stars rating according to the 'Guia do Estudante 2012' Ranking, published by 'Editora Abril'. [9] The list comprehends the Federal Universities of Ceará (UFC), Minas Gerais (UFMG), Campina Grande (UFCG), Pernambuco (UFPE), Rio de Janeiro (UFRJ), Rio Grande do Sul (UFRGS) and Santa Catarina (UFSC), State Universities of São Paulo (USP) and Campinas (UNICAMP) and the Pontifical Catholic University of Rio Grande do Sul (PUC-RS). USP is further sub-divided in two distinct CS programs, the one held at the Institute of Mathematics and Statistics (IME/USP) and the other held at the Institute of Mathematical Sciences and Computing (ICMC/USP).

The methodology for this ranking is described in [10] and has the following process: The 'Guia do Estudante' office contacts yearly all universities in Brazil to catalog all undergraduate programs that will be accepting new students for the next year. Are considered for ranking programs that grant a bachelor's degree, are at least two years old and are in-class. After this step, the office contacts the courses coordinators in order to ask them to fulfill an online questionnaire containing 15 specific questions about the program. Among the topics covered are themes relative to the faculty, scientific production and physical installations. The questionnaires are not graded, only are made available to a group of peer reviewers to help in their grading process. Even if a program does not fulfill the questionnaire it will be graded.

The survey has a group of peer reviewers composed of course coordinators, directors of departments and teachers. They are responsible for evaluating the programs on a scale ranging from 5 (excellent) to 1 (poor) and "prefer not to opine". Each peer reviewer assesses a maximum of 30 randomly chosen programs, preferably in the region where he teaches and excluded those programs from his institution. Each program receives grades from six consultants, the best and worst being excluded. The final score is the average of the four intermediate ones. The process has technical consultancy from Ibope Inteligência and is audited by PricewaterhouseCoopers.

It is noteworthy that, since this is an opinion poll, the results reflect mainly the image that the course has before the academic community. A side effect of this choice is that most of the programs studied are held by public universities, which must be taken into account in the data analysis since they may have different emphases in the quantity and approach in fundamentals disciplines (especially mathematics) in comparison to private universities.

In 2011 the Brazilian Ministry of Education applied the latest National Test of Student Performance (ENADE) on CS programs. While some universities, like USP, chose to not participate, it presents a fairly accurate estimate on how many CS programs are in Brazil. According to it, there are at least 354 programs, 258 private and 96 public. [11]

III. Reference Curricula

As pointed out previously, Brazilian CS programs have their curricular contents mainly guided by two reference curricula. In an international level by the ACM/IEEE Computer Science Curriculum which current revision is from 2008 (CS2008) [3] and in a country level by the Brazilian Computer Society Curricular Reference from 2005 (CR2005) [8].

CS2008 is internally subdivided in three granularities, from bigger to smaller: knowledge areas, knowledge units and learning objectives. The Discrete Structures (DS) knowledge area is the only one that fits (partially) in the definition of mathematics used in this paper. More specifically, DS has the following knowledge units: Functions Relations and Sets, Basic Logic, Proof Techniques, Basics of Counting, Discrete Probability, Graphs and Trees. From these, all but Graphs and Trees were accounted as math.

In accordance with CS2008, 280 lecture hours are necessary to comprise the whole obligatory curriculum, with the math area representing 39 lecture hours. [3] Note that CS2008 only addresses contents closely linked to Computer Science. There are no mentions on the requirements for Calculus, Linear Algebra or Differential Equations, necessary for advanced disciplines.

TABLE II. MATH COVERAGE IN BRAZILIAN CS CURRICULA

University	Total math hours	Total curricular hours	Percentage of math in curriculum
ACM/IEEE [3]	39	280	13.93%
SBC (4 years) [8]	30	160	18.75%
ICMC/USP [22]	540	4395	12.29%
IME/USP [23]	750	2985	25.13%
PUC-RS [24]	300	3045	9.85%
UFC [25]	400	3280	12.20%
UFCG [26]	420	3120	13.46%
UFMG [27]	540	2625	20.57%
UFPE [28]	285	3495	8.15%
UFRGS [29]	360	3240	11.11%
UFRJ [30]	480	3075	15.61%
UFSC [31]	486	3528	13.78%
UNICAMP [32]	510	3000	17.00%

On the other side, CR2005 has a broader definition of mathematics than the one used in this paper. It states that the following topics fall in the area: Linear Algebra, Combinatorial Analysis, Differential and Integral Calculus, Differential Equations, Analytical Geometry, Mathematical Logic, Discrete Mathematics, Probability and Statistics and Complex Variables. CR2005 doesn't detail how much time each of these topics should receive, it only affirms that it's necessary 30 "credits", didactic activity units, for the whole mathematics area. The full CR2005 curriculum requires at least 160 "credits" for 4-year programs or 200 "credits" for 5-year programs.

IV. Data

Table I presents the general panorama of the eleven chosen CS programs indicating their size, location inside the university and course characteristics. While most programs are diurnals (Full-time), with the majority lasting four years, it's possible to perceive two different sources of influence on the undergraduate program based on the location of the department responsible for it: in one side there are the ones that are closer to the mathematics departments in the university, IME/USP, ICMC/USP and UFRJ and the more technological ones, closer to engineering departments.

Table II deals with the total time necessary to achieve graduation and the portion of this time that is dedicated to mathematics as defined previously. It is important to notice that the totals shown include elective disciplines or mandatory internships when they exist.

Analyzing the amount of hours column we can see that there is a great variability in the hour load required by the curricula of different universities and the reserved portion to math. On average $3097h$ are required ($\sigma = 302h$) for 4 years programs, $3270h$ ($\sigma = 212h$) for 4.5 years programs and $3698h$ ($\sigma = 986h$) for 5 years programs. Studied universities have an average of 14.47% ($\sigma = 4.92\%$) of disciplines exclusively in this area.

The most important fact derived from data is that few CS programs achieve the minimum hour load for math according to CS2008 or CR2005. This can be better visualized in Figure 1. Only IME/USP and UFMG fully meet the standards presented, while UFRJ and UNICAMP meet only CS2008.

TABLE I. STUDIED CS PROGRAMS PANORAMA

University	Period	Organization	Foundation	Years to graduate	Students per year	Where is located
ICMC/USP [12]	Diurnal	Public	1979	5	100	Institute of Mathematical Sciences and CS
IME/USP [12]	Diurnal	Public	1970	4	50	Institute of Mathematics and Statistics
PUC-RS[13]	Nocturnal	Private	1983	4	60	Faculty of Informatics
UFC [14]	Diurnal	Public	1975	4	60	Center of Sciences
UFCG [15]	Diurnal	Public	1977	4	90	Center of Eletrical Engineering and Informatics
UFMG [16]	Diurnal	Public	1978	4	80	Institute of Exact Sciences
UFPE [17]	Diurnal	Public	1974	4.5	100	Center of Informatics
UFRGS [18]	Diurnal	Public	1983	4.5	100	Institute of Informatics
UFRJ [19]	Diurnal	Public	1974	4.5	50	Institute of Mathematics
UFSC [20]	Diurnal	Public	1976	4	100	Institute of Informatics and Statistics
UNICAMP[21]	Nocturnal	Public	1969	5	50	Institute of Computing

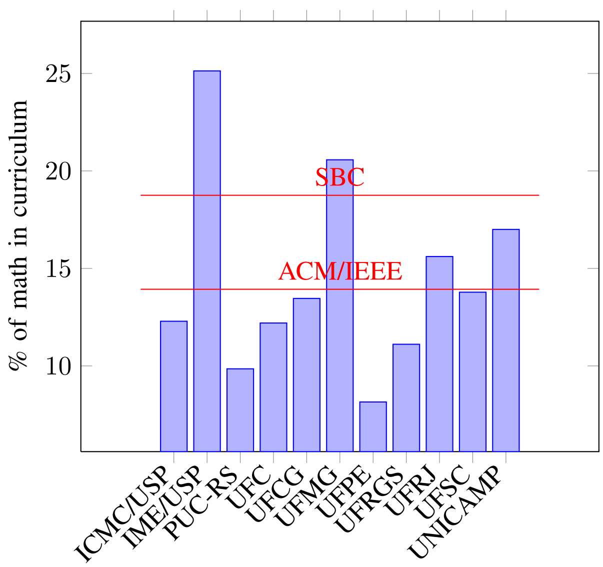

Fig. 1. The proportion of mathematics in each curriculum compared with the reference curricula

This implies that there is no evident correlation between the location of a CS program and its mathematical bias. Despite the fact that the ICMC/USP program is located near the math and statistics departments, it didn't achieve the minimum in both standards.

V. CONCLUSIONS

In Brazil there are many undergraduate rankings available. Beyond Guia do Estudante, the ENADE ranking, for example, could be used to analyze a different set of universities. Just like Guia do Estudante, ENADE analyzes the infrastructure of the university and the level of professors' graduation, but also applies a test on a subset of the freshmen and senior students in order to evaluate the knowledge acquired in the graduation years. [33] Using the Preliminary Concept of Course (CPC) available at [11] the 10 best ranked universities are: Federal Universities of Rio Grande do Sul (UFRGS), Goiás (UFG), Campina Grande (UFCG), the city of Rio de Janeiro (Fluminense - UFF), Minas Gerais (UFMG), Pelotas (UFPel), Viçosa (UFV) and the Pampa (UNIPAMPA) and the private Universities of the West of São Paulo (UNOESTE) and of the North (UNINORTE).

With both comparisons another possibility is to analyze if there is a positive correlation between a highly ranked program in different rankings and the amount of mathematics studied during undergraduation. If so, further investigation may be necessary in order to find if there is a correlation of cause and effect between the math study and the quality of an undergraduate program.

Finally, different studies are possible to measure the actual utility of a more theoretical topic in the professional life of a graduate. One possibility is to apply questionnaires to former students with the goal of identifying strengths and weaknesses of a curriculum.

In this paper it was possible to note that mathematics, although considered an area important for the basic formation of a student in Computer Science, is experiencing a decline in its relevance, in part by the emergence of several new trends in the market that are absorbed in undergraduate curricula.

An analysis of the current emphasis on mathematics in eleven Brazilian CS curricula from ten different universities was conducted through the study of absolute and relative workload in the area. It was found that only two programs fully and two other partially meet the minimum hour load for mathematics in an undergraduate CS curriculum according to two different academic standards, one national and the other international.

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Undergraduate and Graduate Teaching Assistants' Perceptions of their Responsibilities – Factors that Help or Hinder

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***Abstract*—Effective teaching assistants (TAs) are crucial for effective student learning. This is especially true in science, technology, engineering, and mathematics (STEM) programs, where TAs are enabling large programs to transition to more student-centered learning environments. To ensure that TAs are able to support these types of learning environments, their perspectives of training, their abilities, and other work related aspects must be understood. In this paper a survey that was created based on interviews conducted with eight TAs is discussed. The survey has four primary categories of content that are critical for understanding TAs' perspectives: (1) background, (2) motivation, (3) training, and (4) grading and feedback. This research team is first utilizing this survey at Purdue University to test for validity and reliability of the instrument, as well as identifying ways to improve the experiences and effectiveness of the First-Year Engineering Program's TAs' support system, training, hiring process, and any other relevant components of the infrastructure. The more generalizable goal of this research is to further develop this survey to be used by any STEM program as a diagnostic tool for identifying opportunities to enhance the TA support systems and therefore improve student learning.**

Keywords—first-year engineering; undergraduate and graduate teaching assistants; training; motivation; feedback

I. Introduction

Teaching assistants (TAs) have come to play a prominent role in undergraduate instruction. They are fundamental to the success of large introductory science, technology, engineering, and mathematics (STEM) courses. At large universities, graduate teaching assistants (GTAs) teach the majority of the science laboratory and discussion sections [1]. There is also a growing movement towards using undergraduate teaching assistants (UTAs) in introductory courses with large numbers of students [2-4].

As more undergraduate students work as teaching assistants, their unique position as both student and instructor introduces the challenge of balancing student and teaching responsibilities. Another problem is that many teaching assistants reported being assigned to undergraduate courses with no prior training [5]. In the case of GTAs, they are assumed to have the content knowledge, while pedagogical knowledge is not emphasized [5].

Since TAs are crucial to the success of large courses with a student-centered pedagogy, this research was conducted to create a survey to act as a diagnostic tool for STEM program utilizing TAs. Similar surveys have been created to understand TAs' perspectives of the benefits of training, effectiveness of course materials, helpful experiences, and many other aspects of programs [6-9]. This survey was created based on an analysis of existent, relevant surveys and previous research on interviews conducted with TAs in the First-Year Engineering Program at Purdue University. This survey tool targets TA responsibilities, training techniques, and other identified factors to answer the research question. This study is driven by the following research question: How so TAs perceive the affect of their previous experiences, motivations, and training on their ability to enact their responsibilities (e.g., grading, giving feedback, and helping students)?

In our previous study to investigate how TAs perceive their responsibilities and to identify factors that influence their ability to execute their responsibilities, eight TAs (i.e., 4 UTAs and 4 GTAs) from a large introductory engineering course sequence (enrolling about 1700 students) were interviewed in Fall 2012 [10]. This course sequence has introduced the use of authentic, team-based, iteratively-solved open-ended problems, in the form of mathematical modeling activities [11] and design projects. Some of the TAs' common responsibilities include: (1) attending TA training, (2) preparing for class, (3) helping with in-class activities, (4) supporting the course instructor and other TAs, (5) grading and giving feedback on students' solutions, and (6) helping students by answering questions in and out of class. From 18 different responsibilities within these six categories, TAs most frequently discussed five responsibilities from the three categories of training, grading, and helping students [10]. Prior knowledge and experience, training, and intrinsic motivation were among the most helpful factors; time commitment and the open-ended nature of problems were among the most frequent hindering factors. The helpful factors were aspects of TAs' positions that they identified as better enabling them to execute their given responsibilities. The hindering factors refer to difficulties that the TAs expressed.

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II. Literature Review

Fuller (1969) identified three concerns that teachers have: concern about self, task, and impact. He considered these concerns linearly in that teachers progressed through them with experience [12]. Choo et al. (2011) built upon these concerns and proposed the following specifically for graduate teaching assistants: class control, external evaluation, task, impact, and role/time/communication. These concerns highlight teachers' worry about being deficient or incapable [13]. However, the impact concern represents a GTA's hopefulness and desire for growth. In terms of professional development, the aim is for teachers to view these other concerns in terms of growth and improvement, rather than deficiency.

These concerns served as a framework for this study. This study aimed to identify the presence and form of these concerns for both graduate and undergraduate teaching assistants in an introductory engineering course sequence. The three categories that emerged from the qualitative piece of the study were training, motivation, and grading. Training is a crucial piece in TAs development and understanding of both their role and their tasks. Motivation, both external and internal, relates to concerns with external evaluation, role, and impact. Grading and feedback relate specifically to the unique task required in teaching these courses.

A. Training

Training is considered crucial for the success of TAs to fulfill their job requirements [7,14-16], especially grading and giving feedback [10]. There have been various forms of surveys that have analyzed different important aspects of training and identified some fundamental knowledge that should be understood about TAs' perspectives on training, its benefits, and its affects. Some of these include their perspectives of the value of various content within training [7], their understandings of pedagogical approaches and how they feel training affected their knowledge [8], and their understanding of their role as TAs to ensure all aspects align with the programs' intended role for the TAs [9].

B. Motivation

Motivation was identified as one of the helpful factors for TAs in helping students and teams [10]. Motivation and its effects have been a subject of many studies (e.g. [17-19]). Both intrinsic and extrinsic motivations have been discussed in different studies as influential factors in choosing to teach. Some of the intrinsic motivation factors are personal satisfaction with career, working with children, and contributions to society. Extrinsic motivational factors include salary, job status, and job security.

C. Grading – Feedback

Effective instructor feedback is vital for student success; it is also acknowledged to be a challenging responsibility [20]. Many studies have identified attributes of effective feedback [20-23]. Feedback should be timely and constructive, and it should scaffold students' learning [21,22]. Feedback given in open-ended problem solving settings should be responsive to students' solutions [23], while not pushing a single "correct answer" [24]. The amount of progress towards a high quality solution that students make in open-ended problem solving settings depends heavily on the feedback they receive from the instructor, which in many courses are the TAs [23].

III. Method

This study has a qualitatively driven design [25]. In the qualitative component of this study, interviews were conducted with TAs to explore their perspective of their TA position. From this data, a quantitative instrument was developed.

A. Setting and Participants

About eight graduate and eighty undergraduate teaching assistants for two sequential first-year engineering courses enrolling about 1700 students were asked to participate in this study in Spring 2013. The two courses are required for all FYE students and each is a 2-credit hour course (with 4 hours of face-to-face class time per week). The UTAs range from sophomores that just completed the FYE courses to second-year seniors completing their fifth year of college. All UTAs are required to take the courses (or the honors sequence) and pass them with a B or better to be a TA in these courses. Prior to administering the survey, the team piloted the survey with a GTA from the FYE Honors Program at Purdue; the GTA gave feedback which led to some minor modifications. Then the survey was distributed. There was a 25% response rate for GTAs (i.e., 2 GTAs responded) and a 54% response rate for UTAs (i.e., 43 UTAs responded).

B. Instrument

The survey instrument was created based on the prior interview findings to further investigate TAs' perceptions of their responsibilities and the factors that help or hinder their abilities to execute their responsibilities; the survey focuses on prior experiences, training, grading/feedback, and motivation. The survey facilitates understanding of a greater number of TAs' perceptions regarding their responsibilities. This survey contains four sections: (1) background information, (2) motivation, (3) training, and (4) grading and feedback. The motivation, training, and grading/feedback sections consist of 6-point Likert scaled items, with a scale of importance that ranges from not at all important to extremely important, a scale of agreement that ranges from strongly disagree to strongly agree, a scale of beliefs that ranges from very untrue of what I believe to very true of what I believe, and a scale of frequency that ranges from never use to always [26].

The background information section focuses on understanding potentially relevant prior knowledge and experiences that the TA may have (e.g., took the course as a student, level of education, field of study, tutoring experience, and other TA positions).

The motivation section aims to understand TAs' intrinsic and extrinsic motivation regarding their TA position. A motivation category was included to identify intrinsic or extrinsic motivational drive for being a teaching assistant. The questions were adapted from Factors Influencing Teaching (FIT) choice questionnaire by Richardson and Watt (2006) [18].

The training section includes questions about the types of training the TAs received and questions about time spent and effectiveness of the various aspects of training they received. The TAs are queried about three types of training (i.e., university level, departmental level, and course-specific level) and three modes of training (i.e. online, face-to-face, and apprenticeship). These modes of training are also further defined by how they are taught (e.g., lecture, discussion, practice grading, and role playing). There are "other" options wherever applicable to allow a TA to indicate any additional training formats.

The interviews revealed that a primary concern for TAs was providing feedback to their students. In this course, the process of providing feedback is critical to the implementation of the open-ended problems. The feedback and grading portion of the survey asks about the types of work the TAs graded and/or gave feedback on (i.e.. close-ended problems and open-ended problems). The TAs are prompted to rate how prepared they feel to do various grading and/or feedback tasks. The last portion of the grading/feedback section focuses on the types of feedback TAs give. They are prompted to rate how often they feel they use various types of affective feedback (i.e., praise, neutral, and negative) and cognitive feedback (e.g., summarize student work, state correct answer, ask thought-provoking questions, and copy content from training materials). The last portion of the survey prompts the TAs to rank their training and prior experiences from most to least helpful in developing their grading and feedback skills.

IV. Future Work

TA interviews [10] were used to inform the development of a survey. The survey has been administered to the participants within the setting described in the method section. Preliminary results will be presented at the time of the conference. After the data from the surveys are quantitatively analyzed, the research team will utilize this data and the qualitative analysis of the interviews to conduct a final mixed methods analysis.

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Engineering Virtual Studio

Online context and community for underclassmen engineers

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***Abstract*— Myopia on foundations early in undergraduate work is pandemic throughout STEM undergraduate training. This "sink or swim" foundational approach begets attrition and reduced motivation, engagement, and performance for those rugged students who stay in the major. Current approaches to alleviating this myopia, including integrative curricula and extracurricula, provide some context and community, but require great faculty and staff effort, and often requires onerous changes to the base curriculum, while leaving students stranded segueing into the sophomore year. Here we introduce and report on an initial pilot of an online alternative. Our one-credit, pass/fail course, Engineering Virtual Studio (EVS), provides explicit connections between foundational courses and real-world products and problems. The course also fosters both scholarly and pre-professional identity building as constant processes. We report on the course design, work in progress in our pilot year, and opportunity for improvement.**

Keywords—integrative thought; identity; cyberlearning; underclassmen

I. Introduction

Our nation needs engineers that will drive innovation and leadership. Colleges and universities have outstanding undergraduate programs to train these rising engineers. Students receive critical elements of this training, however, only late in their undergraduate education. All engineering programs necessarily begin with foundational study, in mathematics, basic sciences, and underlying engineering principles. Explicit integration over this material and student presentation of ideas happens most often in upper-level or capstone courses. This structure of curricula is sensible given the goal of proper foundation preceding higher difficulty challenges. The big ideas and big challenges, however, are the elements that attract many students to engineering in the first place. Departments of engineering should meet this interest directly, as early in undergraduate education as possible. As programs meet this goal, students become engaged in larger ideas more quickly and become facile in connecting between materials, thinking broadly. With early engagement in big ideas, our students will be more adept at tackling our nation's problems and leading scientific progress.

Currently, however, a vast majority of STEM majors (including our own) are devoted to foundations throughout the first two years. On one hand this foundation is critical to base upper level work; on the other hand a preponderance of the first two years is spent in serial isolation. A typical semester would have each BME student study in courses beside majors in other departments, focusing on material and examples outside their home discipline. Students easily develop disconnect from their primary motivation for the overall enterprise. Disconnect often segues into dispirit, which for many students leads to decreased performance or transfer to another major.

The disincentives built into STEM foundational curricula are entrenched by departments and professors who have built educational programs based on a four-year perspective, not based on retaining students and students' interest as underclassmen. The rigid structure of courses is even more onerous in engineering, within which departments need to deliver engineering foundations, content, and substance as mandated by ABET.

II. Methods – Structure of Online Course

Our Engineering Virtual Studio (EVS) program aims to build support, community, and novel opportunity for our undergraduates (Figure 1). Here is our vision of how undergraduate engineering life will improve with EVS.

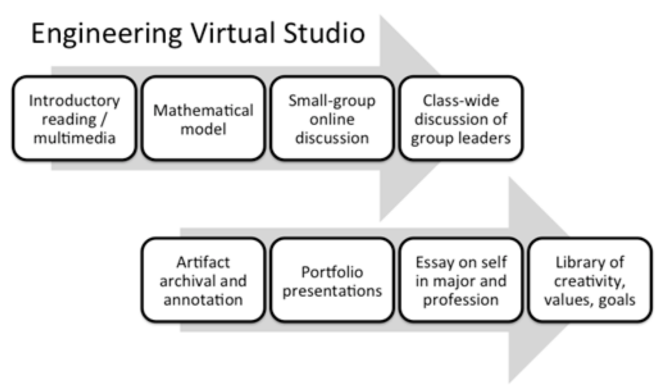

Figure 1
Two streams within EVS: one that introduces and reinforces connection and consideration between foundational material and real-world products and research, and one that fosters investment into scholarly and pre-professional identity.

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Underclassman students register for a one-credit, pass/fail course. Students are assigned a discussion group of six peers and an upperclassman who serves as a mentor / moderator. The work required for the one-credit pass is twofold: online discussion among peers, and an essay at the end of the semester reflecting on how the student is building integrative wherewithal and building his/her own focus within the major.

EVS provides one "bulletin" for each course students take outside the major. Each bulletin links a core concept within that course to a real-world, current topic in BME. Each bulletin includes paragraphs introducing the connection between the core concept and real-world products and research; a review paper or multimedia that illustrates that connection; a computational model simulating that connection; and a set of questions to initiate online, integrative discussion. Each group dissects the published material, explores the computational model, and examines the discussion questions. This group work builds a local community of scholars, both pushed and supported to complement their deep foundational study with broader, more integrative consideration.

In our pilot year, we complemented the bulletins on particular foundational material with articles on broader engineering topics and on integrative thought within engineering education. In subsequent years we will continue to build these broader opportunities, including bulletins that explicitly foster creativity and early entrepreneurial mindset.

Students also build their own scholarly and pre-professional identity through EVS. During the semester students store and annotate artifacts that document their interests, talents, and aspirations. Students build portfolios of these artifacts to provide evidence of consideration of self. Content may come from the bulletins and discussion, course readings, online resources, and most importantly from their own product. EVS will therefore serve as a natural home to accumulate a student's own interest, with a backbone of their own readings and writings.

At each semester's end students write an essay reflecting on successes and works-in-progress toward finding their undergraduate and post-graduate goals, with identification of subsequent steps toward concretizing and substantiating those goals with evidence. Within this essay students address how they have integrated and considered material across the semester. Some of this thought may address the bulletins, but the broader goal is a self-evaluation of how the totality of the student's training has built their identities, both scholarly and pre-professional. These essays are kept in a student's library so each student can track their own progress throughout their undergraduate training.

III. THEORETICAL AND PRACTICAL BASIS FOR EVS

Pedagogical literature across academe and particular to engineering has recently recognized the advantage of introducing integration and innovation throughout a curriculum, rather than delaying bigger approaches and questions. In the National Academy of Engineering report "Educating the Engineer of 2020," a central recommendation to schools was that "the essence of engineering – the iterative process of designing, predicting performance, building, and testing – should be taught from the earliest stages of the curriculum, including the first year." These experiences "connect engineering design and solutions to real-world problems so that the social relevance of engineering is apparent(.)"

The next passage, however, recognizes that while these early experiences seem to aid in retention, there is little "rigorous investigation" of "how to evaluate individual student performances" and that presents the real need for investment and study into the impact of these experiences. EVS project will address this exact need, through constant recording and analysis of online student responses. Bulletins in the pilot year offered some room for creativity, but admittedly this was limited to broader discussion rather than explicit design consideration. We will keep the student experience online and virtual, but with subsequent years and the advent of the sophomore version integrate virtual creativity through mathematical models.

An essay by Dr. Gretchen Kalonji in the same volume calls for engineering programs to "boldly reformulate engineering education" to move away from "the tyranny of the assumption that 'courses' are the primary (and in many cases almost the sole) mechanisms for student intellectual development." Dr. Kalonji calls for establishment of formalisms that recognize, reward, and prioritize a broader view of the big questions in engineering, societal impacts of those questions, and each student's personal investment into their role in those questions and impacts. EVS will build content, environment, and community to value exactly these goals. Students will invest in their own learning and their own identities across the curriculum, which will prime each student's passion for their interests and direct application of those interests to society.

One basis for the EVS approach lies in constructivism. According to a recent review by McDaniel and Wooldridge, "Constructivist teaching methods therefore differ from traditional education in that students are expected to take responsibility for their own learning in order to actively create knowledge structures." The structured elements within EVS all support this approach: the examination of core concepts, integrative models, and open-ended questions with peers and a mentor; the reflection on their own skills and worldviews in the semester-ending essay; and the fostering of a community that places explicit value on the development of the person as a thinker, explorer, and inventor ready for real-world engagement, rather than solely as a student. With this "construction," students will be more flexible in applying foundations to different, new, and open questions (von Glasersfeld, 2005; Kuhn, 2007). The rigorous foundations our students learn in their coursework will remain 100% as rigorous and complete. EVS adds a light exoskeleton to these foundations within which students will build their own constructivist wherewithal. We directly and explicitly address observed gaps in integrative learning, reflective learning, and writing in engineers compared with their undergraduate peers (Lichenstein et al 2000).

IV. Report on Initial Pilot

In 2012-13, 120 freshman biomedical engineering majors participated in a pilot of EVS. We built two types of bulletins: general exploration of connections between first-year material and real-world BME, and specific ties between topics in first-year physics and precise problems or products in BME. In subsequent years we will expand the freshman bulletins to tie between foundational math, chemistry, and biology as well. Sophomore EVS will provide ties to biology, math, and foundational engineering, while providing more opportunity for students to research their own specific interests with broader opportunity for creative exploration and simulated design.

Overall participation and quality of writing indicate that the one-credit, pass-fail, online model successfully engaged students and provided connections across the curriculum. Students posted within each discussion at least once over 95% of the time. Each group then needed to post to a course-wide board; these postings occurred 93% of the time without reminder from course staff. We did note, in the two-week window during which students could discuss, the vast majority of activity transpired late into the period.

In responses, students demonstrated deep consideration of the readings and suggested discussion topics. For example, in consideration of replacement tissue and organs, one group summarized:

> "Our group discussed the articles and reached the consensus that although they had great potential, the only plausible technique, given today's technology, was the regrowing of more structural tissues such as windpipes, as opposed to a complex functional part i.e. the heart. Consequently, trying to predict which technology would be the most successful in the long term would be difficult, because the technologies with the greatest potential are in the earliest phases of development.
>
> Next we discussed technology, such as skin sprays, which allows victims of severe burns to quickly regrow their own skin by stimulating the cell tissue in the inflicted area. The healing time could be reduced from several weeks down to a few days. This technology is in place and has proven to be very beneficial. We believe that it has the potential to be extended towards other issues and could potentially be very beneficial in other areas. Although this technology was not specifically addressed in the article, the ability of the skin spray to drastically reduce healing time, makes it a very important technology moving forward…"

Our initial pilot in student self-growth, through artifact annotation, portfolio build, and reflective essay, has also proven effective as a proof-of-principle that freshman can substantively integrate and grow from these investments into identity. Of the 118 essays analyzed from the first semester, 68% showed insights into connections across their curricula, 71% showed the beginnings of a scholarly identity, and 54% displayed some form of pre-professional identity. The 96 essays analyzed in the second semester showed similar results. Of these, 45% showed standard insights into curriculum connections, and 11% showed growth in this area. Standard expressions of scholarly identity were found in 30% of essays, and 23% of essays showed growth in scholarly identity. Finally, 38% of essays exhibited standard expressions of pre-professional identity, and 8% showed growth.

Two passages from student essays exemplify the growth in the areas described:

> "…Classes at first appear to have no rhyme or reason, but as the semester goes on, and we learn more and more with the guest lecturers in BME 140, everything seems to fall into place. All of my classes have fed into the other, from calculus and learning about cross and dot products, to physics and stresses and strains. All which appears to be disorderly has order."

> "Although initially I thought that biology was too difficult and possibly some of the concepts were unnecessary, over time I began to see how the things we learned fit together and how they fit with the things I learned in my previous semester. For example the lectures over cell systems, signal transduction, and repression helped me understand how the drugs would interact in the body and the lectures on sequencing, transcription, and translation helped me understand how the next generation sequencing we learned about in BME 140 truly work..."

V. Conclusion

The quantitative and qualitative data presented here reveal that students engage in both threads, connecting foundational ideas to real-world engineering and building their own identities. Our analysis of the semester-ending essays provides a baseline of evidence for student summative consideration across the semester, but room for improvement. We have, however, shown a proof of concept, that a lightweight, online intervention can provide context and community for engineering underclassmen who otherwise would be predominantly or wholly disconnected from the major during foundational coursework. We aim to further build and improve this concept, toward broad diffusion across US undergraduate engineering education.

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Development of a Flash Drive Design Project for Engineering Graphics and Design

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Abstract—

A major challenge in engineering design graphics classes has been the development of semester-long projects, which supports curricular goals while maintaining student interest. In this paper, we will describe a project to develop flash drive casings. The project scenario was structured as a request by a client to design a themed set of flash drive casings and a presentation case suitable for use as a gift to outstanding employees and high value clients. Each student rapid prototyped one flash drive casing of his or her own design. The project was implemented as a series of team and individual assignments spread over the semester, with the product of those assignments returned to the instructors in memo format.

This project was implemented in three phases, over several semesters, with the number of students increasing at each stage to ensure that its full scale adoption was successful. The initial test of the curricular elements was made in two, approximately 20 student summer classes. At that time, several challenges were identified. Reflection on this phase revealed a need for additional written documentation containing "project hints" to help students provide designs that meet the rapid prototyper's production constraints. It was also determined that a number of intermediate assignments were needed to motivate students to remain on schedule for project completion.

The project is currently nearing the end of development phase 2 and most design issues have been resolved. However, curriculum changes are warranted in response to student conceptual difficulties. As in many graphics design projects, a major challenge has been the development of three-dimensional spatial skills. Students have had difficulty creating designs containing layered structures, particularly those needed to secure the electronics within the casing. As expected in a first semester, first year course, some students have shown an inability to follow detailed instructions. While this weakness is normally only a grading issue, the flash drive covers are prototyped directly from their CAD files, making type of error particularly problematic. One major success of the project has been student excitement in the project and the improvement of their graphics skills from re-creation of existing designs to the development of novel designs.

Keywords—Graphics Project Development; Flash Drive

I. Introduction

The Engineering Design Graphics Program's Industrial Advisory Board recently recommended modification of current curriculum to emphasize original design and the introduction of "real world" issues, such as budgeting and non-graphics-based communications. In addition, the program purchased a state-of-the-art rapid prototyper with improved output quality and increased production rate.

These recommendations were implemented through a major revision of the course project. The authors chose to apply the "independent project method" described by Lee [1]. As noted by Bell et al. [2], a well-designed scenario has the potential to: (1) "provide opportunities for students to integrate the learning outcomes from the lecture and laboratory-based teaching sessions," (2) "enhance generic skills such as teamwork, problem solving and communication," and (3) "extend their knowledge using some of the principles of PBL." Further, their results "demonstrate the value of a hybrid approach to an engineering curriculum, which embeds elements of problem- and project-based learning alongside traditional lecture and laboratory teaching." [2].

The availability of rapid prototypers allows an engineer (or engineering student) to move through the entire design process from idea to part creation [3]. Additionally, the prototypers assess no penalty for the creation of a wide variety of complex objects with a high degree of manufacturing precision [4], and are emerging as an industrial process [5-7]. This capacity makes it an effective adjunct to computer aided design by allowing students to realize their designs. Until recently, the cost of rapid prototypers has been prohibitively expensive, but they have decreased in cost over the last few years, with low-end model prices ranging from $400 to $4,400 [8].

II. Project Development

A. Student Population Description.

Students in this course were drawn from a variety of disciplines, ranging from engineering transfer students to industrial distribution majors. General studies students also enroll in this course, as they attempt to enter engineering after failing to meet the College of Engineering's entrance requirements. The majority of students were in their first year of college and therefore had minimal ability to perform the analysis required by an intensive design project.

B. Project Development Phases

The ultimate goal of this revision was to introduce a project suitable for introduction into the graphics component of the Freshman Engineering Program and into the first year engineering design graphics course. The combined course sections serve several thousand students per year, in sections approaching 100 students. On this scale, even minor issues in the modified curriculum had the potential to cause significant disruption in the course. Therefore, the authors chose to introduce curriculum modifications in three phases, with revisions occurring at the end of each phase. The phases and their scheduled semesters were:

Phase 1: The creation and testing of the design project and the development of a project manual – summer sessions I and II of 2012

Phase 2: Intermediate scale-up of curriculum to increasing numbers of student and revision of the project manual – Fall Semester 2012 and Spring Semester 2013

Phase 3: Full scale introduction of the project into courses – Fall Semester 2013

C. *Additional Curricular Goals*

As previously noted, the project was used as a vehicle to introduce non-CAD curricular content to the students. The authors chose to insert the following goals into the course: (1) the introduction of an engineering design paradigm, with an emphasis on satisfying design constraints, (2) increasing the variety of communication methods applied by the students, (3) the basic elements of project planning, particularly the use of Gantt and PERT (Project Evaluation and Review Technique) charts, and (4) the development of basic budgets.

D. *Course Project Description*

The project required students to design a series of custom flash drive casings and a presentation case. The students were required to identify a common theme for the presentation set. The theme (e.g. biomimetics of ocean creatures, important engineering structures, or military weapons engineering) tying the drives together needed to be suitable for use a gift from an engineering consulting firm. The exact areas of expertise of the firm were left undefined to allow the students maximum flexibility in their choice of theme. Examples of student designs are shown at right in Figures 1 and 2.

E. *Course Assignments*

As the project was developed, an effort was made to create a project structure that could be reused in future semesters (1) a sequence of design memos, (2) a final design portfolio, (3) a project presentation, and (4) rapid prototyping each student's design.with minimal adaptation. Thus, an effort was made to isolate the item designed, so that other items could easily be inserted/exchanged. The authors chose to implement these goals through the following major project assignments:

The first two assignments for the project were designed to move the students through an iterative design process, with the last two assignments capping the project. Throughout the semester, a number of smaller homework assignments were given to keep the students on track for the major project completion.

E. *Course Assignment Schedule*

The following timeline was followed during the semester:

Week 1: Project Assignment and Design Brainstorming Exercise – The project was assigned in the form of a memo to the project teams. The brainstorming exercise required pairs of students to generate 50 ideas for flash drive casings in 10 minutes. The rapid pace of idea generation was deliberately chosen to reduce the level of intragroup criticism.

Week 2: Project Teams Assigned – The project was assigned to teams of 4 members. Team membership was chosen by the instructor. Additional descriptive information regarding project was provided to the student teams and they were asked to begin researching possible designs for their drive casings.

Week 3: Full Project Manual Handed Out – The project structure was provided to the students and a detailed description of the project's deliverables was supplied.

Week 4: Concept Memo and Associated Sketches Due – The memo required each group member to submit sketches of potential flash drive casing designs and themes for consideration. The memos were returned with critique of the sketches and comments on potential problems with specific designs.

Week 6: Flash Drive Electronics CAD Drawing Due, Detailed Discussion of the Project Portfolio, and a Project Planning Lecture and Assignment – The students were assigned the creation of a dimensioned CAD drawing, based on measurements of the flash drive electronics performed by the students using a digital micrometer. The lecture described project planning processes. Students were required to generate PERT and Gantt charts for the project using the software package *GanttProject* [9] and to assign responsibilities for the project.

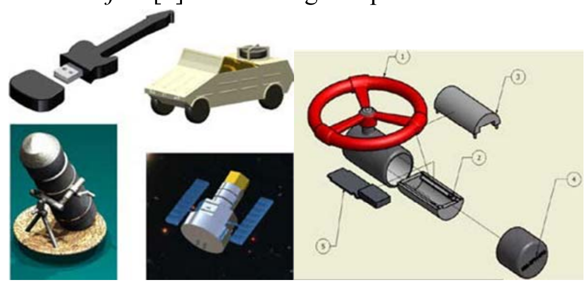

Figure. 1. Examples of designs for flash drive casings.

Figure. 2. Example flash drive cases printed on an Objet rapid prototyper (left and middle). Example set of flash drives and a case based on the space program (right). The case was designed to mimic a segment of the international space station.

Week 8: Final Design Choice Memo Due – This memo contained the final flash drive design and a theme that bound the flash drives into a cohesive set. The students were required to attach updated isometric drawings of the flash drives.

Week 11: Parametric Model of Flash Drive Electronics

Due – These models were used in flash drive assembly drawings and provided a mechanism to allow students to examine issues such as part fits and physical assembly problems.

Week 12: Files for Each Individual's Flash Drive Casing Design for Rapid Prototyping Due – CAD files used by the rapid prototyper were reviewed prior to printing. Subject to available printer time, the rejected designs could be revised and resubmitted for printing.

Week 13: Working Drawings of Individual's Proto- typed Flash Drive Casing Due – This assignment was aimed at keeping students progressing towards project completion.

Week 15: Project Portfolios Due and Presentations Given – The project presentations were structured to resemble intra-company sales pitches with the projects "competing" for the right to be produced.

F. Phase Assessments

1) Phase 1:

We introduced the curriculum into two small classes with less than 20 students in each section. The smaller classes allowed intensive instructor/student interaction as challenges in the curriculum schedule and project developed. The issues that arose during this phase were (1) a need for additional documentation to clarify the assignments, (2) The need for tolerance values for the *Objet* rapid prototyper, and (3) the need for design recommendations for use with the rapid prototyper.

2) Phase 2:

In phase 2, we scaled the project up to 5 class sections of 50 to 55 students each and entailed printing of over 1,400 separate parts. At the end of the semester, meetings were held students and with the design laboratory manager. The discussions with the students yielded only minor recommendations including rescheduling some of the assignments and earlier creation of the STL files used by the rapid prototyper. Discussions with the design laboratory manager indicated that the parts were printed over a 4 week period at the end of the semester, with the rapid prototyper operating continually during that period. This level of output requires consideration of several factors, including:

Material Cost: The most obvious factor was the cost of the material (~$300/kg). A decision was made to limit each student to 30,000 mm (~31g) of printed material, based on available funds from course fees.

Design Laboratory Time: Time required for printing using a rapid prototyper falls into two categories; student technician time and printing time. Technician time typically occurred during the setup of the print jobs and post-printing part cleaning. Depending on the equipment used, these times can vary greatly. In addition, the printing load end of each semester, occasionally resulted in mechanical problems with the prototypers.

Printing Time: Rapid prototypes require only minimal oversight during the printing process, permitting overnight and weekend print jobs, and making it most efficient to print large numbers of parts in each manufacturing run. Most rapid prototypers have constrained print volumes. However, because the flash drive casings are small; the constraining factor is their cross-sectional area, since this limits the number of parts that can be printed in any batch. Therefore, the authors have added a maximum cross-sectional area restriction to the project's design constraints.

Submission Management: Each student was allowed to print one flash drive casing. A file and parts management scheme was required in order to ensure that printed parts were credited and returned to the individual. The expansion to the larger number of students quickly revealed that the system needed to be revised to provide additional information on the submitted parts and in the submission file names. As a consequence, students were required to emboss their team number and name to more easily facilitate return of student casings.

A post semester review halfway through phase 2 indicated that students were experiencing problems with the design process, rather than the project itself. Therefore, materials were added to support the students' design skills. The materials included: addition of a design paradigm to the course materials [11, 12] and addition of material to help students build teaming skills and to understand the issues that occur during team formation based on Tuckman's stages of group development [10].

III. Conclusions

The authors' experience in this curriculum revision has confirmed the benefits of a multi-stage review process. This development, currently in the second "scale-up" phase of the planned curriculum improvement, has benefitted from the re- vision cycle. We are nearing the end of the second semester of phase two and now have reasonable confidence in the project's ability to survive contact with the larger number of students. In addition, the program's faculty has adopted the project for other engineering classes and the authors are working to adapt the project to those needs.

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Enhanced STEM Learning with Online Labs:

Empirical study comparing physical labs, tablets and desktops

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***Abstract*- India's educational challenge includes a large school going population, shortage of science teachers and lack of science labs in many schools. To counter this challenge, the Online Labs (OLabs) pedagogy is designed as a complete learning environment with tutorials, theory, procedure, animations, videos and simulations while the assessment includes conceptual, experimental, procedural and reporting skills.**

We discuss two separate empirical studies using OLabs to study the performance gains, student attitudes and preferences while using physical labs, desktops and tablets. The first study was at a school that compared students who learnt individually with OLabs on desktops, to students who learnt with the traditional teacher led physical labs. The second study was at a science camp and compared OLabs on desktops to OLabs that were context adapted for android tablets. There were significant differences between the physical labs and the self study mode using OLabs on desktops, but no significant differences between OLabs on desktops compared to OLabs on tablets.

Keywords—Olabs; traditional labs; animation; simulation; online labs; virtual labs; elearning; cognitive learning; conceptual skills; experimental skills; procedural skills; reporting skills; assessment

I. INTRODUCTION

The National Focus Group on "Teaching of Science" suggests prevention of marginalization of experiments in the school science curriculum. In this regard, investment is required for improving school labs to promote an experimental culture. Majority of the schools in developing countries, lack both minimum infrastructure and trained teachers. Often assessment of practical skills for a large class size is difficult and may comprise of well written assignments or objective assessments alone.

OLabs science simulations are based on sophisticated mathematical models that offer a complete learning environment of science practical labs with interactive tutorial animations, video demonstrations and assessments. OLabs was recommended by the Central Board of Secondary Education (CBSE) as a teaching and learning aid to the 15000 schools that follow the CBSE curriculum.

We discuss two separate empirical studies using OLabs to study its effectiveness, performance gains and student attitudes and preferences using different modalities and compare it to traditional labs. The first study was at a school that compared students who learnt individually using OLabs to perform the experiments on the computer lab, to students we did the experiments at the teacher led traditional labs.

The second study was at a science camp and compared students learning with OLabs on desktop computers v.s. OLabs that were context adapted for low cost android tablets. There were significant differences in learning and performance between the teacher led traditional labs and the self study mode using OLabs on desktops, but no significant differences between OLabs on desktop computers compared to OLabs on tablets.

II. SIMULATION FOR PRACTICAL SCIENCE EXPERIMENTS - A SURVEY

Many educators suggest that computer simulations offer considerable potential for the enhancement of the teaching of science concepts. Simulations enable students to have direct control by modifying variables and being able to visualize the effects of their changes [1]. While both traditional laboratory activities and simulation are forms of inquiry which engage the learner in the process of observing, hypothesizing, experimenting and forming conclusions, computer-simulated experiments, as inquiry tools, are considered by some authors to be superior to conventional laboratories [2]. A model-based learning using simulations within a complete learning environment instead of stand-alone simulations was discussed in [3] Some authors have proposed a framework for combining traditional and virtual labs based on specific learning outcomes such as cognitive, affective and psychomotor related objectives and concluded that student's conceptual understanding was enhanced by the combined learning approach [4], [5].

As students can immediately see the output to simulations based on the input they provide, they can make connections between the hypothesis and the results [2]. A framework for learning-enabled online assessment of practical skills, which gives due consideration to both the structure of the practical assignments and immediate feedback promotes learning[6]. Simulations teach both real and theoretical behavior to the learner [7]. Reference [8] through their interactive science simulations allowed students to explore science topics and concluded that with minimal explicit guidance students were able to perform in ways similar to how scientists explore phenomena. Immediate responses may encourage students to examine various system states without fear of making mistakes or being criticized. Control of variables enable students to assess the effect of each individual variable as well as their combined effects, promoting clearer understanding of this key aspect of inquiry work. OLabs provides a flexible simulation environment, which maps to the school curriculum while allowing additional variables that can be controlled by the student to enable a richer learning experience.

Simulations engage the learner, provide visualization and show the effects and consequences [9]. Some studies suggests that simulations used in science education can be classified along four dimensions: the amount of user control, the extent and nature of the guiding framework of how information is represented, and the nature of what is being modeled [10]. OLabs consists of rich interactive simulations based on accurate mathematical models, tutorial animations and video demonstrations, feedback and scaffolds, and the assessment of various skills. Simulations offers a learner direct experience of a system, even though it is simulated [11].

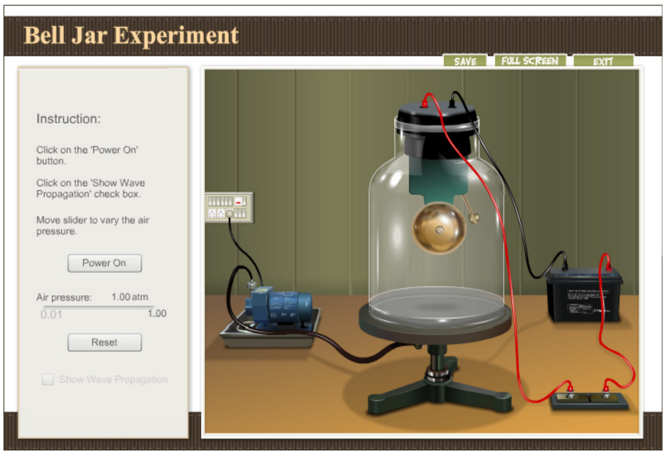

Fig. 1. Simulation of the Bell Jar experiment.

The OLabs simulation labs allow a student to experiment with dimensions that are impractical or impossible in a lab, e.g. performing experiments in a zero gravity environment. It eliminates time-consuming setup and allows learning of experiments that require equipment that is too expensive to purchase. The complete set of supporting materials such as the theory, lecture notes, animation and video tutorials are in an organized form as related to the experiments being performed and has supplementary reading on the related material. The simulations and assessments have automated feedback and scaffolds to aid in better learning outcomes. Assessment of lab skills includes conceptual knowledge, procedural and manipulative skills, understanding the experiment and the equipment including manipulating them and reporting and interpreting skills.

III. THE OLABS DIFFERENCE - MULTI-PRONGED LEARNING ENVIRONMENT AND ASSESSMENT

There is universal acceptance of the importance of performing experiments in the school physical lab to enhance students' conceptual understanding in science. When there is limited time to access physical science labs, the learning cycle is limited as learners cannot try out different scenarios [12]. In addition, a formal assessment of science lab skills is lacking, with most schools employing the traditional theory based or multiple choice questions (MCQs) to evaluate students.

Simulations are not a total learning package but provide only a part of the learning experience but must be integrated into a curriculum, which provides support for the simulation and in which the simulation supports other learning activities [13]. OLabs is built not just as stand-alone simulations but as a complete learning environment with supporting theory, animations, videos tutorials, interactive simulations, assessments and reference material.

Simulation based labs for science experiments have been an increasingly growing trend to alleviate this problem but they provide only a part of the lab experience. What is needed is an integrated approach for assessment-for-learning of simulation based lab skills. Such an approach will have the following four quadrants –a) simulation based labs (Fig. 1) b) feedback and scaffolding c) assessment of lab skills (Fig. 2) d) animations (Fig. 3) and video tutorials in an organized form as it relates to the experiments being performed and supplementary reading on the related material.

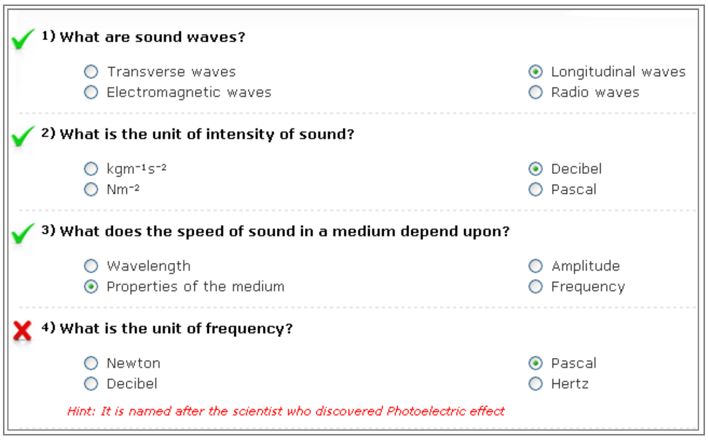

Fig. 2. Assessment – Mutliple Choice Type.

Assessment of practical skills in science in an objective manner is a difficult task with the difficulty increasing manifold if the assessment is to be carried out when a class size is large. The Central Board of Secondary Education (CBSE), India mandates that conceptual skills, procedural skills, experimental skills and reporting skills are improved and assessed as part of science labs and hence our study incorporates all four skills.

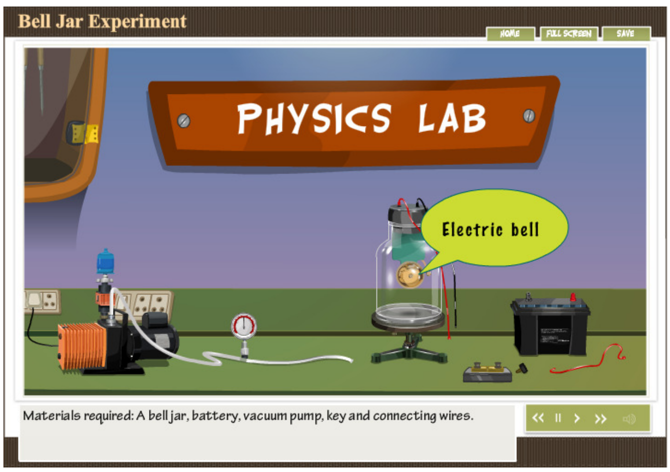

Fig. 3. Animation of the Bell Jar experiment.

IV. Collaborative Accessibility Platform for Practical Skills

OLabs are hosted on a distributed Collaborative Assessment Platform for Practical Skills (CAPPS) [14]. CAPPS reduces the cost of deployment of labs by scheduling and allowing secure access of online labs. In addition to this, CAPPS has a collaborative authoring module to create new labs and a built-in learning management system. The iLabs developed at the Massachusetts Institute of Technology [15] that provides this kind of architecture for developing and deploying labs built by multiple institutions. CAAPS provides a single user interface to labs developed by multiple institutions, thus allowing the student to access any available lab that are built by different authors and geographically distributed at different institutions.

V. Research Study

A. Research Questions

1. How do traditional lab learning with teacher instruction and OLabs without teacher intervention but tutorial e-learning material compare when evaluated by the four types of assessments such as conceptual, procedural, reporting and experimental skills?
2. On evaluating the four assessment types, are OLabs with content and context adapted for tablets comparable to OLabs on desktops?

B. Participants and Materials

There were two separate studies conducted using OLabs. The first study comparing traditional labs with OLabs at the computer lab was conducted in a school in Kerala, India in with (n=59) eleventh grade students. The second study comparing OLabs on tablets with OLabs on desktop was done during the DST Inspire Science Camp in May 2012 with (n=62) eleventh grade students.

Android tablets and Desktops were connected to the OLabs server. Traditional Labs had the physical equipment to perform the experiments.

C. Measures

A 5 point Likert-scaled questionnaire to gauge student perceptions of the ease-of-use and preferences for OLabs and for device types was conducted after the post-assessment.

The CAPPS tracks every input of the student, including the current state of the experiment, variables changed by the student, pages visited and time spent on each page, thus providing a complete history of all student activity. The number of questions attempted and the answer choices selected are logged. These have been used in the analysis.

D. Case 1 Traditional Labs v.s. OLabs

The students were randomly divided into two groups using the cluster sampling method of numbers for the experimental groups, one using OLabs and the other control group using the traditional labs. The students were given a brief introduction about the study and then given the pre lab assessment to check their knowledge level of the given experiment at that stage. In the computer lab: they were instructed to go through the theory first, followed by the procedure, tutorial video/animation, the simulation and then the viva questions. The traditional lab was conducted exactly as it is typically done in the school, with a subject matter expert from our team explained and demonstrated how to perform the complete experiment after which the students performed the experiment.

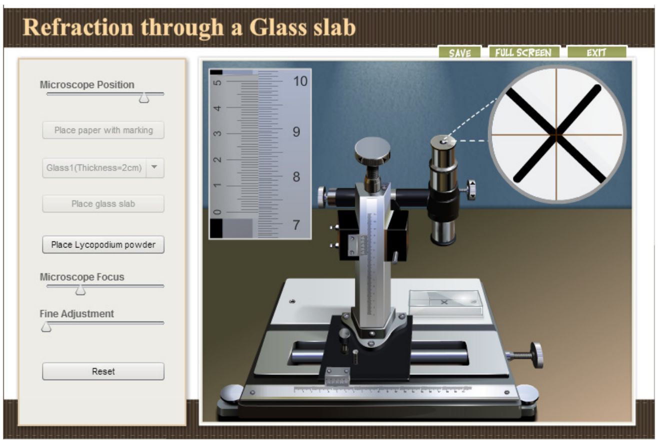

Fig. 4. Simulation of experiment 'Refractive Index of a Glass Slab'.

The students from both the groups performed the experiments and then completed the lab records using the template provided. Then the students were given the post lab questionnaire. Finally they answered a post lab survey. The experiment selected for this study was, "Refractive Index of a Glass Slab" and the objective of the lab is to determine the refractive index of a glass slab (Fig. 4).

E. Case 2 OLabs on Desktops v.s.Tablets

The experiment selected for this study was the 'Verification of Archimedes' Principle' (Fig. 5) and the objective of the lab is to establish the relationship between the loss in weight of a solid and weight of water displaced when the solid is fully immersed in various solutions.

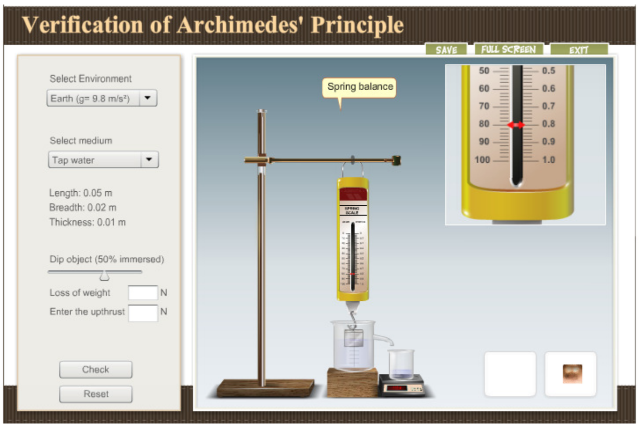

Fig. 5. Simulation of experiment 'Verification of Archimedes Principle'.

Students were randomly divided into two groups for the tablet and the desktop studies and were assessed using the same pre-test and post-test. They were asked to go through the learning materials such as the theory, procedure, video, animation tutorials and then perform the experiment after which they needed to answer a Likert scale questionnaire. The learning material was similar for the tablets and desktop though it was context and content adapted for tablets.

VI. Discussion

This study suggests that an integrated OLabs environment which included learning tutorials relevant to the simulation has the potential to increase STEM learning. When compared to traditional labs with teacher demonstration, OLabs had an advantage in conceptual skills, while traditional labs had an advantage in procedural and reporting skills.

OLabs was equally effective on both desktop computers and on android tablets though the context and content of OLabs was adapted to fit the smaller screen sized lower powered android tablets.

A. Case 1 Traditional Labs v.s. OLabs

In both groups, the performance improvement between the pre-test and post-test scores could be significantly noticed using paired t-test. After adjusting for pre-test scores, there were significant effects of the two between-subjects-factors: Instruction type, F (1, 48) = 4.51, $p < .05$, partial $\eta^2 = .086$; and Gender, F (1, 48) = 14.87, $p < .005$, partial $\eta^2 = .237$. Adjusted mean post-test scores suggest an advantage to traditional laboratory instruction (M=13.28, SE=0.34) over OLabs, (M=12.4, SE=0.33); as well as an advantage to Males (M=13.76, SE=0.31) over Females (M=11.91, SE=0.37). The interaction between instruction type and gender were insignificant.

Fig. 6. Mean Improvement in Score (posttest-pretest) based on type of Lab and on Gender.

As all the students in the OLabs group worked with the simulation, the advantage seen in OLabs group over Traditional Labs in conceptual skills may be a direct result of performing the simulation.

Interestingly, analysis based on the four assessment types suggest an advantage to Traditional Laboratory for the Procedural and Reporting skills (p<.05), with no significant difference seen in Experimental skills (p >.05), and an advantage to OLabs in the Conceptual skills (p <.05).

A possible reason for the lower performance in the procedural skills of the OLabs group may be that the traditional group had the advantage of instruction and demonstration by the subject expert. Though the OLabs group was instructed to watch the tutorial video and animation, we noticed that many of the students skipped this and went on directly to perform the online simulations.

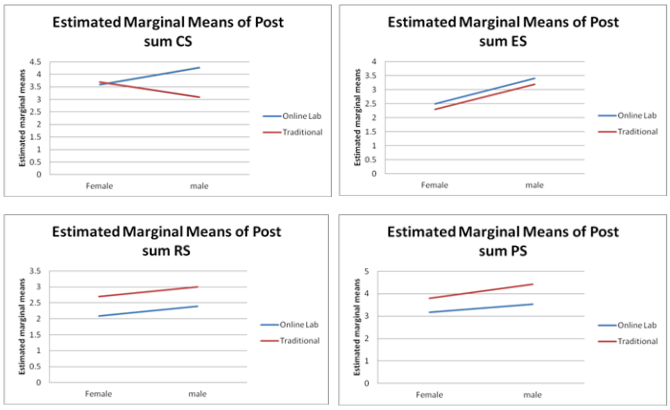

Fig. 7. Estimated Marginal Means of Post Sum Conceptual Skills (CS) Experimental Skills (ES), Reporting Skills (RS) and Procedurral Skills (PS).

As all the students in the OLabs group worked with the simulation, the advantage seen in OLabs group over Traditional Labs in better conceptual skills could be a direct result of the learning environment integrated with the simulation.

TABLE I. Summary table for each category based on Instruction Type and Gender

Skill Type	Instruction Type Traditional v.s. Online Labs	Gender
PS	T>O	M>F
CS	T<O	M=F
ES	=	M>F
RS	T>O	M=F

There also seem to be an advantage to males over females in the overall performance for PS and ES skills.

Most studies of simulations have focused on conceptual under-standing, providing promising evidence that simulations can advance this science learning goal. We have included four types of assessments required by the Central Board of Secondary Education, India and a complete learning environment that attempts to replicate teacher instruction.

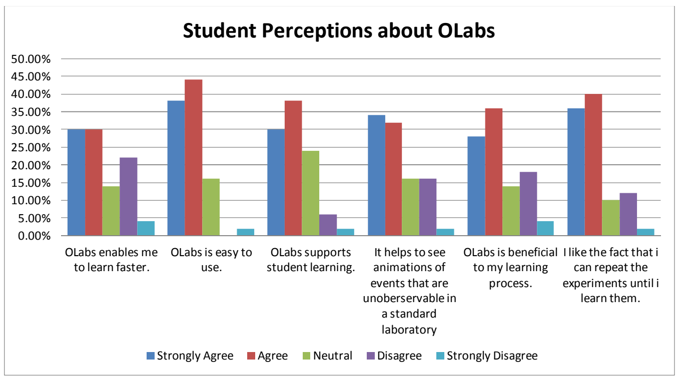

Fig. 8. Student Perceptions about OLabs.

It would be interesting to replicate this study so that students are mandated to go through the theory sections, the tutorial videos and animations before attempting the simulation.

B. Case 2 OLabs on Desktops v.s.Tablets

As the research study was held as a competition at a Science camp held at Amrita University and the students were motivated to perform well. Unlike in CASE 1, which was a mixed ability class from one school, the students selected to attend the camp were all high performers from different schools.

The students were randomly divided into two groups. Both groups were given the same instruction and performed the same experiment, the only difference being that the group with the tablets had content that was context and content adapted for the smaller screen.

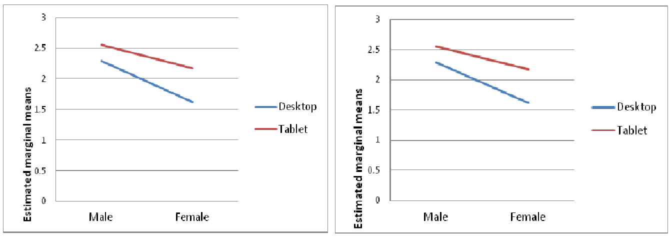

Fig. 9. Estimated Marginal Means of Post Sum Reporting Skills(RS) and Experimental Skills (ES).

A paired t-test showed that the total mean post_test (11.1167) score for both is significantly higher than mean pre_test(9.2333) score. The mean post_test (11.4) score is significantly higher than the mean pre_test(9.5) score for device tablet and the mean post_test (10.8333) score is significantly higher than the mean pre_test(8.966) score for device desktop ($p < .05$ in both cases). Hence both groups improved their performance after using OLabs.

For this OLabs experiment, there seems to be an advantage to males over females in the overall performance for ES and RS skills ($p < .05$ in both cases).

TABLE II. SUMMARY TABLE FOR EACH CATEGORY BASED ON INSTRUCTION DEVICE AND GENDER

Skill Type	Instruction Type (desktop or tablet)	Gender
PS	=	=
CS	=	=
ES	=	M>F
RS	=	M>F

However, there is no difference in test scores between Desktop and Tablet in post_test ($p > .05$) showing that in spite of context and content adaptation for the smaller screen size and the capacity of the android tablets, the learning outcomes are similar.

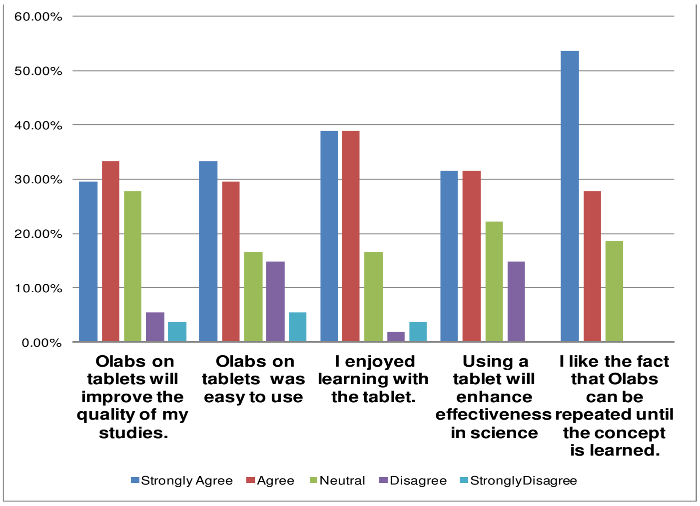

Fig. 10. Student Perceptions about OLabs on tablets.

VII. CONCLUSION AND NEXT STEPS

Science learning is a complex process and simulations built with supporting learning material have the potential to advance multiple science learning goals, including motivation to learn science, conceptual skills, procedural skills, experimental skills and reporting skills.

This study comparing pre and post test scores showed that that the integrated OLabs environment significantly increased STEM learning using both desktop and mobile devices in all skills.

When compared to traditional labs, students using OLabs had a significant performance improvement in conceptual skills than in traditional labs. While the simulation itself was developed to be similar to the traditional lab, OLabs had an integrated learning environment that includes video demonstration, animation, references and the conceptual theory behind the experiment was more useful than just performing the experiment after a tutor lead demonstration. OLabs could be repeated many times and 81.4% of the students liked the fact that they could repeat the experiments until they learnt the concept.

Overall the traditional lab students performed better in the reporting and experimental skills and a possible explanation could be that the traditional group had the advantage of a demonstration of the entire procedure of the experiment by the subject expert before performing the traditional lab. This was to done to maintain the current traditional labs in India, where the teacher demonstrated the experiment before the students attempt to work on it.

OLabs was equally effective using either desktop computers or android tablets even though OLabs was context and content adapted to fit the smaller screen size and lower processing power of the android tablets.

The assessment in the school showed an advantage over males to females in science practical skills for procedural and experimental skills whereas the assessment at the Inspire Science Camp showed an advantage to males over females for experimental and reporting skills. An interesting area of study in the future would be to understand the cause of the lower performance in girl students and perhaps find ways to modify OLabs and traditional labs to overcome the gender differences in STEM learning.

VIII. ACKNOWLEDGEMENT

This work derives direction and inspiration from the Chancellor of Amrita University, Sri Mata Amritanandamayi Devi. OLabs is developed by Amrita University and CDAC. OLabs supported by the Department of Electronics and Technology (DeitY), Government of India. The Collaborative Accessibility Platform for Practical Skills (CAPPS) project was partly supported by the HP Catalyst Leadership Award. We also thank the faculty at Amrita University for their valuable feedback.

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Outcomes of a Three-Year In-Service Secondary Teacher Training Program in Engineering Design*

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***Abstract*— We have developed and implemented a comprehensive, three-year professional development program for in-service secondary teachers to prepare them to teach engineering design and problem solving, and to use design-based teaching approaches in their science curriculum. The program used a constructionist, immersion pedagogy and a three-phase learning cycle. The program consisted of intensive summer workshops followed by monthly one-day workshops, school visits, and support activities during the academic year. This paper describes the program philosophy and activities, and presents outcome results using both qualitative and quantitative data. Pre- and post-test results indicate the workshop pedagogy and program structure were successful in meeting the goals and desired outcomes of the program.**

Keywords*— *Teacher Professional Development, Teacher Training, Engineering Design

I. INTRODUCTION

According to the National Academy of Engineering and the National Research Council (NAE–NRC) Report, *Engineering in K-12 Education*, introducing engineering concepts into K–12 education has the potential to increase student engagement, improve learning in science and mathematics, increase technological literacy, provide a better understanding of what engineers do, and increase the number of students who pursue STEM careers [1]. However, the Report also notes that there is limited data to support these claims, in part because there are still few programs to study, and in part because of the variety of program types and their emphasis on different outcomes.

School administrators considering adding engineering to the curriculum face three questions: What engineering material or concepts should be included; what is the most effective way of introducing this material into the school curriculum; and who is qualified to teach them? Our program, the Rice Engineering Design Experience (REDE), like most others, bases its content on the NAE–NRC Report principles that K–12 engineering education should emphasize "the design process, the engineering approach to identifying and solving problems," along with engineering habits of mind including systems thinking, creativity, collaboration, communication, and attention to social and ethical considerations in choosing technological solutions. Many believe these are the essence of technological literacy and essential skills for citizens in the 21st century [2]. Focusing on engineering design, problem solving, and habits of mind represents a useful pedagogical strategy in the absence of national learning standards for K–12 engineering.

The REDE program began in 2009 with a two-year grant from the Texas Teacher Quality Grant Program* for professional development of high school science teachers. This focus was motivated by the recent addition of a Texas high school graduation requirement for a fourth year of science (and mathematics). One of the handful of fourth year science courses approved was a new course on Engineering Design and Problem Solving, which had explicit learning standards. Few teachers were prepared to approach such a course. We proposed an experimental, prototype training program based on techniques we had used to introduce university undergraduates, both aspiring engineers and other majors, to the same subjects.

During the course of our program, Texas modified the fourth-year science requirement and added additional courses. It became clear that almost no Houston, Texas high schools were going to offer the Engineering Design course, and we changed our focus from preparing teachers for that specific course to giving them the skills to **infuse** team-based design projects and engineering-oriented material into existing core science classes. Our hope was that this approach could achieve the potential benefits of incorporating engineering in secondary school with the advantage of reaching every child.

During the second year of our program the granting agency awarded us a third year of funding and allowed us to enroll some middle school teachers. This program was never structured or viewed as a research program, but we did use a mixed-method evaluation to give us an indication of how well we met our general goals. This paper describes the program and results over its 2009-2012 period.

II. THE RICE ENGINEERING DESIGN EXPERIENCE

The specific objectives of the REDE program can be grouped into three general goals:

- Give teachers the content and implementation skills to develop and integrate project-based learning lessons, open-ended activities, and design challenges into science courses to enhance student motivation and learning.

* This work was supported by the Texas Higher Education Coordinating Board through the Teacher Quality Grants Program, with additional support from the Rice University George R. Brown School of Engineering.

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- Provide teachers with the experience, knowledge, and skills necessary to guide student teams through engineering design problems that integrate science and mathematics concepts aligned with state standards.
- Familiarize teachers with engineering professional practice, the content of the different engineering areas, and the nature of various engineering degrees and their requirements, so that they can advise students.

It is a rare secondary school teacher that has such a knowledge and skill set, necessitating a comprehensive professional development (PD) program. In addition to the training, the program provided teachers with instructional materials, online resources, and continuing support to implement effective teaching strategies and to develop a community of practice.

A. Tne Professional Development Challenge

Designing a PD program to meet the goals above is a challenge. Most teacher PD programs focus on improving or updating knowledge and skills in an area that teachers have already studied. Unlike for core subjects, there are no teacher credentialing standards for engineering, virtually no pre-service training programs [3], and in-service PD is rare and variable in content [4]. It is not surprising that there is a wide variation in what takes place in classrooms in the name of engineering education. For our program we could not assume any prior knowledge of engineering on the part of participants.

We believe that only a deep understanding of engineering design and problem solving by teachers can lead to transformational change in the classroom and the benefits claimed for incorporating engineering in secondary school. Open-ended design problems have multiple "correct" solutions that represent different choices of how to meet the design goals within the problem constraints; guiding students through them and assessing the results from student teams requires a new set of skills for science teachers. The only way to understand and learn to apply the design process is to do it. Like learning to swim, one can read books, listen to lectures, and watch demonstrations, but eventually, one has to jump into the pool and actively struggle to master the skill. And as Kolb notes, "It is difficult, if not impossible, to teach in ways that one has not learned" [5].

The REDE program began in 2009 as a two-year program with a single cohort of participants taking part in extended summer workshops and academic year meetings, with over 100 contact hours per year. Ten high school teachers enrolled in 2009; two more, plus one middle school teacher joined the next year in 2010. Later the program was extended for a third year; Five teachers joined in 2011, all but one middle school teachers. Thus, the program enrolled a total of 18 teachers, although during the course of the program a few participants became inactive because they left teaching or changed subjects. In addition to an immersion in engineering design, the program incorporated characteristics that have proven to promote teacher learning [6]: a focus on engineering content and a pedagogy that builds on the teachers' existing subject skills; a well-defined image of effective classroom learning and teaching; in-depth, active learning experiences; opportunities for reflection and collaboration that engage teachers as adult learners, and an extended duration of formal training followed by ongoing support and continuing education.

B. Program Activities

Each year of the REDE program consisted of an extensive summer workshop, 5–10 full-time days, plus academic year meetings for about one full day per month. The initial 2009 summer workshop provided a ten-day immersion in the design process for the beginning participants. Teams of teachers were asked to design, build, and demonstrate a prosthetic hand using rapid-prototyping materials (LEGOS NXT systems). The workshop led the teams through the ten steps of the design process using an innovative three-phase learning cycle, illustrated in Fig. 1.

First, Building the Knowledge Base, (BKB) developed *content knowledge* through reading, lectures, and activities. For example, for design Step 5: Develop Multiple Concepts and Solutions, the BKB material covered brainstorming, conceptual blocks to innovative solutions, and how to break those blocks. During the second phase, the Challenge, the teacher-teams implemented that content knowledge to devise multiple solutions for their design problem. During their active experimental work they were supported and mentored by course staff and instructors to build confidence, keep forward momentum, and insure success. In this stage teachers developed their experiential, *intrinsic knowledge* of design.

The third phase was Advancing Classroom Technique (ACT). Teachers came together to reflect on and share their experiences in working on the project. Guided by master teachers and the instructors, they discussed how to implement this step of the design process in their classroom, how to integrate design into the STEM subjects they teach, how to guide students through it, and how to deal with anticipated problems. This stage provided *pedagogy skills* and knowledge. The class then moved on to the next step in the design process, repeating the BKB, Challenge, and ACT cycle.

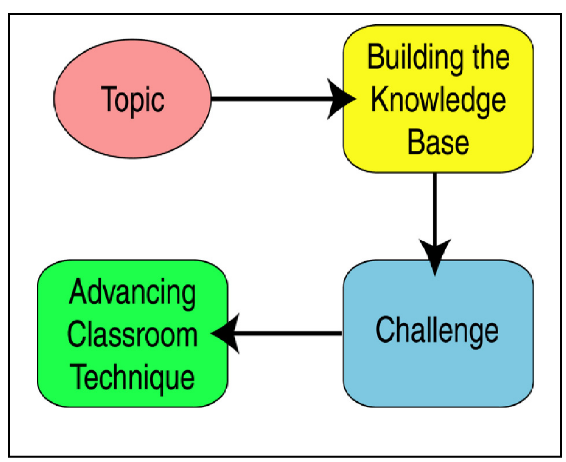

Fig. 1. The three-phase learning cycle used in the workshop.

All through the steps, the teams wrote reports documenting their progress. Such reports were an essential component of the design process, but they also served as formative assessment tools for the instructors to modify the pace or content of the workshop as necessary. At the end of the workshop, the teams presented and demonstrated their solutions to the Challenge, and together the teachers had a final ACT phase to discuss the entire design process, and its curricular implications.

The 2010 summer workshop challenged the participants to test and develop several Design Teaching Kits (DTK). A DTK is a set of hands-on activities, plus a design contest, to supplement the teaching of a specific set of science topics. It does not replace curriculum but enhances it. It also provides information for students on the engineering design process, the difference between science and engineering, and engineering disciplines and practice. The REDE DTKs were based on activities developed at the University of Virginia as senior engineering design projects [7-9]. For example, the *Save the Penguins* DTK supplements lessons on the nature of heat, radiation, convection, and conduction, and insulating materials. Teams of students make observations about heat flow, measure the insulating properties of different materials, and then design an enclosure, an "igloo," to minimize the melting of a penguin-shaped ice cube in a heated environment. Teachers in the workshop tested and modified the activities, aligned them with state science standards, and wrote scaffolding information for teachers. These kits were subsequently supplied to the teachers. Another kit focused on solar energy, solar cells, electric measurements, and motors, torque and gears.

The final 2011 summer workshop included a review of the design process with a short team design project, as several new participants had joined the program. A particular focus of the workshop was how to tailor projects to the ethnic, gender, and cultural diversity of the student body, and to incorporating English language proficiency activities into design projects. A key point is that technical communication and the vocabulary of engineering and design is a "foreign language" to virtually all students, not just English language learners, and activities and techniques were shared that help all students develop good oral and written communication skills.

All during the program, the monthly academic year meetings provided review of the summer workshop material, and support for the teachers using design projects in class. These meetings also covered the majority of material on engineering professional practice, the content of the different engineering areas, and the nature of various engineering degrees and their requirements. Most meetings included a talk and laboratory tour by an engineering faculty member, to help put an engineering discipline in concrete terms. All the material from the workshops and meetings is archived in an online collaboration site available to the participants and other interested teachers. The site also provides tools for communication between participants, forums, blogs, and a wiki. This resource will remain in place after the end of the project to facilitate ongoing work and community building.

III. Results

The effectiveness of our program was assessed using both quantitative and qualitative measures. Pre- and post-tests were written and graded by the project directors. These were used as formative assessment during the program to guide meeting activities, and as a final summative assessment of the program. Independent external evaluators surveyed participants after workshops and meetings, held focus groups, and visited classrooms to observe classroom activity, and to interview students.

A. *Pre- and Post-Tests*

The pre-and post-tests consisted of a combination of 16–17 open-ended questions and multiple choice items. Pre-and post-test items differed by changes in the ordering of the items, wording changes, and different questions. We identified eight specific outcomes or objectives of interest for our program, as shown in Table I. Each objective was associated with one or more questions on the pre- and post-tests. Over the three year program, participants took both tests a variable number of times, depending on when they were active in the program. For our summative evaluation we compared the first pre-test score of a participant with their last post-test score, and computed a participant average (arithmetic mean) for each objective, and for the entire test. The pre-test data represents results from all 18 enrolled participants; the post-test data represents results from 17 participants.

As shown in Table I and Fig. 2, post-test scores were higher for all objectives, and increased over pre-test scores an average of 23 percentage points.

TABLE I. PROGRAM OBJECTIVES AND TEST SCORE RESULTS

	Objective Description	**Pre-Test**	**Post-Test**
A	Develop, integrate, & implement design-based, open-ended activities for science classes.	44%	70%
B	Explain the engineering design process, & compare it to the scientific inquiry process.	61%	77%
C	Organize, develop, & guide student design teams.	70%	85%
D	Apply appropriate formative & summative assessment to team project outcomes.	48%	85%
E	Be able to describe engineering practice & discipline areas.	50%	93%
F	Be able to advise students about educational paths into STEM careers.	64%	71%
G	Explain engineering ethics, responsibility to the public, & consideration of social values in design choices.	58%	81%
H	Develop student communication skills through documenting team design projects.	38%	52%
	Average for all objectives:	54%	77%

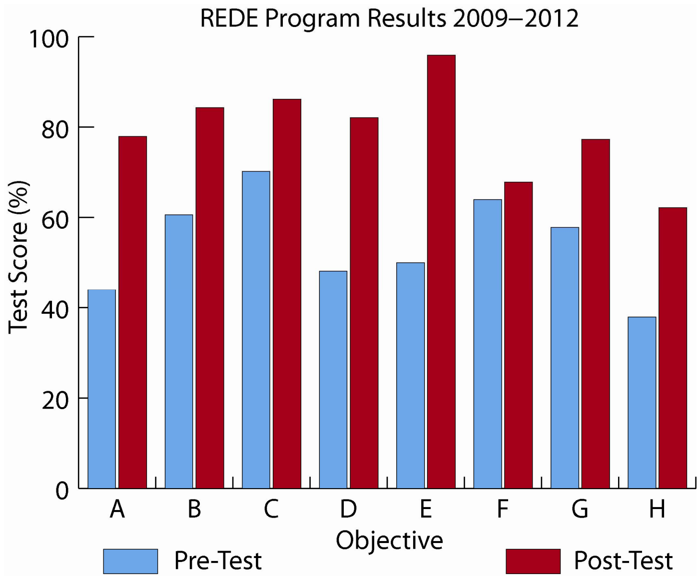

Fig. 2. Pre- and Post-Test Scores by Program Objective. The pre-test data represents results from all 18 enrolled participants; the post-test data represents results from 17 participants.

B. Observations

Over the course of the grant participants were observed and interviewed by external evaluators to determine their expertise and comfort in teaching the design model to their students. To triangulate the visit, a student survey was developed and administered to students in the observed class. The observations, based on program goals, evaluated participants' use of the design process with their classes, the formation of effective teams to solve the problems and the integration of design-based exercises into science classes where applicable.

Secondarily the observations were designed to record the dissemination of information on careers in the STEM fields and the preparation required for pursuing a career in the field. The observation/interview/student survey also encouraged the participants to address issues such as intellectual property and ways to protect it. An Observation Protocol initially developed for observing science and math teachers was modified and used as the guiding instrument. One-time direct observations were conducted to document changes in teacher practice. All the participants seemed committed to using the design model in their classrooms. Their responses on questions relating to the use of the model (100% response) indicated they were using it with their students. Over the three years the observers witnessed students engaged, working in groups and using the design process. What changed was the level of teacher comfort with the process and therefore implementation of effective challenges within expected frames of time.

Participants were rated on a 5-point system: 1 Not Evident, 2 Not Observed, 3 Needs Improvement, 4 Satisfactory, and 5 Excellent, on teacher and student behaviors. Four teachers were observed in both 2010 and 2011. Their total scores declined from 169 in 2010 to 151 in 2011; however, three teachers were observed in both 2011 and 2012. Their total scores increased from 114 to 190.

Respondents were asked what was most beneficial about the training. Some responses related directly to the structure of the workshop and the learning cycle used, such as, "Getting the student perspective on working as a member of a team on a design project…," "The connections to the real world. The structure was modeled in the way we should do it in class," and "The most beneficial part was designing the prosthetic hand."

Students had a positive attitude toward doing design-based projects based on survey results, with 98.7% saying they liked doing the design contests. "It was really fun coming up with different ideas …that would help mankind." "I found …hands on projects is the way I learn best." "Usually students do not get the chance to build creations at this level." "We learn new skills from these projects." The percentage of students indicating they received information about engineering careers increased from 58.1% in 2010 to 80.0% in 2012. The source of this information primarily came from teachers (40.2% in 2010 to 68% in 2012). Most students, 87%, also said they planned on taking STEM classes in college, and 75% said they were planning a STEM major in college and a STEM career, with 24% mentioning engineering as a possible career choice.

C. Student Achievement

A matched comparison groups design was used to evaluate whether there were differences in student achievement for teachers that participated in REDE training compared to student achievement for a similar group of students attending schools that were demographically comparable to the REDE schools. A criterion-referenced state assessment was used as the outcome measure for both mathematics and science. Students were matched on race/ethnicity, gender, gifted and talented, and socioeconomic status. If all variables did not match, decisions were made to find the best match based on the strength of the relationship between the variable and the Texas Assessment of Knowledge and Skills (TAKS) scale score.

Three years of student-level TAKS data were available for 7 of the participating schools.

Over the three year period, students of teachers that participated in REDE outperformed the comparison group for both percent passing and commended performance on the mathematics and science TAKS. Science passing rates for REDE students increased from 74.5% in 2010 to 84.3% in 2012, although there was a slight decline of 1.5 percentage points from 2011. Science passing rates for the comparison group were 70.4% in 2010 to 73.0% in 2012, with a slight decline of 1.4 percentage points from 2011. Commended rates for REDE students increased from 8.5% in 2010 to 19.7% in 2012. For the comparison group, commended rates increased from 6.5% in 2010 to 14.6% in 2011, but declined by 2.5 percentage points for 2012.

An independent-samples t-test was conducted to compare student achievement scores in science and mathematics for students in the treatment (REDE) group and students in the comparison group for 2010, 2011, and 2012. For 2010, there was a significant difference in the science mean scale score for the REDE students in grade 10 compared to the students in the comparison group; however, for grade 11, there was no significant difference in science scores. For 2011 and 2012, the mean mathematics and science scale scores of REDE students exceeded the comparison group for all grade levels. These differences were statistically significant.

IV. Conclusions

This was a pilot program with a modest number of self-selected participants from the Houston, Texas area. While the three-year duration of the program had many advantages, it also meant that some teachers left and entered the program at various points. We also ended up with a mixture of high and middle school teachers, some from science faculty and some from technical and career training faculty. The results and conclusions should be viewed in light of this small and diverse data set.

The workshop pedagogy and program structure were successful in meeting the goals of the program in regard to giving teachers the experience, knowledge, and pedagogical skills to integrate engineering design and habits of mind into their science classrooms. The survey data indicates that their students obtained a better understanding of what engineers do, engineering disciplines, careers, and STEM educational paths. It is much harder to assess whether this program led to increased student learning in science and mathematics, or an increase in technological literacy. The results of standard tests in science and mathematics are influenced by many factors, and technical literacy and problem solving are rarely a part of such exams. Still, the limited data we have are encouraging. It would take a detailed longitudinal study to determine if the students of our teacher participants actually pursued STEM careers at rates that exceeded their peers.

Other approaches have been used to introduce engineering into secondary schools. A series of studies shows that replacing conventional science curriculum with design-based teaching of science concepts resulted in superior student knowledge gain, engagement, and retention compared to scripted-inquiry teaching [10-12]. The engineering design pedagogy was most helpful to low-achieving, traditionally underserved students. Stand-alone engineering courses are another approach. Project Lead the Way, for example, claims significant gains with its sequence of engineering courses for middle and high school [13]. However, these courses require an expensive contract, are rigidly structured, and are usually offered as electives. The infusion approach we used avoids difficult curriculum restructuring and reaches every child by using some science laboratory time for open-ended, design-based activities. This requires considerable teacher training, as do all the other approaches. This program was a learning experience for the authors as well as the participants, and based on our experience, we believe equivalent results could be achieved with a one-year intensive professional development program, or with a one-semester course for pre-service teachers. We are currently applying what we have learned to a program for teams of middle school teachers from four schools in Spring, Texas.

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Young People's Perceptions of Computing Careers

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***Abstract*— Recruitment into computing-related undergraduate degree courses is challenging in several countries. This is despite employers reporting skills shortages, and the sector generally offering better salaries than for graduates of more popular courses. This paper describes a study (n=111) of the interest of 16 and 17 year olds in taking Computing-related degrees, particularly those that lead to user experience (UX) careers, where there is both a local and global skills shortage. The picture that emerges is of surprisingly pronounced and entrenched attitudes, which are worthy of a more detailed study. Only one of eight typical computing job roles (Tester) was familiar while the term UX was almost unknown. The females in this study expressed antipathy even towards finding out about computing careers. An unexpected additional finding is the commonplace, and apparently inappropriate, use of Myers-Briggs-style questionnaires in offering careers advice on computing to local school children. This paper will be of interest to those who seek to progress professionalism in the field of computing and to recruit (particularly female) school leavers into computing degrees.**

Keywords— Computing and Gender, Computing Careers

I. Introduction

Recruitment into computing-related undergraduate degree courses is challenging in several countries. This is despite employers reporting skills shortages, and the sector generally offering better salaries than for graduates of more popular courses. This paper describes a study of the interest of teenagers in taking computing-related degrees, particularly those that lead to user experience (UX) careers, where there is both a local and global skills shortage. The project grew out of a group discussion at a national event involving 16-year olds, colleges and universities, employers and public policy bodies. The other stakeholders realized that they could not respond adequately to a teenager's request that, unlike the situation for medicine, law or plumbing, the computing profession could not describe a student's progression over the next ten years before demanding their commitment.

After a review of the situation in other countries, we focus on a single local high school, one with a high university participation rate, and investigate the views of 16 and 17-year olds (n=111) through an intermediary. Ethical constraints limit both the access to the subjects, and the generalizability of the data, yet the picture that emerges is of surprisingly pronounced and entrenched attitudes, which are worthy of a more detailed study.

A. Evolving Professions in Computing

The recent rapid growth in career opportunities in User Experience (UX) offers new opportunities for human-centred careers in computing. Such roles help to counter the geeky/nerdy image of workers in computing, while the high salaries and rapid career advancement add to the lustre. Universities have added degrees in UX to those in Human Computer Interaction (HCI) or Interaction Design. Thus one might expect strong demand from school leavers, especially since they have lived their entire lives with access to the Web. Yet these "Millennials" appear to lack desire to study and work in the field of computing.

There is an alarming downwards trend in the number of young people, particularly females, choosing to study computing (this definition is broad and includes IT, IS, Networks, HCI, Digital Media, Interaction Design) as a subject at secondary school or as a career path. This is despite technological advancements, faster and cheaper access to the Internet, the popularity of social networking sites, the increasing numbers of online transactions and the widespread use of devices such as smart phones, laptops, iPhones or the eReaders. Several UK organisations, such as NAACE, BCS, The Chartered Institute for IT, and the Royal Society have expressed their concerns over this issue. The latter's call for evidence attracted 120 responses, highlighting the complex nature of the issue.

This has implications for HCI, as the stereotypical view of computing people as "lacking in empathy" both becomes a self-fulfilling prophecy and marginalises those who do care about the user. HCI job roles, on the other hand, have become better defined in recent years, with a range of roles defined in competency frameworks such as the UK's Skills Framework for the Information Age (SFIA) [1], following many years of engagement by the community with those who define professionalism and job roles in computing.

II. The Evidence Of Decline

The literature reviewed for this study demonstrates that the issue of engaging young people, especially of female students in computing classes or undergraduate programmes and careers is a global consideration. A study [2] of school leavers in

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Germany found only 7.6% chose to major in Computer Science (CS) despite a dropout rate of 38%. A report by the Victorian Government in Australia [3] finds a worrying low regard for computing amongst school leavers, though other research [4] suggests there is no such issue for India. The OECD data for Europe [5] in Table 1 indicates a steady downward trend although some smaller or lower-salary countries stabilise or even slightly increase.

Table 1: OECD data for Undergraduate Computing students 2005-7 [5]

Country	2005	2006	2007
Denmark	1259	1143	1212
Finland	1843	1785	1819
Iceland	94	91	71
Norway	1770	1666	1537
Poland	19133	19931	20119
Sweden	1742	1787	1463
UK	29191	27617	24875
Estonia	364	350	431
Slovenia	128	144	164
total	***57529***	***56520***	***53698***

In the UK, The Royal Society [6] highlights the decrease in the numbers of students across the UK "with a fall of 33% in just three years in Computing GCSE students, a fall of 33% in six years in A level Computing and 57% in eight years in A Level Computing students in England" and find a similar trend in Wales, Northern Ireland and Scotland. Scotland has a different educational system to the rest of the UK, and needs [7] 10,400 new computing employees a year. Current participation in computing qualifications falls well short of this. The Scottish Qualifications Authority (SQA) 2006-2009 data shows a 3% decline in university entrance exam (Higher/Advanced Higher (AH)) passes in computing-related subjects, and 17% in the more junior Standard Grade Level.

Authoritative voices in the UK [6] suggests this decline is due to "poor quality of computing curriculum limiting the students' understanding and enjoyment" and that the Computing education in schools does not inform young people about the relevance of a career in IT. BCS cites a TV sitcom [9] as contributing to the poor media image of computing scientists and ICT specialists, presenting ICT jobs as "low status, routine, badly paid, held by anti-social geeks and likely to be offshore or evil hackers" [10]. Additionally only a small number of teachers in England have a degree in the subject [11]. Google CEO Eric Schmidt gained widespread press coverage by criticising the British computing curriculum and teaching approaches [12]. More recently BCS and others have worked together to respond [13] to these challenges and in England the new Computer Science curriculum, and, based on recent UK government announcements [14], have influenced policy.

The situation in Scotland is seen [8] as a little better to the rest of the UK: primary school students learn Scratch programming and in secondary schools, computing is integrated into almost every subject on the curriculum. Nevertheless, Scotland shares the very low female representation in computing courses. In 2011, only 26% of those achieving A-C results (ie "good" passes) in Highers were females, and this worsens to 17% (80 female, 381 male) for the AH (the equivalent of first year at a Scottish University). Students take a practice "Prelim" exam before sitting these examinations, and, in 2011, only 20% of those taking the AH Computing Prelim were female.

A. Comparisons with other countries

Over the last ten years similar situations appear to have emerged in other countries and been addressed at different speeds and in different ways. Californian computing education was considered [15] a "land of missed opportunities" where connections are not made between computing and learners' interests. Just as in the UK, high school students were seen as learning how to *use*, rather than *create*, software; teachers lacked computing qualification; counsellors advise college-bound students away from computer science. High school students' perceptions of computing professionals are people who sit "in front of computers and programming all day" [16]. Students at Carnegie Mellon University analysed academic papers, popular media and interviews to establish that "the images of computing were for the most part either absent or negative" [17]. Most were aware that the public had a narrow perception of CS and identified a gender gap in the enrolment data of their own department, which they attributed to cultural issues.

In their attempt to understand stereotypes in CS, German and American university students were asked to write computer autobiographies [18], (a method also used [19] for the purposes of understanding the reasons why undergraduate students are dropping out of CS courses). They identified negative stereotypes even in the biographies of CS students. While non-CS students used stereotypes to "differentiate themselves from nerdy computer experts, even some CS students distanced themselves from CS with comments such as "normal Computer Scientists", because of "the implicit low status of the prevalent stereotype about computer scientists" [18].

However, computing is not negatively portrayed in all countries. An analysis of South Indian cinema draws attention to the reversal of this image in India, in contrast to the western culture. Though there is still a distorted understanding of computing, a positive image of programmers and computers in Indian films transcends cultural, class and gender barriers. For example: fathers in rural parts of India, who once would refuse their daughters' requests to move away from home to pursue a career, now think "if they work for computers, it is good" [4]. This positive portrayal of computers and their users in Indian media is claimed to make India a "leader in the Information and Communications Technology for Development (ICTD) movement…" and why India has no problems in convincing its youth in pursuing computing careers.

Different terms may be significant here – CS has a more technical focus in some cultures than using the terms computing, IT or ICT.

B. Awareness of computing careers

"Loss of interest in the field and its potential careers" is cited as the most important reason why students leave computing courses [19]. Typical statements highlight the narrow understanding of the field, viewing careers as purely programming. Another study [20] summarises the findings of Eccles et al. (1999): "values attached to relevant job characteristics were significant predictors of teenage career aspirations". An analysis [21] of career expectations formed at age 16, concludes that, while a teacher's description of an occupation is influential, school resources devoted to careers advice "have limited influence on children's career expectations". That some of this data comes from the 1970s suggests a longstanding tradition of teachers being influential in their students' career choices.

In attempting to stem the decline, most initiatives target underrepresented groups – females, ethnic minorities and the underprivileged. The results show a common style that seems to work, but most of these studies require longitudinal methods to gauge effectiveness in changing perceptions and ultimately convincing these groups to take up a career in computing.

C. Summary

The declining interest in computing subjects appears to be global and confirmed by studies from the USA [22], Australia [3] and Germany [2]. This causes great concern to industries, governments and educational institutions. An exacerbating factor (for the computing community) is that female participation in higher education is now notably higher than male in many industrialised countries. The consistent factors that emerge are the:

- Computing curriculum lacks relevance and context that is interesting to young people
- Quality of learning and teaching experience
- Impact of negative first experiences with computers
- Personal attributes
- Lack of qualified teachers
- Lack of career guidance and career options in computing
- Negative images of computing

The literature shows that a partnership of governments, educational institutions and industry are working hard to design more engaging, relevant and pedagogically-effective computing curricula. These partnerships are also providing better infrastructures and national learning resources and mediums such as intranets for learning tools and best practice to be shared. If successful, these should gradually increase interest and participation in computing as a subject or as a career, however there seems very little to be done in order to achieve a more direct shift in the attitudes of young people. Retention studies at universities [19], [20] show that these negative views even influence those students who have chosen to do a degree in the field. There is a large amount of literature relating to intervention programmes that have been implemented to change the declining interest in computing. Much of this literature, eg [23], [24] shows that for any intervention programme to be successful, raising awareness of computing and related careers is crucial.

III. Research Objectives

The scope of this investigation is in the context of identifying the requirements for a website for High School students and is limited to discovering young people's awareness and perception of computing careers, and the way in which these might have an impact on their career choices. The objective of this research is to answer the following questions:

- Which factors shape young people's career choices?
- How much do young people know about computing jobs and to what extent does this impact on their career decisions?
- Are there negative perceptions of computing careers and computing professionals that might affect young people's career decisions?
- Are there gender differences in young people's interest in, awareness of and pursuing of the computing career path?
- Are there negative perceptions of computing careers and computing professionals that might affect young people's career decisions?

There are complex ethical issues to consider in a study involving people aged under 18, and the timescale for this was such that a prolonged ethics approval process was not feasible. Thus we sought an ethically-valid compromise. The involvement of these young people is certainly justified to ensure that they can contribute, as stakeholders, towards the design of a system, such as a website, intended for their use. Beyond the scope of this paper is a review of how to carry out academic research with children and young adults – a highly specialised area which requires considerable training. After discussion with the faculty's ethics advisor, it was agreed that

- no one aged under 16 would be involved in the study,
- the researcher would have no direct contact with the 16 and 17 year olds being surveyed, but rather would ask their teacher or career advisor to administer the questionnaire survey in the context of their general teaching and support roles.

Thus students could input as stakeholders as part of a website design process, but there are limitations on the validity of applying inferential analysis to the resulting data. This was not the only ethical constraint in the overall project - for the design of the website we would have preferred qualitative input from our stakeholders, but accepted evaluation by a domain expert instead.

A. Questionnaire

A structured questionnaire was designed based on an existing attitudinal survey [3] of young people's awareness of computing careers. The questionnaire consisted of four pages with 12 questions that aimed to gather data on the following six sub-titles: demographics, familiarity with computing job titles, knowledge of and interest in computing careers, factors affecting career choices, source of career choices and young people's perception of computing jobs. All the items, except for age, were closed items (four point Likert scale plus "Don't Know") for ease of analysis and to enable generalisations. The questionnaire was piloted on 7 people between the ages of 19 to 55 before the edited version was administered to the target group.

Table 2- Demographic Information

	Frequency	Percent
Female	43	38.7
Male	68	61.3
Age 16	53	47.7
Age 17	58	52.3
Studying computing	31	27.9
Not studying computing	80	72.1

One of the considerations for this study was to find samples to represent young people at the career decision stage of their lives. The survey was administered by a qualified teacher, a Head of Year with responsibilities for career advice under exam conditions during the timetabled "study skills" classes. The teacher agreed to give the following verbal explanation to the students:

- This survey will take no longer than ten minutes.
- You do not have to complete the questionnaire if you do not want to.
- If you feel uncomfortable with any of the questions, you do not need to finish it.
- The results will be used to help identify how best to advise school leavers about career opportunities.

Additionally a short explanation was printed on the survey sheet. Only age and gender was captured as personal data. 126 students from the final two years (S5 and S6) of a secondary school in Edinburgh took part in the study at the beginning of school year 2011/12, and 111 completed responses were received. Unexpectedly, another 11 were returned from those listing their age as 15 (at that time of year, some children had not reached their 16th birthday) and, after taking ethical advice, these were excluded from further study and destroyed. At the time of the study, the total number of S5/S6 students in the school was 341 (178 male, 163 female). The selection of participants was arbitrary based on the classes of the teacher who agreed to administer the questionnaire, 43 females and 68 males completed the survey, thus females were underrepresented in the sample. Due to the number of 15 year olds, we cannot be precise, but approximately 40% of eligible boys and 30% of eligible girls participated.

For the purposes of this study cluster sampling [25] was used, as a secondary school already consists of a natural selection of the age group required for the survey; however it should be noted that the secondary school where the survey was administered is in an affluent part of Edinburgh and does not represent the entire population of young people in Scotland or in the United Kingdom (UK). The school also has an unusually high proportion of students who progress to university.

IV. RESULTS

A. *Students who have already chosen a career*

The majority (72 or 64.9%) of these students have already decided on their future jobs. 22 (30.6% of the above subset) first heard about this job from family, 19 from media and 17 from someone who does the job. Unexpectedly, Teachers (6) and career advisers (4) were cited by few. In terms of a computing career, 31 said they will "definitely not" and 27 said they are "not likely to" pursue a computing career. Only 7 students said they will "definitely pursue" a computing career and the same number said they "might". These seemingly low figures are consistent with overall percentages of the population in professional computing careers, but one might expect a higher proportion from those likely most to progress to higher education.

B. *All students*

49.5% of the full sample stated that they know "very little" (41) or "nothing" (14) about ICT careers, and, when asked if they would like to learn more about ICT careers, 40.5% (45) were "not sure" and 27% (30) said "definitely not".

We used modes to analyse the response to questions about perceptions of computing jobs (1=Strongly agree (SA); 2=Agree (A); 3=Don't know (DK); 4=Disagree (D); 5=Strongly disagree (SD))

Table 3: Modal responses to perceptions of computing jobs

	Mode
12a. Computing careers lack human interaction.	2
12b. There are not enough jobs in the computing industry.	3
12c. People who work in the computing industry are mostly socially awkward.	4
12d. A career in computing would be very boring.	2
12e. Computing is a male dominated field.	2
12f. A computing career involves sitting in front of a computer all day.	2

C. *Applying statistical tests*

Despite the stated limits to the validity of inferential analysis, some standard statistical tests were run on the data to see if it suggests any particularly strong relationships, ie those for which $p<0.001$, or a 0.1% chance of error, compared to the more typical 1% or 5% tests.

A Mann-Whitney U test comparing those who would "definitely pursue" (7) with "definitely not pursue" (47) suggest a strongly significant difference between those participants for the following perceptions of computing jobs:

- "Involves human interaction" ($U=36$, $z=-3.3$, $p< 0.001$).
- "Computing is fun" ($U=27$, $z=-3.9$, $p<0.001$).
- "Computing is prestigious" ($U=27.5$, $z=-3.8$, $p<0.001$).

A Pearson's correlation was used to analyse the relation between *knowledge of computing* and enthusiasm for *pursuing a computing career* finding significance level less than 0.001 and $r=0.652$ (Table 4).

Table 4 Knowledge of Computing * Pursue Computing

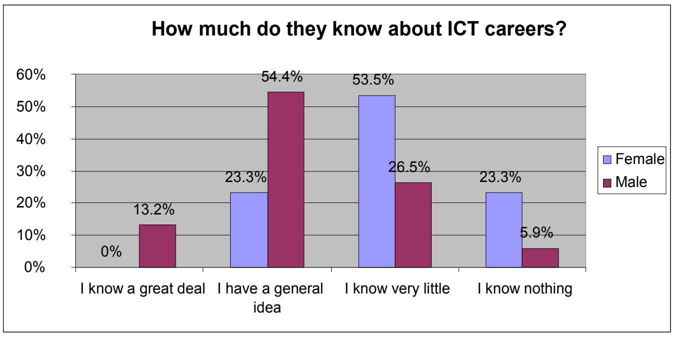
		Pursue Computing Career	Knowledge of Computing Careers
Pursue Computing career	*Pearson Correlation*	1	.652**
	Sig. (2-tailed)		.000
	N	111	111
Knowledge of Computing Careers	*Pearson Correlation*	.652**	1
	Sig. (2-tailed)	.000	
	N	111	111

**. Correlation is significant at the 0.01 level (2-tailed).

Similar Pearson's analyses suggest that young people's *positive perception of computing careers* is correlated with *intent to pursue a computing career* ($p<0.001$, $r = 0.630$) and *knowledge of computing* ($p<0.001$, $r = 0.383$).

D. Gender

The differences between male and female respondents is quite pronounced – compared to the males in this study, the females are much less likely to be studying computing, even less likely to study it in future. They say they know little about computing careers and have no interest in finding out.



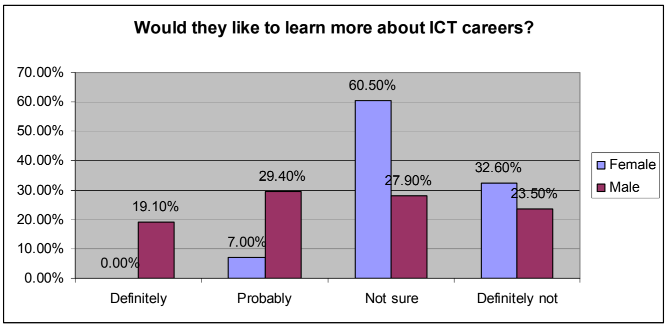


Figure 1 Awareness of, and interest in, ICT careers (MvF)

This may be due to the sample – only 11% (F) v 38.2% (M) were studying an ICT-related subject, 95.4% (F) v 67.6% (M) were *unlikely to*, or *would definitely not*, pursue an ICT career. However these gender differences reflect typical gender splits in university computing departments and in ICT-related graduate recruitment in the UK.

E. Awareness of Typical Roles

We listed eight typical computing roles (drawn from local job adverts to represent a cross section of computing specialisms) and asked familiarity with these. The range of responses was unexpected. The majority said they know exactly what a *Tester* does while a majority claimed they know a "little bit" about what a *Games Developer*, *Software Engineer* and *Programmer* do. For *Systems Analyst*, *Database Developer* and *Security Engineer*, most knew *little* or *nothing*, *while User Experience Developer* is the only computing job in the list which the majority of all the students had "*never heard of it"*. This is particularly surprising, given high salaries and local skills shortage in this field, and that these jobs provide the high levels of human interaction desired by participants. On reflection, alternative terms such as UX Design, Interaction Designer, or Usability Professional, though less prevalent at the time, might have elicited a different response. An analysis (March 2013) in Google Trends of these terms suggests that a more prevalent term now would be UX Design Jobs, or UX Designer Jobs. In the UX industry, globally, there is both a lack of formal definition of UX Designer v UX Developer, but also a degree of consensus about what each does. Local recruiters tend to use the terms more interchangeably.

The gender divide on this question – only a single female knew what was involved in this job, and a proportionately more females than males had "never heard of it" – is particularly interesting, as the local UX industry has a roughly even gender split. A similar set of results was found for the term Systems Analyst.

Table 5. Awareness of User Experience Developer role

No Answer	2	1.8%
Never Heard Of It	65	58.6%
Heard Of It, But Don't Know What It Involves	26	23.4%
I Know A Little Bit Of What This Person Does	12	10.8%
I Know Exactly What Is Involved	6	5.4%
Total	111	100%

V. Discussion

The results indicate that the majority of these young people have already decided on their future jobs by the ages of 16/17. Family, media and "people who are already doing the job" seem to have most impact on students' career decisions. This contradicts a study [21] of past cohort data which suggested the teacher was the greatest influence on their students' career decisions. This could indicate that any intervention programme to reverse the current trends in computing should involve families and media, while any product to challenge misperceptions should present people from the computing industry as role-models.

Our study is consistent with previous research (for example, [19] [22] [26]) which highlights the lack of popularity of computing subjects and careers among young people in the western world. While not every young person is suited to computing, from this sample a surprisingly high proportion "definitely do not want" a computing career. Lack of knowledge, or negative images, of computing people and careers is correlated with this lack of interest. Conversely, the more these young people know about computing and computing careers, the more they are likely to have positive perception of the field. While we might expect interest in, and knowledge of, to be related, the majority (typically estimated at 60-65%) who work in the UK computing industry do not have a computing qualification and tend to join the profession after converting from an earlier degree. An early intervention programme to inform young people of computing careers and the opportunities available in the field appears likely to increase interest and lead to an earlier choice of a computing career.

Answers to other questions in our survey suggested that career decision factors of location, commuting, ease of promotion, or salary appeared not to differ between those who do, and do not, want to pursue computing careers, while studying computing at school does unsurprisingly correlate ($p<0.001$) with *positive perception*, *knowledge of computing*, *interest in learning more about computing*, and *intent to pursue computing career*. This suggests that the computing profession needs to influence subject choice that students and parents make from age 13 onwards.

This study is consistent with literature on gender difference: the proportion of girls who study computing and who want to pursue computing as a career, is significantly lower than that of boys. A far lower proportion of girls, than boys, in our survey state they know anything about computing careers, that they would like to learn more about computing careers, or hold positive perceptions of the field. Again, earlier intervention is needed to attract more girls to the computing field.

VI. Future Work

Our data gathering was to establish requirements for a website, which was developed and prototyped with teachers to a positive response. Subsequent initiatives (such as http://www.bigambitionscotland.com/) have already addressed issues that we planned to address, but a further, much more detailed study appears to be justified into teenage attitudes to the range of computing careers. Such a study should ensure equal participation by males and females, cover a socio-economic range of schools, and go through the ethical processes to allow a wider range of younger children to participate. This could be triangulated with investigations into the views of parents, employers, teachers and careers advisors.

One aspect, that space does not permit us to cover here, is the apparently widespread use of Myers-Briggs (MBTI) [27] (or MBTI-style) tests in existing websites to advise students on careers, particularly in those websites promoting computing careers. Discussions with specialists in human resources suggests this is, at the least, an abuse of the MBTI licensing requirements, while an international recruitment consultant has provided us with rich reasons why he considers such tests are ineffectual for most, if not all, aspects of recruitment into graduate computing roles. It may even be that the mechanistic nature of these tests only serves to confirm antipathy towards computing. For example one study [28] suggests "ESTJs, ESTPs, ENTJs and ENTPs make good systems analysts" and "ISTPs, INTPs, INTJs make good programmers" It's not hard to imagine that a 16 year old might intuitively reject such a reductionist view.

In subsequent work, we would like to document the development and expert evaluation of the web-site, and place this in the context of other recent "Computing in Schools" initiatives in the UK.

VII. Conclusion

Despite the acknowledged limitations of this study, this school is typical of Scotland in terms of the gender split of students studying computing. Thus specific intervention programmes, such as Google's two-month-old F scheme [29] or Scottish Resource Centre's "work with women entering further and higher education, those in education and women working in SET" [30] are steps in the right direction. While both initiatives appear to be effective in supporting females who have already chosen the field, there seems to be a dearth of initiatives to recruit more young girls into the field in the first place. Our female participants say they don't know whether working in the computing field is prestigious or if there is a high job demand in computing. Young people need this data in an understandable form.

This study confirms other work [31] which found that, by the ages of 16/17, the majority of the young people already have an idea about their future careers. Therefore, any intervention programme that aims to promote computing careers should do so earlier. The expert evaluators involved in the website evaluation stage of the project told us that, while young people may say they have made their career decisions, they tend to change their opinions while studying for a degree, or realise that they cannot gain the qualifications required for their choice and end up having to change their plans for future. Thus there is a subsequent window of opportunity to inform about careers in computing.

An unexpected finding of this study is that Careers Advisers or Teachers seem only to play a very small role in the career decisions these young people make. The major influences on these young people's career decisions are, respectively, their parents, the media, and someone who already works in the field. Furthermore, when asked who they think should inform them of computing careers, most believe that it should be someone who does the job. If this is consistent in other schools, then any intervention programme to change perceptions of young people should focus more on parents and role-models, and on careful media campaigns. Although inconsistent with the findings in Australia [3] that rated people from the industry and work experience more highly than the family; this may be due to differences between careers advice practices in Australian and Scottish schools.

In line with works of [16], [19] and [26] the findings of this study also suggest students have an "incorrect perception of the computing field or none at all" or the images of computing are "either absent or negative" [17]. If generalizable, the attitude of Scottish youngsters is similar to that of 14 to 19 year olds in Victoria, Australia and the following negative images of computing careers are still waiting to be challenged in Scotland:

- Computing careers lack human interaction.
- A career in computing would be very boring.
- Computing is a male dominated field.

- A computing career involves sitting in front of a computer all day.

Encouragingly, in contrast to previous studies [18], the majority of the participants disagree that the people who work in the computing industry as ‘socially awkward’.

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Teaching Computer Programming Based on Patterns with Activities and Collaborative Games Using Concrete Materials for High School Students

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***Abstract*— The courses in computing, especially those focused on software development, require many skills of novice students of computer programming. Due to the fact that computer science is a new area for most of novice students, they demonstrate great difficulty in initial courses in this area. They do not have specific skills in computer programming. This work presents the results obtained from the application of a teaching method, for computer programming students of the integrated high school mode, that combines patterns-based programming and games. The games uses concrete materials and collaborative activities based on sports in non-formal spaces. The results show improvements in students' motivation and in programming abilities. The method proposed in this work takes advantage of analogies between programming logic and games using concrete materials in order to develop programming skills.**

Keywords— teaching programming; patterns; games; collaborative activities

I. INTRODUCTION

Concern over the lack of manpower in technology, especially in the area of Informatics, has been drawing a lot of attention these days, both by the government, and by private enterprise. The Federal Brazilian Government will invest R$ 1.2 billion in Federal Education, Science and Technology from 2012 to 2014 [9]. Part of these funds will be allocated to the creation of computer professionals and mid-level technician, with priority to integrated school. An integrated school in Brazil offers traditional high school learning together with a technical learning. The great majority of the Federal Institutes in Brazil offers a course that combines a technical course in computer science and traditional high school. Today, for instance, the Federal Institute of Mato Grosso (IFMT), an institution that hosts this study, offers this course in three of the ten campuses.

With respect to courses where the base of technical training in programming, the initial goal should be the mastery of the basic concepts of algorithms and computer programming. Most students encounter great difficulties, whether resulting from a deficient training in Elementary Education or the total lack of focus of the course in which they are entering. This is due to the fact that most of them are motivated users of computer technology and choose the course based on this fact.

In order to meet the demand for Information Technology professionals is essential to enhance the quality of teaching and learning in courses in computing. One of the bottlenecks of these courses is the high failure rate and evasion at the beginning of the course in the disciplines of programming and algorithms [12]. In general, students who enroll in integrated courses are teenagers, aged from 13 to 15 years. In the case of IFMT, half the vacancies of the courses is designed for students who attended all nine years of primary education in public schools and the other half, called for universal access [7], which are the vacancies for the students that had not completed all primary education in public educational institutions or came from of private institutions.

Thus, given the particularities of the students in question, it is necessary to search for new approaches and teaching methods, as opposed to the traditional teaching of algorithms and computer programming. In the traditional teaching of programming, the content is presented orally by the teacher and after the students go to the informatics laboratory to solve computational problems using a programming language. As shown in [2], in the traditional way, the teacher presents content and some examples by means of a pseudo code and asks the students to make some exercises. The traditional way cannot easily motivate students to become interested in discipline; it is not clear to students the importance of certain content for their training [3].

In this paper, we present and discuss results obtained by combining the teaching pattern-oriented instruction [6], and games to high school students in the integrated mode. The games use concrete materials and are based on sports and collaborative activities in non formal spaces, making analogies with computer programming.

In Section II, we discuss advantages of teaching

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programming based on patterns and the necessity to propose new methods to approach it. In Section III, we describe and analyze the proposed method by means of a pre-post case study involving collaborative games using concrete materials and programming patterns. In section IV we analyze the interaction and participation in the games created by students. In Section V, we present the results of the study and future work.

II. PATTERNS OF PROGRAMMING IN LEARNING

Novices students in programming present many difficulties, such as problems related to the lack of ability of abstraction and lack of skills to deal with problems. In the case of students fresh out of the ninth year of elementary school there are other learning problems, especially in mathematics, physics and chemistry.

The two major challenges for the students are learning a new programming language and learning how to create a solution that solves a given computational problem [16]. Regarding the first problem, learning the rules of syntax and semantics of a programming language is relatively complex. However, the biggest challenge for the novice programmer, is really interpret the problem, solve it algorithmically and code the algorithm into a programming language.

Experienced programmers can easily solve a problem, identifying which statements to use, what data types involved, as well as distinct ways to solve the same problem using different strategies. Based works with previous programming experiences of students for teaching programming language Pascal, Johnson and Soloway [8] discuss that experienced programmers are able to solve new problems using previous experience, adapting previous solutions to solve them. These previous experiments provide the basis for the programming patterns, which are solutions that recurrently appear in computational problem solving. Programming patterns reflect programming strategies designed by experts. Thus, students take advantage of good programming practices.

These basic patterns also called educational programming patterns [14] contains the skeleton in which the problem will be solved by then beginner in computer programming. Programming patterns form a basis for initial micro solutions that can be adapted and combined by the students during the development of their programs.

A programming pattern describes a solution to a problem and provides information about the context in which it should be applied [2]. Thus, students starting their studies in programming, when faced with a particular kind of problem, can direct their resolution from the known patterns. The teacher has a key role in this process, which will be discussed later. Clancy and Linn [5] described how patterns can be used in the teaching of programming, concluding that students need to make the process of learning, creating and reshaping programming patterns, making it a regular practice in their learning programming process. Thus, the teacher should create the exercises in order to stimulate the use of simple patterns, combinations of different patterns, and stimulation of the creation of new programming patterns by the student.

Programming patterns are solutions to computational problems. They are basic blocks for the development of programs. Programming patterns refer to the classification of computational problems according to your goal [10]. Thus, the student may, by identifying a classification from the problem to be solved, which programming pattern can be used for preparation of a program. Another problem for the beginner in programming is the lack of abstraction ability. In the study made by Haberman and Muller [6], they propose a teaching method of abstraction, combined with problem solving and the use of programming patterns. In this study, the authors investigated the influence of the combination of patterns-based instruction with abstract data types. Thus, the study showed that it is possible to combine teaching with other pattern-based teaching methods.

Considering teaching programming, other issues are discussed by Muller [10]. One issue is the student's ability to recognize similarities between problems, particularly between the problem at hand and problems encountered and solved previously. Due to this fact, there is a need to develop new teaching methods to approach patterns in programming learning.

In the next section, we describe and investigate the teaching method proposed in this work.

III. CASE STUDY

The experiment was conducted in two stages, during the year 2012, in the course Algorithms and Logic Programming, offered in Technical Computing, Integrated mode in high school. 30 students in the first year of high school participated in the experiment, 18 boys (60%) and 12 girls (40%) aged between 13 and 15 years.

For this work, we explore the patterns for selection available by Bergin [4]. As a reference to loop patterns, we explore the patterns available in Astrachan and Wallingford [1].

We categorize the programming patterns into three types: selection patterns, loop patterns and combination patterns. The table below shows the patterns used in this work, types and an example code in the programming language C++.

TABLE I. SUMMARY OF THE PATTERNS USED IN THE EXPERIMENT

Pattern Name	**Patterns presented in the classroom**	
	Type	***Code***

Simple choice	Selection	if (a > 0)
		{
		b = 10;
		}

Pattern Name	Patterns presented in the classroom	
	Type	***Code***

Alternative choice	Selection	if (a > 0)
		{
		b = 10;
		} else {
		b = 20;
		}

Sequential choice	Selection	if (a > 0)
		{
		b = 10;
		} else if (a == 0)
		{
		b = 20;
		} else {
		b = 30;
		}

Serie of possibilities	Selection	switch (a) {
		case 1:
		b = 10;
		break;
		case 2:
		b = 20;
		break;
		default:
		b = 30;
		}

Loop and a half	Loop	cin>>a;
		while (a > 0) {
		b = b + a;
		cin>>a;
		}

Process All Items	Loop	for (i=0;i<10;i++){
		cout << i;
		}

Counter	Combination	if (average >= 6.0) {
		approve = approve+1;
		}

Accumulator	Combination	if (num % 2 == 0){
		pairs = pairs + num;
		}

The implementation of lists, as well as the presentation of programming patterns was made using the programming language C + +. Used for encoding programs to IDE Dev C + + version 4.9.9.2, using the objects input and output data (cin and cout). Despite the use of C + +, we do not use object orientation in this study. The description of each step is given below.

A. First step: approach using Pattern Oriented Instruction (POI)

In this step, which occurred in the first half of 2012, we worked the introductory part of building programs, as well as patterns of selection and repetition. Content such as data types, declaration of variables, assigning values to variables and mathematical operations using variables related to programming patterns.

The POI approach, described in [6] was used in this step. The instructional materials used by the teacher and students have been adapted for POI. The patterns were presented and discussed in the classroom and computer lab with students. Sometimes, given the difficulties of abstraction presented by most of the students are examples relating to issues of everyday patterns familiar to the student, such as the usage patterns of the school uniform.

Also in this stage, students have two classes, just to reinforce the concepts of programming patterns in the school gymnasium. In these classes the teacher was only reinforced what worked in the classroom, without going into any game. This activity also served to prepare students for the second stage of the study.

After the presentation and discussion of programming patterns, we ask students to solve exercises lists containing programming problems, relating the solution to the programming patterns discussed above. In the final step, we applied a questionnaire to evaluate how students used programming patterns in the encoding of programs as well as the difficulties faced by them and also on motivation to program.

The first question sought to know whether the process of solving the proposed exercises, what is the student's behavior with respect to programming patterns. The results were that 73.3% searched patterns to be used when solving exercises, 20% started to encode the problem in the programming language before searching the pattern to be used, and 6.7% waited a feedback from the teacher to copy the response.

About the greatest difficulty in the use of patterns in coding programs, subject of the second question, the result was that 33.3% could not relate the problem to be solved to a certain pattern; 43.4% failed to match patterns creating a new pattern programming, 13.3% did not understand what it does and what good programming patterns, 10.0% have no difficulties in the use of programming patterns.

The third issue related to motivation to program, the results showed that: 60% of students relate that motivation depends on the problem you are trying to solve, 20% responded that they are often motivated to program; 16.7% responded that the motivation for program is related to points (reward) to solve a problem or list of exercises, 3.7% answered that they are often unmotivated to program.

The last question sought to identify the expectations about students' motivation before a working methodology using games outside the computer lab. The question was about changing the space of classes, classroom and computer lab for the school's sports court and using other materials unrelated to teaching computer programming. All students responded that a change in this direction could be a differentiator for learning patterns-based programming.

School year in IFMT is divided in four quarters. In each quarter, we made a final evaluation. The passing grade for the IFMT is 7.0.

In the first quarter, the simple average of the notes in a scale between 0 and 10 was 6.22 and 6.42 in the second quarter. Therefore, at this stage, the overall mean of the experimental group was below the average minimum passing in the school year.

B. Second step: using patterns approach with collaborative games and activities using concrete materials

This step happened in the second half of 2012, and was divided into two sub-steps that are described below.

1) Work using games offered by teacher

Classes took place at this stage merging activities in the computer lab and school sports court. In the computer lab, students solved the lists of proposed exercises and sports court, at first, took part in activities involving sports games suggested by the teacher. Classes were interspersed so that every two classes, one was held in the gymnasium.

The games chosen for the experiment explored all the patterns that were worked in the computer lab. In these games, we use concrete materials related to sports games popular in Brazil, such as football, volleyball and handball.

The suggestion was made by the game played by teacher and some students. Then the teacher presented and discussed programming patterns related to the game, with examples relating to lists of exercises, linking the concepts of programming patterns in the game that was running. For example, in a volleyball match, the pattern **counter** is used to mark the score of the match, as well as the pattern **loop and a half** is used to limit each set of the match, since while the number of points scored by one team is less than 15, the game continues.

Because it is a new environment for teaching and learning programming, different from what they were accustomed in the first half, we made some guidance to students about work in the sports field. These guidelines were intended not to scatter the students' progress in school, establishing the boundaries in which they could move. With these guidelines, this step of the experiment was successful.

2) Work using games created by students

In this activity games using programming patterns analogies were created by students. The class was divided into 5 groups with 6 students each. Each group had the task of creating or adapting a known game, which should be built in order to demonstrate the programming patterns, both for those who were playing, and for those who were watching the game. For the creation of the games were made available to students balls of volleyballs and soccer, masking tape for marking sports court and plastic bottles. This task constitutes the following steps:

a) **Description of the game**: each group described the game created, taking into account the materials used in the game, the programming patterns identified and the rules of the game, which are also described as the interaction happens between players;

b) **Presentation of games for other groups**: after the description, each group demonstrated, playing for the other groups, the operation of the game according to the rules defined by the group;

c) **Games between groups**: after the presentation of the games for the other groups, the students of the group that created the game, invited students from other groups to participate in the game created.

We recorded on video throughout the implementation process of the games created by students. Each group submitted via social networking site Facebook, a document containing a detailed description of the game created. The table below shows a summary of the games created by students, the materials used, the goal of every game, the patterns used in the creation and execution of the game and the number of players participating in each round of the game.

TABLE II. DESCRIPTION OF GAMES CREATED BY STUDENTS IN GROUP

Group	Games created by students			
	Materials	***Goal***	***Patterns***	***Players***
Group 1	Ball of soccer, beams and masking tape	Achieve five points with the fewest errors out of 10 trials	Loop and a half, process all items, alternative choice and counter	03
Group 2	Tree branches and masking tape	Getting the other team's tree branch and return to his field without getting caught	Loop and a half, simple choice and alternative choice	14
Group 3	PET bottles, soccer ball and bleachers of the gymnasium	Hit the bottles with the ball using only the feet, each bottle has a score. The player with the highest score after 5 attempts, wins the game.	Loop and a half, serie of possibilities, counter and accumulator	02
Group 4	Ball of volley	Eliminate all opponents until one person remains	Loop and a half, simple choice and counter	06
Group 5	Four dice, chairs to be used as obstacles and masking tape	Be the first player to reach the center of the sports court	Alternative choice and process all items	04

At the time of the game, the teacher was asking students to interventions that would tie the game with part of the programming patterns. For example, in the game of group 1, with each round the students stopped the game and together with the teacher, explained the combination of patterns used in the game, in which case the loop process were all items and counters. Another example is the group 4 where the goal was to kick a ball in pet bottles arranged in the bleachers of the gymnasium. With each move, the students organized themselves and took the roles of varying patterns of counters and accumulators.

We note that in the description of the games, all groups were able to include and adapt programming patterns in the activities created. In presentation of the games to the other groups, we found that all groups were able to describe the patterns and combinations of patterns used to create game schedules, according to the rules of the game. Finally, in games between the groups, all students understood the use and combination of programming patterns in the game that was running. Thus, we consider that the experience using collaborative games with concrete materials has been successful in teaching and learning computer programming based on patterns.

In the process of creation, all groups created effective activities for work and gaming programming patterns, proposing activities relevant. Regarding originality in the creation of games, groups 3 and 5 activities created fully original. The games created by groups 1, 2 and 4 were adaptations of games already known by the students.

It is worth noting that adjustments were made in the games through a combination of a game already known by the students, with the increase of tasks or steps to highlight the connection between the game and programming patterns. In the games created by groups 3 and 5, the activities and proposed solutions were beyond what was requested, with a higher degree of innovation compared to other groups.

As the first step of the study, we did two evaluations at the end of the third and fourth quarter 2012. The simple average of the third quarter, on a scale between 0 and 10 was 7.31 and the fourth quarter, 7.52. The results were greater than in the first quarter.

IV. ANALYSIS OF THE INTERACTION AND PARTICIPATION IN THE GAMES CREATED BY STUDENTS

For the analysis of the interaction and participation in games created, we have adapted four categories among the 10 based on Newman, Webb and Cochrane`s model [15]. Following we describe the four categories.

Category 1. Relevance: Relevant states or diversions.

Category 2. Novelty, new info, ideas and solutions: New problem related information or repeating what has been said.

Category 3. Ambiguities; clarified or confused: Clear statements or confused statements;

Category 4. Practical utility (grounding): Relate possible solutions to familiar situation or discuss in a vacuum.

Considering the category 1, the relevance was strongly identified in groups 1, 2, 3 and 5. In group 4, some diversions were identified. We believe this occurred because the characteristic of the game created utilized an strategy for elimination of opponents and some degree of brute force boys to play the game. Even at any given time, some female students refused to participate in the activity.

With respect to category 2, all games were created, both in its creation and in its implementation, innovations, new ideas and solutions. Highlighting the activities present in games created by groups 2, 3 and 5. In these games, besides taking into account the patterns of programming, students were led to think about how to solve the problems encountered in game shape, trying new strategies and interacting with them in search of the best group performance.

In category 3, ambiguities were detected mainly in game created by group 1. Although ease in execution of the game, by using combinations of patterns more complex schedules, for example, the pattern loop and a half inside another loop and a half, leading to ambiguous interpretations, where students on some occasions could not identify which the bonds were being executed in this game, teacher intervention was necessary at various times due to these factors. Ambiguities were also identified in game created by group 2. We believe that these ambiguities arose during the game due to activity count with 14 players in each match, which also made necessary the intervention of the teacher to clarify that the pattern used at any given moment of the game was different from that identified by the student. In the games in groups 3, 4 and 5 we did not detect problems with ambiguity, perhaps because these games use less complex combinations of patterns than in groups 1 and 2.

In category 4, the practical usefulness with respect to programming patterns was identified in all groups. As in all games the teacher related patterns with lists of programming exercises to be solved in the computer lab, students and even commented related relationships between certain stages of the game with certain exercises.

V. CONCLUSIONS AND FUTURE WORK

In this paper we present and compare two approaches for teaching computer programming based on patterns for high school students in integrated mode. The first approach used only the POI approach. The second approach was made using the POI approach together with collaborative games using concrete materials in a non-formal environment for teaching computer programming. Considering the motivation to learn programming, the second approach proved to be very promising with respect to the first, considering the age and socio economic cultural level of the students involved in the study.

We could observe that the work done outside the classroom and computer lab, contributed greatly both to stimulate the creative process and the students' motivation to learn computer programming. We also had an increase considering the notes of the first half of the semester. In the first half of the semester the average was 6.32 and the standard deviation was 1.986. In the second half of the semester the students obtained an average 7.41 and the standard deviation was 1.394. There was a significant increase of 17.42% on average between the two semesters.

The profitable interactions and participations were identified in all the games created by the groups. However, the level of interaction and participation depended on several factors. The first was that, regardless of the materials used, the more students involved in the games, the greater the participation of the whole class. In games such as Group 1, which had only three players per round, attention, both with regard to the game as with respect to programming patterns were lower. Already in the second group match, who counted in each round, with 14 players, so the attention of the students who participated in the game, as the students who were outside, was superior.

In future work, for achieving stronger results, we will perform other pre-post case studies, using the same test in both stages. We will also study the use of concrete materials and collaborative games in teaching of object-oriented programming to high school students in integrated mode.

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***Abstract*— This paper describes the Digital Culture BA degree: an engineering-arts undergraduate curriculum that combines competency-based education (CBE) and knowledge-oriented education (KOE) structures and related Pull-Push approaches. The degree has been offered for three years at Arizona State University, has 200 enrolled students and is continuing to grow. The degree embeds nine knowledge-oriented concentrations, each offered by a relevant participating department, within an interdisciplinary CBE context. The CBE part of the degree provides customized access to 40 interdisciplinary digital culture courses from 12 different academic units by connecting these courses through a set of core competencies. Access to courses is not determined by fixed prerequisites but rather by having one of several possible combinations of lower level competencies. This flexible curriculum is attractive to students, promotes integrative collaborative learning that inspires innovation, and prepares the type of engineering-arts experts and complex problem solvers that are currently needed in creative industries. This type of degree also presents several important challenges for educators and administrators. To address these challenges we developed project based assessment approaches, custom web-based software for advising a very diverse student body, as well as online tools for facilitating peer critique and feedback in large creative classrooms.**

Keywords*— *interdisciplinary; engineering; arts; media; competency-based education

I. Introduction And prior work

In a recent interview for the Sunday New York Times [1], Tony Wagner of the Harvard Graduate School of Education, identified three "reinvented" colleges where students are trained to innovate: The Olin College of Engineering, The MIT Media Lab and the D School at Stanford. One similar characteristic of these three programs is that all three combine training in engineering and arts. (Engineering in this paper will be used broadly to connote both engineering and computing. Similarly Arts will be used to connote design, architecture, media arts and visual and performing arts). Research and education that bridges arts and engineering has long been associated with innovation. Industry examples of engineering-arts induced innovation include Apple Computer [2], Bell Labs [3], and Pixar [4]. The Beyond Productivity Report of the National Academies [5] identified education and research activities that bridge arts and engineering as a catalyst for innovation and creativity in the 21st century. The report predicted the continuous growth of creative industries that rely on the merging of arts and engineering expertise [social media, interactive computing, games, mobile design etc.]. The increased merging of engineering and the arts is part of a bigger trend. There is growing evidence [6,7,8] that the complex problems of the 21st century can not be solved through exclusive reliance on STEM approaches. The technological and scientific dimensions of complex problems have to be addressed in tandem with the many human-centric dimensions of these problems. Such holistic and innovative solutions require diverse teams that combine humanist and scientific skills and perspectives [9, 10] and can address in an integrative manner quantitative and qualitative issues [11].

Accordingly, in the past 15 years we have witnessed a rapid increase in the number of undergraduate [12] and graduate programs [13] that merge engineering and arts perspectives, with the goal of preparing students to collaborate in diverse teams, produce innovations with direct real world impact, contribute to the growth of creative industries and solve high dimensional problems. We see a growing support for liberal education [12] and the emergence of federal (Creative IT), industry (Intel, EA) and private (Mellon, MacArhur) funding streams dedicated to education efforts that bridge the arts and engineering. The proliferation of studio pedagogy in engineering [14, 15] is one of the most obvious educational benefits of the increasing connections between arts and engineering. The use of studio pedagogy as meeting ground for arts and engineering practices is also benefiting arts education. It is promoting evidence-based, quantitative analysis and assessment of studio training [16] and of arts-based training overall [17]. However, the complex cultural differences between the arts and engineering fields have also produced challenges both in industry [18] and academia [12]. Engineering and arts differ in key parameters. The fundamental knowledge basis for engineers and artists are fairly distinct as engineering starts from science principles and arts from aesthetic and form construction principles. The trees and branches of knowledge, or tool boxes [9], of engineering and arts, do not have significant overlap and thus require sequences of learning that are fairly independent. The "traditional axiom in engineering education is learn the basic sciences, then learn the applied sciences and then reduce this knowledge to practice" [14]. Where as arts training does all three concurrently, with practice starting even before basic theory is well understood. Engineering training focuses on "derivative innovation" (derived by applying knowledge of existing scientific principles) [14] whereas arts training focuses on originality (where creative outcomes start from blank pages). Much of engineering education and research focuses on increased efficiency and productivity, whereas arts training focuses on contemplation and meaning [19, 20]. Although engineering and arts use some similar terminology (especially in media arts contexts), in many cases these terms arise from different ontologies and thus their usage leads as often to misunderstandings as to connections [21]. For example, in collaborative development of interactive systems for neurorehabilitation, a bioengineering student uses the term "effective feedback" to denote an accurate and simple (easy to comprehend) mapping between a body movement parameter and a constructed information stream that may promote self-assessment by the user. For the arts student "effective feedback" is an information stream with formal and aesthetic characteristics that engage the user in a purposeful meaning-extraction interaction [22]. All these differences, make the combination of engineering and arts within a traditional curriculum challenging.

II. Key design concepts of the Digital Culture Curriculum

Most traditional curricula are examples of knowledge oriented education (KOE). Such curricula focus on the principles and concepts that need to be learned in each discipline [23, 24]. KOE curricula often follow a "push" model where the student follows a constrained pre-structured path that covers all key concepts of the discipline [25]. A KOE-Push approach may serve well the transmission of established knowledge in a discipline (it can produce engineers that know all the basics) and the combinatorial transmission of established knowledge in closely interrelated areas (it can produce bioengineers that know the basics across biology and engineering). However, KOE approaches can not produce combinatorial curricula across arts and engineering since the areas are distinct in purpose and knowledge structure. To train good artist-engineers through a KOE approach requires two parallel majors [26]. Although this approach can cover the basics in both areas it does not address comprehensively the issue of integrative engineering-arts education.

Integrative curricula across engineering and arts, especially when related to evolving application areas (like new media), require a combination of competency-based education (CBE) and knowledge-oriented education (KOE) and a related combination of Pull-Push approaches. CBE focuses on "why something has to be learned and how it can be used in solving a complex problem" [23, 24]. CBE focuses on allowing students to "pull" the knowledge they need on demand to solve "authentic" complex problems relating to their future work [27]. In the 21st century, CBE is evolving to allow this "pull" to occur through many new channels (like online learning or peer to peer learning) rather than through only traditional lectures in classes [28].

Because CBE focuses on complex problem solving, and complex problems are better solved through diverse teams, many contemporary CBE curricula include significant collaborative projects components. Collaborative teams that include many differing perspectives can better avoid getting stuck in local minima [9]. In such teams, a collective expertise for solving the problem tends to emerge from the interactions of team members [29]. CBE is thus well fitted for structuring effective integrative engineering-arts curricula. The diversity of purpose and concepts of these two areas becomes an advantage within the context of authentic problem solving [4] rather than a friction point within KOE which focuses on learning of fundamental disciplinary concepts. However, teams can only solve problems effectively if each member possesses adequate individual expertise in their area of knowledge [9, 30].

We therefore structured an engineering-arts curriculum, the Digital Culture BA, that embeds different KOE concentrations within a CBE context. Students bring the expertise gained through their disciplinary concentration into a network of interdisciplinary courses and projects that are connected through a common list of competencies. In the next section we present three key components of the implemented Digital Culture curriculum: the structure of the degree and its enrollment data, the online tool that helps students customise their paths through the degree, and Critviz - an online tool that helps expand the concept and capacity of the studio based classes of the Digital Culture curriculum so that the studios can bring large numbers of diverse students together to perform authentic tasks. We conclude with a section on lessons learned.

III. Results

A. The structure of the degree and enrollment data

The digital culture degree provides interdisciplinary engineering-arts training for students interested in careers in 21st century creative industries: social media, media arts, interactive computing, multimodal digital communication, responsive environments, games, mediated learning, theme parks, and more. 120 total credit hours are required for completion of the Digital Culture degree. They are allotted as follows: 49 hours of Digital Culture core credits, 30 hours of concentration credits and 41 hours general studies credits. There are nine available concentrations (see Table 1).

Concentration credit hours are earned through a sequence of 10 three credit courses aimed to give the student fundamental expertise in a contributing disciplinary area of digital culture. For example students in the Media Processing concentration can complete a path of EE courses focused on signals and systems, or a CS path focused on data structures and algorithms. The student can select their 13 Digital Culture core courses from a menu of 40 courses provided by 12 different academic units spanning the Schools of Engineering, Design, Arts, and Social and Cognitive Sciences. Twenty of these courses were newly developed to address key digital culture topics (e.g. Animating Virtual Worlds, Physical

Computing, Motion Capture for Interaction) in an interdisciplianry manner. The remaning 20 digital culture courses were exsiting courses that were adapted to fit the digital culture rubric. All 40 digital culture courses are connected by a set of 27 core competencies (proficiencies) developed by faculty of the participating units with input from industry partners (see Table II).

Digital Culture Concentration	**Jan 2013**	**Fall 2013***
Music	43	60
Art	37	41
Design	29	36
Media Processing	17	22
Film	17	21
Arts and Design Studies	12	15
Interdisciplinary Arts and Performance	3	6
Technological Entrepreneurship	5	6
Theatre	4	6
GRAND TOTALS	**167**	**213**

Table I: concentrations and enrollments

		Total	Required	Provided
		Sum	Sum	Sum
1	Computational Tools	36	22	14
2	Form and Composition	35	19	16
3	Narrative Construction	28	15	13
4	Cultural Practice and Studies	27	14	13
5	System Design/Development	22	9	13
6	Collaborative Principles	18	8	10
7	Editing and Processing	18	12	6
8	Fabrication and Building	17	8	9
9	Visualization and Sonification	17	8	9
10	Media in Physical Space	16	7	9
11	Improvisation and Iterative Design	15	8	7
12	Routine Activity and Decision-Making	15	9	6
13	Algebra	14	10	4
14	Communication and Networks	14	7	7
15	History and Theory	14	7	7
16	Modeling and Inference	14	9	5
17	Perception and Cognition	13	7	6
18	Project Design and Production	13	7	6
19	Social Mechanisms and Understanding	13	7	6
20	Reflective Practices	12	6	6
21	Research Methodology and Writing	12	5	7
22	Digital Archiving and Publishing	11	5	6
23	Performance and Interaction	9	5	4
24	Computational Media Analysis	8	5	3
25	Embodiment and Kinesthetics	8	3	5
26	Sensors and Signals	8	4	4
27	Calculus	7	3	4

Table II Competencies

These 27 competencies are diverse and represent key knowledge components of 21st century creative industries. Individual courses provide competencies at various levels (a 300 level course produces 300 level competencies). Access to each course is not determined by fixed prerequisites but rather by having one of several possible combinations of lower level competencies. Completion of each course provides a student up to four new competencies, which further "unlock" access to more advanced courses. The same proficiency can be gained through courses in different disciplines. For example, the "modeling and inference" 300 proficiency can be gained through a 300 level computer science, industrial design, digital music, or anthropology course, meaning students can gain entry to courses via radically different paths. Therefore, the same upper level course can be reached through multiple paths. (See Table II for a list of competencies and their freqeuncy of use in connecting coures).

The Digital Culture degree acknowledges that the same competency can have multiple instantiations generated by different ontologies or related trees of knowledge. Instead of trying to resolve these differences in favor of one generating ontology, the degree (and its constituent collaborative courses and projects) leverages this diversity of perspectives for exploring the multidimensionality of complex problems, generating innovative insights, and preparing students to work in diverse creative teams. This of course generates a challenge for the instructors. In a traditional disciplinary learning hierarchy [23], the instructor can expect a relatively uniform cohort of students who have acquired a particular competency through the practical application of a constrained set of skills, and knowledge acquired through a predefined learning sequence. In the case of Digital Culture courses, the student cohort is very diverse in terms of skills and knowledge (and interpretation of competencies) since students come from different disciplinary concentrations of the degree and have followed different paths to the courses. Thus Digital Culture core courses can not focus on teaching of specific basic skills. Basic skills a student needs are covered by the disciplinary courses provided by the concentrations (and in the case of cross training skills by remedial courses - see lessons learned), or by a student initiated knowledge "pull". The Digital culture courses focus on meta skills: how different competencies (and generating ontologies) can be combined to solve complex problems - with special focus on 21st century creative industry contexts. As students advance through the degree their understanding and application of competencies improves which is why a competency is offered at different levels (200, 300 etc).

Let us look at an example that illustrates the relation of skills to competencies in the Digital Culture degree. Table III shows three competency combinations that open access to the 300 level course on Compositional and Computational Principles for Media Arts. The instructor can expect that all students will be able to apply computational tools to media authoring and have some 200 level experience with computing but can not expect specific programming skills from all students. The instructor can expect that all students have composed a visual and/or sonic and/or text based work but can not expect that all students have specific composition skills in one of these areas (i.e. 3D computer animation). The instructor can also expect that all students have experience either in improvisatory performance or rapid prototyping. The outgoing competencies are Communication and Networks 300, Computational Media Analysis 300, Embodiment and Kinesthetics 300, Performance and Interaction 300. This denotes that the instructor will focus on combining the existing skills of the students toward developing interactive embodied media systems, as well as placing these systems in a historical context. The instructor will not be directly teaching computer coding or formal principles for narrative tension and release. It is assumed the students already have these skills and if not they will "pull" them by their own initiative through an online resource or peer to peer approach. Furthermore, the course will help students contextualize some of their required disciplinary training achieved through their chosen concentration and inform their remaining selections of Digital Culture core courses.

Path 2	Path 2	Path 3
200 Computational Tools	200 Computational Tools	200 Computational Tools
100 Narrative Construction	200 Form and Composition	200 Form and Composition
200 Performance + Interaction	200 Improv and Iterative Design	200 Performance + Interaction

Table III: Competencies for 300 level media computing course

Each student over time accumulates a proficiency collection representing a unique pathway which can be analyzed and used as a customized guide, pointing the student to specific types of research opportunities (junior year) and capstone projects (senior year) eventually leading to employment opportunities best fitted to their particular set of interests. The key mechanism used by faculty to assess performance and progress is the inclusion of collaborative projects in each core course [28]. A senior year capstone project is the overarching mechanism used to demonstrate the training provided by the Digital Culture degree. Creative industries place significant weight on what future employees can actually produce and on their ability to collaborate in diverse teams for catalyzing innovation [5]. In course evaluations, students rate each course not only for its content but also on how the course engaged the expected incoming and outgoing competencies. This data, in combination with data from the paths students have chosen, allow instructors to assess the status of the digital culture network in terms of overall course and competency usage and in terms of efficient generation of listed proficiencies (edges) by each course (node).

The digital culture degree was launched two and half years ago. There are currently 165 students enrolled in the digital culture BA and based on current admissions data that number will grow to 220 by next Fall (see Table II). It has been challenging to advise so many students, each with a different concentration, a different custom path and a different background. In response we have developed the online digital culture visual planner (presented below) to assist students with exploring future alternative paths and to encourage them to participate in their advising. The significant weight placed on collaborative projects throughout the digital culture degrees creates a significant review and assessment challenge. As discussed earlier, studio based pedagogy is a very effective way to to bring engineering and arts students together but it is a hard model to scale as it requires continuous hands on mentoring and review of process and product [14]. We have developed a online studio/peer critique tool (also presented below) to assist us with scaling the studio model to large number of students.

B. The Digital Culture Visual Planner

The Digital Culture Visual Planner is an interactive web based interface for students to visually explore possible pathways through the DC curriculum. The system is personalized, it knows which classes each student has already taken and thus which competencies each student has obtained. The system also knows which classes are being offered in future semesters several years in advance and the associated competencies those courses require. Using this information, the tool visualizes for each individual student the landscape of future pathways he or she might take towards graduation. The student can make hypothetical decisions about which courses to take next, and see various subsequent pathways open or close. The student can explore the long range implications of taking one class versus another, safely trying out various pathways through the curriculum. Finally, as the student actually sets out following a path, leading to internships, capstone projects, and onward to a job and a career, they leave a trail of "breadcrumbs" so that newer students can see where these paths may extend to beyond the courses themselves.

The interface for this tool is quite simple. The screen has two main panels. The first panel shows a list of all the possible competencies in Digital Culture, with highlights over the competencies already obtained by the student. A second panel shows a semester by semester list of course offerings. These two panels are interactively linked to each other. Rolling the mouse over elements in one panel will highlight related elements in the other. For instance, rollover a specific course and the competencies related to this course will highlight. Or, rollover a specific competency and all the courses that provide this competency will highlight in the other panel. This dual action "brushing" allows for an interactive exploration of the web of interrelationships between courses and competencies.

In order for a student to truly explore various pathways through the curriculum, the tool needs a mechanism by which the user can simulate, or create a hypothetical scenario. For this the tool allows the user to "pin" a future course, or simulate the completion of this course. A pinned course will cause a cascade of effects, adding to the students collection of competencies, and opening up all those future courses that these new competencies would unlock. As this cascade of effects unfolds, these newly opened courses look and act as though they are now available to take, but visually they retain a different look and feel to indicate to the user that these effects are due to the provisional or hypothetical "pinning" of a class. In addition, as the pinned courses open up access to new courses, these courses too can be pinned, creating a further cascade of options.

C. *The online studio crit/peer critique tool*

Our Digital Culture degree emphasizes collaborative projects and is growing fast. This leads to large classes of up to 100 students where multiple teams with diverse membership work in parallel on collaborative making. To serve this need our physical spaces are reconfigurable "maker lab" classrooms, where the boundary between the lecture hall and the fabrication shop is not clear. As instructors, we want students to acquire and hone both technical and creative skills, and although students do receive traditional letter grades, individual assignments rarely have clearly "right" or "wrong" answers. We focus on experimentation, discussion, critical thinking, invention and creative risk-taking. In this setting, making mistakes is often the very best way to learn.

The prevailing studio pedagogy model consists of few students receiving feedback and evaluation from a single [or few] expert instructor [14, 15]. This model can be ideal at a certain small scale, but as the classroom grows, the amount of attention the instructors can provide declines linearly with the numbers of students in the classroom. More students simply mean less time to spend evaluating each individual. Additional teachers or assistants can be added, but the problem of scale persists. Shifting larger classrooms to use peer critiques can alleviate this problem by increasing the amount of feedback each student receives. "Because teachers do not have time to provide extensive feedback, peer conferences are a way to engage students in meaningful formative assessment dialogues with each other" [31]. This shift however only changes the nature of the problem from that of "instructor overload" to "critique management." The bottleneck is no longer the instructor's time and attention, but how to effectively manage a large, cohesive critical discussion. These discussions can of course be distributed over multiple groups or multiple class sessions, but this fragments the class and/or leaves little time for anything but critique.

Organizing our classes around peer critique is ideal for the kinds of material we teach, but the scale of our classes presents a logistical problem. Running fully inclusive in-class critiques with 50 - 150 students is difficult in face-to-face settings. Using online tools to help facilitate large critiques is an obvious direction, so we sought a method for conducting peer critiques for our classes via the participatory web. We found existing technology for sharing and turning in student's digital projects (e.g. uploading files to BlackBoard, blogs, message boards, email attachments) less than optimal for both instructor and peer evaluation. Often these tools caused more cognitive overhead, complexity, message overload, and confusion than they were worth. It quickly became clear that there are no existing online tools designed to facilitate a large classroom critique session. We decided to develop CritViz: a system specifically intended for the purpose of facilitating high quality, real-time critique sessions for large classes.

In CritViz the instructor creates assignments which consist of descriptions of the work to be done, supporting documents, screencasts, code examples and relevant readings. Importantly, each assignment has two deadlines. One for when the work is due, and the other for when the critique is due. Students log on and see a list of assignments with large countdown timers. When the timer reaches zero (usually a week or so) students can no longer submit work. Next the critique period begins. Each student who successfully submitted work is assigned to review the work of five other students (at random), give them critical written feedback on their work, and importantly rank order the works.

We currently have 19 classes that have used CritViz, with 10 currently running it this semester, including one high school class. There are currently 618 users in the system. Since starting CritViz a year ago, 172 assignments have been created by faculty for students, and students have responded to these assignments with 6451 responses, leading to 11,010 peer critiques. We have had a total of 288,647 unique page views on the system, and are averaging over 60,000 page views per month. Through CritViz's countdown timers, assignment uploading, and randomized peer feedback, we can now run effective critiques in much larger classes. But we have also seen some unintended positive changes in overall classroom "motivational structure." Students who have used CritViz report that an audience of peers—as opposed to just a teacher—elevates their work quality and effort.

IV. LESSONS LEARNED

Student centric education works but needs to be used with care. The Digital Culture degree had 100% retention last semester. That is a very high number for any degree but particularly impressive for a large scale degree at a large scale public university where a number of students are also holding down jobs to finance their education. The degree is actually the fastest growing undergraduate major at ASU. Discussions with students have shown that the main attraction of the degree is its flexibility that allows students to custom build their paths. Other key attractive elements include the applied nature of the degree (its focus on preparing students for future jobs in creative industries) and the interdisciplinary collaboration emphasis. However, it is also becoming clear that not all 18 year-old students are ready to self-advise their career. Many students enroll in the degree (and choose a concentration) based on what they like to do rather than because of careful exploration and career planning. For example, the most popular concentration is that of Music because students enjoy listening to and making music using new media. However, for most of them making music will be an avocation not a vocation. Much of our early advising effort for these students is to emphasize the need for them to use the degree to gain strong technical skills in new media development (thus making them employable in multiple industries) rather than making music. We therefeore expect more technical concentrations (i.e. media processing), or concentrations with broader applications (desing, technology enterepreneurship) to grow in enrollment.

Interdisciplinary education needs to address basic cross-training skills. Working successfully in interdisciplinary teams requires each member to have expertise in one area [9, 30] but also many times requires members to have basic working knowledge of skills outside their expertise. For example, a specialized artist working in an interdisciplinary digital culture team requires basic programming skills to prototype their work and be able to participate actively in implementation discussions. Their preparation/concentration in the arts does not provide them with that skill. Therefore, the digital culture degree now integrates introductory courses and one credit deficiencies modules that cover basic cross-training skills (programming, rapid prototyping, 3D fabrication, principles of form, calculus).

Assessment of training through projects needs to be introduced gradually. Collaborative projects are a key training assessment mechanism in the Digital Culture degree. For students used to Knowledge Oriented Education models from high school, this can be a hard transition. The Digital Culture degree now requires that all freshman and sophomores attend a weekly presentation forum where juniors and seniors present their projects and receive critiques from interdisciplinary groups of faculty and visiting experts from industry. This introduces underclassmen to project based assessment and offers a good opportunity to upperclassmen to present their work in a friendly environment. These forums also help build community.

V. CONCLUSION AND FUTURE WORK

Interdisciplinary education that bridges engineering and the arts can prepare students who can work proficiently in diverse teams to solve complex problems in an innovative, human centric manner. The demand for such students in creative industries is increasing. Curricula that combine KOE and CBE approaches, like the digital culture degree of Arizona State University, can help bridge the differences between engineering and the arts. Such curricula are highly customizable and thus are attractive to students. Tracking of placement and career evolution of students who graduate from such degrees is necessary in order to fully assess and evolve these types of innovative degrees. Sharing of outcomes (including innovative tools like the visual planner and Critviz) may help increase the impact of efforts like the Digital Culture degree but require a forum of institutons that are willing to support the generalizaiton of tools and approaches.

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Developing an Interdisciplinary Health Informatics Security and Privacy Program

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***Abstract*—Health informatics is one of the nation's largest growing industries. To protect health information systems, it is extremely important for health informatics professionals to be well educated and trained in information assurance, and to understand the many concerns of security, privacy, integrity and reliability. To meet this demand, we are creating a new, interdisciplinary curriculum model of Bachelor of Science in Computer Science (BSCS) concentration in Health Informatics Security and Privacy (HISP) at North Carolina Agriculture and Technical State University (NC A&T). To establish this BSCS concentration in HISP, we developed a new course on health information systems in the Department of Computer Science, a new course on Mathematics for Health Informatics in the Department of Mathematics, and modified an existing course in the Department of Management to include topics on business practices relating to health information technology. We also developed three course modules on health informatics security and privacy and are integrating these course modules into the existing information assurance courses in the Department of Computer Science. This paper describes the new curriculum, the new courses, and the three course modules we have developed.**

Keywords—health informatics, health information systems, security and privacy, HIPPA curriculum.

I. INTRODUCTION

Health informatics is one of the nation's largest growing industries. Compared to other data intensive industries, the health care industry is underinvested in information technologies. Recently, President Obama has made the use of information technology and electronic health records a top goal to cut down costs in the US healthcare system, offering up to $27 billion in government funds aimed at speeding the switch from paper to electronic medical records [1].

Together with many other factors, mandated electronic recordkeeping and tightened patient privacy regulations are making health informatics a sought-after skill. US News & World Report named Healthcare Informatics as one of the top careers. According to Don Detmer, CEO of the American Medical Informatics Association (AMIA), the main professional body relating to health informatics in the U.S., approximately 70,000 health informatics specialists are needed [2]. According to the US Bureau of Labor Statistics, employment of medical records and health information technicians is expected to grow by more than 20% through 2018, resulting in over 207,000 jobs creation by 2018 [3].

With the government's increasing interest in electronic health records and growing investment by healthcare organizations in technology, a degree in health informatics or health information systems will give graduates some of the strongest career opportunities in today's economy. To protect health information systems, it is highly important for health informatics professionals to be well educated and trained in information assurance, and to understand the many concerns of security, privacy, integrity and reliability. To meet this demand, we are creating a new, interdisciplinary curriculum model of Bachelor of Science in Computer Science (BSCS) concentration in Health Informatics Security and Privacy (HISP) at North Carolina Agriculture and Technical State University (NC A&T).

This project is the joint effort of the Department of Computer Science, the Department of Mathematics and the Department of Management at NC A&T. To establish this BSCS concentration in HISP, we developed a new course on health information systems in the Department of Computer Science, a new course on Mathematics for Health Informatics in the Department of Mathematics, and modified an existing course in the Department of Management to include topics on business practices relating to health information technology. We also developed three course modules on health informatics security and privacy and are integrating these course modules in the existing computer security and information assurance courses in the Department of Computer Science. Such a curriculum will produce computer science graduates who have skills in health informatics, as well as skills in security and privacy in health information systems. It will also allow students in the field of nursing or health care to learn about health informatics and health information systems, allow students in mathematics to apply mathematics to health informatics, and allow students in management to learn about the business aspects of health informatics. This project leverages the strength of the existing information assurance program at the Department of Computer Science, and the existing collaboration among Department of Computer Science, Department of Management, and Department of Mathematics. The three departments collaboratively established the University's Center for Cyber Defense, a national Center of Academic Excellence in Information Assurance Education (CAE/IAE) designated by the Department of Homeland Security and the National Security Agency.

This paper describes the three new courses we developed, the three new course modules, and the new

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curriculum of Bachelor of Science in Computer Science concentration in Health Informatics Security and Privacy at NC A&T. The curriculum model and instructional materials produced through this project can be adopted by educators in multiple disciplines such as computer science, information assurance, health informatics, information technology, mathematics, and business.

Some institutions such as Walden University [2], DeVry University [3], and University of Illinois at Chicago [5] offer bachelor's programs in health informatics. However, most of them are based either on information systems or information technology with only a few core health informatics related courses. There is not enough emphasis on security and privacy issues in health information systems. Topics like security policies, architectures, risk management, disaster recovery and business continuity, network security, and cryptography are not commonly covered by these degree programs. Knowledge of security is a key requirement for graduates to function effectively in mid- to high-level specialist positions in a health care organization. Our program is unique in that it is interdisciplinary, and it emphasizes health informatics security and privacy.

The remainder of this paper is organized as follows: Section II describes our BSCS Concentration in Health Informatics Security and Privacy. The new courses and course modules developed for the BSCS concentration in HISP are described in Section III and IV. Section V concludes the paper.

II. The BSCS Concentration In Health Informatics Security And Privacy

The BSCS concentration in Health Informatics Security and Privacy requires the following core courses:

- COMP323: Introduction to Healthcare Information Systems
- MATH 410: Mathematics for Health Informatics
- MIS640: MIS Topics
- An Information Assurance elective (choose from: COMP320: Fundamentals of Information Assurance *or* COMP321: Computer Systems Security *or* COMP420: Applied Network Security *or* COMP421: Security Management for Information Assurance)

In the regular BSCS program at NC A&T, a student normally needs four years and with 124 total credit hours to graduate [6]. The course requirements are listed by category in Table I. The proposed BSCS concentration in HISP requires the same number of total credit hours as the regular BSCS program, and the same number of credit hours in each subject category as shown in Table I.

In the 59 computer science credit hours, 9 credit hours are computer science electives. For the BSCS concentration in HISP, the 9 credit hours will be used for taking the following courses: COMP323: Introduction to Healthcare Information Systems, MATH 410: Mathematics for Health Informatics and an Information Assurance elective course. In the 27 General Education credit hours, 3 credit hours are required for approved Business Electives. For the BSCS concentration in HISP, the course MIS 485: MIS Topics will be used to satisfy the Business Electives requirement.

TABLE I. BSCS Program Requirements

Subject Category	**Credit Hours**
Computer Science	59
Mathematics	20
Science	12
General Education	27
Free Elective	6
Total	124

Currently the three new courses have been developed, and have been approved by the University. The course "COMP323: Introduction to Healthcare Information Systems" was offered in the Fall 2012 semester. The courses "MIS 48:5 MIS Topics" and "MATH 410: Mathematics for Health Informatics" are being offered in Spring 2013 semester. The BSCS concentration in HISP is in the final stage of being approved by the University Curriculum Committee. The following sections will describe the three new courses and course modules for the concentration.

III. The New Courses For The BSCS Concentration In Health Informatics Security And Privacy

This section describes the new courses we developed for the BSCS concentration in Health Informatics Security and Privacy.

A. Course 1: COMP323 Introduction to Health Information Systems

This course introduces broad aspects of health care information systems. The goal is to prepare students with knowledge for effectively managing health care information systems. The main topics of this class include: types of health care information and data, regulations, standards, and laws of health care information, history of health care information systems, main features of EHR systems, information technologies in health care information systems, health care information systems certifications, security in health care information systems, and management of health care information systems.

This course was offered in the Fall 2012 semester for the first time. The textbook is Healthcare Information Systems by Karen A. Wagner [7]. Four projects were given to the students. These projects are described below.

Project 1

Research available job openings in Healthcare Information Systems (Informatics) or closely related areas. Find one or two job types that most interest you. Find out what the education requirements and skills needed for the job(s) are. State why you are interested in this/these particular job(s).

Project 2

Search the Internet and find five healthcare information system vendors that offer EMR products. Compare and contrast the functions and features of each product. Submit at least a three- page report explaining your findings. Also submit a presentation slide for your homework.

Project 3

Search the Internet for health organizations and find out which ones are using Web 2.0 technologies to establish connections with patients or other consumers. Describe how they are using Web 2.0 technologies.

Project 4

This is a hands-on project on using an open source health information system (OpenEMR [8]) to create a health care practice and keep track of patients' medical records. The detailed description of the project is as follows.

In this project, you are given the following scenario:

For the past two weeks, Travis has been having severe headaches. He decides to schedule an appointment with Dr. Gregory Wallace at McLeod Health Center for the 25th of November. On the day of his appointment, Travis arrives and checks in with the front desk clerk, Ms. Susan Jones. Because this is his first visit, Travis must be added into the system. After giving all of his information to Ms. Jones, Nurse Wise calls him to the back and begins filling out a new patient encounter form for him. She checks his vitals, family history, and enters a brief consultation description. She then walks Travis into exam room 4, where he waits for Dr. Wallace. Dr. Wallace enters the exam room after about twenty minutes and begins the examination. He asks Travis about his migraines, and asks many other questions. Dr. Wallace concludes that Travis needs a prescription for apaprox. He is given a prescription for 30 pills of 200 mg that he is to take in the morning orally. Travis then walks to the front desk to pay for his visit and to get a receipt. Ms. Jones informs Travis that because of his insurance he only has to pay a co-pay of $25.00. Travis pays his co-pay and takes his receipt and leaves to go pick up his prescription.

You are to create Travis's visit from beginning to end using OpenEMR. You must accomplish the following tasks:

- Create a practice
- Create a pharmacy
- Create three users: Dr. Gregory Wallace, Nurse Patricia Wise, and Ms. Susan Jones
- Create patients demographics
- Enter patient vitals
- Enter patient history
- Enter prescription
- Enter Patients receipt

B. Course 2: MIS485 MIS Topics

This course is a capstone course for undergraduate MIS majors and for other students who are interested in MIS topics. It focuses on emerging information systems (IS) and information technology (IT) topics. The topics covered in this course may vary from business data communications, the business practices relating to health information technology, health informatics, Internet security and privacy, electronic business and electronic commerce, data mining and data warehousing, strategic information systems, IS/IT project management, to IT infrastructure.

This course is being offered in Spring 2013. The textbook for this course is "Handbook of Informatics for Nurses & Healthcare Professionals" (5th edition), by Toni Lee Hebda and Patricia Czar [9]. This course covers the following main topics:

- Informatics in Healthcare Professions
- Ensuring Quality and Best Use of Information
- Professional Use of Electronic Resources
- Healthcare Information Systems
- Selecting a Healthcare Information System
- Information Security and Confidentiality
- System Integration and Interoperability
- The Role of Standardized Terminology and Languages in Informatics
- Telehealth
- Evidence Based Practice and Research

In this course, each student is assigned with a group of articles that focus on one area in Health Informatics. For each article, he/she is required to cite one paragraph that best represents the spirit of the article, and then write a 1-2 page proposal for corporate use of Health Informatics using the concepts/techniques/models provided in these articles and relating them to the lectures. Based on the given articles each student will prepare a presentation that summarizes those articles in 15-20 minutes.

This course was taught in the Spring 2013 semester. The instructor's observation of this course is that, Health Informatics topics were well received by the students. Students are aware of the demands of IS/IT in health industry, the importance of health informatics, as well as the shortage of healthcare IS/IT professionals.

C. Course 3:MATH410 Mathematics for Health Informatics

This course examines the mathematics of health informatics. It covers mathematical core competencies that are needed for advanced research in health informatics. Topics include cryptography, biostatistics and linear programming. In addition the course covers new developments in the application of mathematics to health informatics privacy and security.

This course was offered in the Spring 2013 semester. It covers the following topics:

- Descriptive biostatistics and sample distribution
- Probability distributions and Estimation
- Testing hypothesis, regression analysis, nonparametric and distribution-free statistics
- Heath information privacy and security

Four projects are assigned to the students. They are described below:

- *Project 1*: This project involves writing R programs to compute basic statistic such as mean, variance and percentiles, and plotting statistical graphs. R is a free programming language used for statistic computing and graphics.
- *Project 2*: This project involves using R packages abd, asbio and tsmodel, and analyzing breast tissue data.
- *Project 3*: In this project, students use R for Poisson distribution, Estimation and Hypothesis testing.
- *Project 4*: In this project, students select a topic on their own in health information security and write a paper on that.

The instructor found it challenging to teach and design suitable projects for students. Students seem engaged and excited about the topics covered and the projects given in the class.

IV. The Course Modules

A. Course Module 1: Health Information Assurance and Security

This course module introduces information assurance as it relates to health information systems. It discusses laws including Pre-HIPAA (Health Insurance Portability and Accountability Act) legislation, HIPPA, Gramm Leach Bliley Act, Sarbanes-Oxley Act of 2002, Patient Safety and Quality Improvement Act of 2005, and Health Information Technology for Economic and Clinical Health (HITECH). It also investigates strategies and process models for securing information and discusses information assurance and security industry standards such as ISO 17799, Control Objective for Information and Related Technology (COBIT), the Health Information Trust Alliance (HITRUST) Control Security Framework (CSF), ISO/IEC 27002:2005, ISO/IEC 27001:2005, ISO 27799:2000, NIST (National Institute of Standards and Technology) Special Publication 800-53, ISO 27799:2008, ISO 17090:2008, and ISO/TS 25237: 2008 [10, 11]. A number of scenarios or mini-case studies are designed to help students have deep understanding of HIPPA. An example scenario is listed in Table II.

This course module was integrated into the existing Computer Science course "COMP320 Fundamentals of Information Assurance," in the Spring 2013 semester.

B. Course Module 2: Access Control in Healthcare Information Systems

This course module introduces Role-Based Access Control (RBAC) based on the NIST model [12], and exposes students to current open source health information systems OpenMRS [13]. The NIST RBAC model is organized into four step sequences of increasing functional capabilities, which are Flat RBAC, Hierarchical RBAC, Constrained RBAC, and Symmetric RBAC [12]. A series of scenarios are developed to assist students to understand the above four types of RBAC models. Some scenarios are used for in-class discussion, and others are used as homework. An exemplified scenario and discussion questions are listed in Table III [14].

TABLE II. AN EXEMPLIFIED SCENARIO FOR TEACHING HIPPA

Scenario: *Joe applies for a job in a robot factory and must take a pre-hire drug test. Before taking the test, he signs a HIPAA authorization allowing the drug test results to be given to the factory. While taking the test, one of the lab technicians notices that Joe is exhibiting symptoms of another medical problem. When she tells Joe about her observations, Joe decides to take another test. Unfortunately, this second test reveals that Joe has a serious illness.*
Question: *Under HIPAA, should the technician disclose this information to the factory?*

TABLE III. AN EXEMPLIFIED SCENARIO FOR TEACHING HIERARCHAL RBAC

Hierarchical RBAC Scenario: *Because a Doctor role can create a Secretary role, Doctor Kelly makes a Secretary role for John a new hire brought in to update patient information. Often, Larry logs in as an LT (Lab Technician) and performs his assigned lab procedures. Doctor Hart is a Doctor. However, Doctor Hart's thirty years of experience has allowed him to be selected as the hospital administrator and is thereby responsible for all hospital staff. He now logs in as a HA (hospital administrator) role.*
Questions: *1) Map out the roles connecting them with lines in either a tree or inverted tree structure. Next, map the users to the corresponding roles.* *2) Can a Doctor share resources with an LT? Explain why or why not.* *3) Could Doctor Hart, while in the HA role, create a Secretary role like Doctor Kelly did?*

Student will be asked to create roles and permissions on the OpenMRS system given a scenario. The students will also learn how RBAC is implemented using J2EE architecture in OpenMRS.

This course module was also integrated into the existing Computer Science course "COMP320 Fundamentals of Information Assurance" in the Spring 2013 semester.

C. Course Module 3: XML Security in Health Information Systems

This course module provides a basic introduction to XML (Extensible Markup Language) which is widely used in representing health information. Health Level 7 (HL7) versions 3, whose specifications are completely based upon XML is introduced. HL7 is a non-profit organization that provides standards for the exchange, integration, sharing, and retrieval of electronic health information that support clinical practice and the management, delivery and evaluation of health services. Techniques used to secure the data being transmitted in XML format, such as XML signature, and XML encryption are discussed [15].

As a case study, the students are also introduced to Microsoft HealthVault [16] – a cloud based system that helps people collect, store, and share health information with family members and participating healthcare providers. It connects with a variety of third-party applications and devices to help people manage their fitness, diet, and health data. The students will learn how health information is represented in XML format in Microsoft HealthVault. This course module will be integrated into the Computer Science existing course "COMP621 Web Security."

V. Conclusion

This paper describes the new curriculum of Bachelor of Science in Computer Science (BSCS) concentration in Health Informatics Security and Privacy (HISP) we are developing at NC A&T. This is through the joint effort of three departments: the Department of Computer Science, the Department of Mathematics, and the Department of Management. For this interdisciplinary program, three new courses and three course modules have been developed. These new courses and new course modules are described in this paper. One course was taught for the first time in the Fall 2012 semester, and the other two new courses are being taught in the Spring 2013 semester. One course module has been taught, and two course modules will be taught in the near future. The BSCS concentration in HISP is being approved by the university. Our future work will include advertising this program to computer science students, as well as advertising the new courses to students in related disciplines such as mathematics, management, information systems, nursing, biology, etc.

Acknowledgement

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AIRSPACES: Air-propelled Instrumented Robotic Sensory Platform(s) for Assateague Coastline Environmental Studies - A Multidisciplinary Experiential Learning and Research Project at a Minority Serving Land Grant Institution

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Abstract—*AIRSPACES (Air-propelled Instrumented Robotic Sensory Platform(s) for Assateague Coastline Environmental Studies) project funded by the Maryland Space Grant Consortium (MDSGC) provides a model platform to involve a multidisciplinary team of Science, Technology, Engineering, Agriculture, and Mathematics (STEAM) students in a challenging experiential learning and research endeavor that promotes active learning in field and laboratory settings. The overarching goal of the project is to develop an autonomous surface vessel to collect and map selected water quality variables, geo-located with GPS sensors in lakes and ponds on campus, as well as Assateague and other nearby coastal bays for further scientific analysis. The project has been adapted for undergraduate students; however, outreach efforts by engineers and scientists at NASA Wallops Flight Facility have provided an overview of expanded scope of the goals and objectives that may be addressed in a professional setting.*

Keywords—STEAM; Multidisciplinary; Robotics; Active and Experiential Learning; Environmental Studies

I. INTRODUCTION

During a NASA-ASEE Summer Faculty Fellowship at NASA Goddard Space Flight Center's (GSFC) Wallops Flight Facility (WFF), the primary author had been involved with a preliminary feasibility study and simulations for an under-actuated Surface Autonomous Vehicle (SAV) under the auspices of the OASIS (Ocean Atmosphere Sensor Integration System) project [1]. The OASIS project goals are aimed at gathering oceanographic data. It has been adapted and modified to form the basis of the AIRSPACES project with the overarching goal of involving a multidisciplinary team of undergraduate STEAM majors to design and develop smaller SAV platforms instrumented with GPS, compass, and several water quality monitoring sensors that may be deployed in lakes, rivers, and bays in low to moderate wind and current. While design efforts of the project are led by engineering, engineering technology, and computer science students, the scientific objectives of the project are delineated by involved faculty in the School of Agricultural and Natural Sciences (SANS). Undergraduate and graduate students from SANS biology and food sciences program at UMES are also encouraged to participate in the project and deploy the designed platforms to collect and map water quality data in locations of interest. Besides STEAM students at UMES, an exchange student from the University of Maryland College Park (UMCP) also worked on the project in the summer of 2012 and made significant contributions. Johns Hopkins, the lead institution of MDSGC coordinates a summer exchange program for engineering students enrolled at minority serving institutions (MSI) in Maryland that includes Morgan State, UMES, and UMCP. In 2012 summer, the exchange program supported two students from each campus to work on existing NASA related project at one of the other campuses.

NASA engineers and staff have also revived a dormant internal project at WFF titled, ROVER (Remotely Operated Vehicle for Environmental Research) and have integrated experiential learning of undergraduate students in cross-disciplinary teams as a predominant emphasis in the endeavor. To this end, the lead NASA engineer of the ROVER project and supporting staff developed a kit for a remote-controlled SAV platform and provided the kit to the project team at UMES in 2012 summer. The UMCP exchange student worked with UMES students to assemble the mechanical and electrical components (Figure 1) to construct the remote- controlled *ROVER X-2* platform. The ROVER baseline design uses electric ducted fan propulsion to maximize safety and minimize corrosion and *fouling* (Figures 2a and 2b). Remote control is accomplished using a

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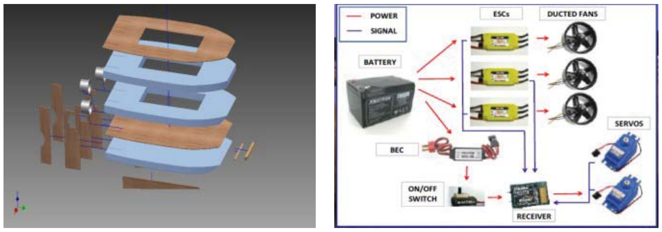

Figure 1 : Rover Kit (Mechanical and Electrical)

75 MHz radio control system, with two receivers onboard for redundancy and increased reliability. Steering is provided by a pair of rudders that deflect water and air in

Figure 2a: CAD solid model Figure 2b: R/C ROVER X-2

forward operation, and deflect water in reverse mode. For the initial phase, a LABQUEST 2 interface [2] was utilized to collect geo-located water quality data such as salinity, pH, dissolved oxygen (DO) and temperature with Vernier sensors [3] on the boat (Figures 3a and 3b). Subsequently,

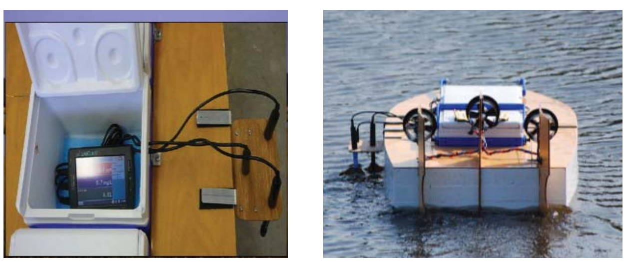

Figure 3: LABQUEST 2 interface with Vernier Sensors on ROVER X2

efforts were also devoted in 2012 summer to replace the LABQUEST 2 platform with GPS integrated ARDUINO microprocessor board [4]. The Vernier sensors were interfaced with the ARDUINO board and the readings were appropriately calibrated. Utilization of the ARDUINO board will lend itself favorably to evolving the ROVER X-2 to a fully autonomous surface vessel for gathering water quality data. Besides lakes and ponds, the ROVER X-2 can be deployed in rivers and coastal bays for long duration (2-hours) in low to moderate wind and current, and could potentially be utilized for ground-truthing satellite data.

II. STUDENT LEARNING, CROSS-DISCIPLINARY COLLABORATION AND TEAMWORK

UMES students have also independently designed and developed a smaller autonomous surface vessel which they call, “Shrimp” (Figures 4a & 4b) under the auspices of the AIRSPACES project. Shrimp has a single propeller and a rudder system for navigation and can be deployed in the autonomous or remote controlled navigation mode in lakes and ponds in low wind and current.

Figure 4a: UMES Shrimp

Figure 4b: Shrimp deployed

A LEGO-NXT brick is utilized for logging GPS and Vernier sensor data in both modes of operation. In the autonomous mode, the GPS and compass units specifically developed for NXT bricks by Dexter Industries [5] are used. NXT code is developed using NXT-G graphical programming as well as ROBOT-C. A multiplexer has been acquired and is being interfaced to a sensor port of the NXT to allow incorporation of additional water quality sensors on the “Shrimp” platform.

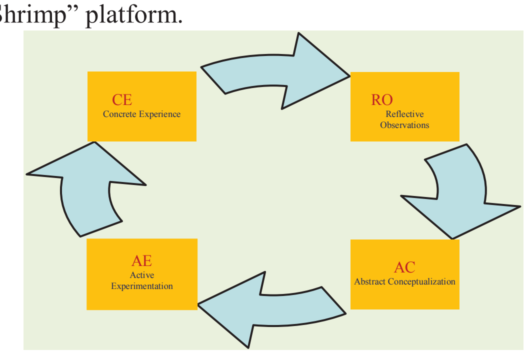

Figure 5: Kolb’s Experiential Learning Cycle

Although the “Shrimp Boat” designed by the students can only be deployed in lakes and ponds under low to moderate wind, it encompasses a rich set of learning outcomes that may be desired by future employers, including NASA. While no formal framework is used to structure the project activities, project leaders have made efforts to integrate all aspects of the Kolb’s experiential learning cycle (Figure 5) [6] to move the project goals forward. From the inception of the project, the student participants hold weekly meetings and discuss success and pitfalls with the action items from the previous week and set goals for the following week. The faculty supervisors are present at these meetings for advice and to ensure the project remains on track, but senior students are encouraged to take leadership roles and to keep a vibrant vertically integrated group together. Interested engineers, scientists, and staff from NASA Wallops Island facility which is about 70 miles from UMES campus are invited to attend these meetings.

III. ONGOING EFFORTS AND RESULTS

The data collected using LABQUEST 2 on the ROVER X2 needed significant post processing to retrieve data related to

Figure 7a & 7b: Desired and actual path followed by boat

specific points of interest. This was one of the reasons why efforts were devoted in the latter half of summer of 2012, to use ARDUINO UNO with an independent GPS shield and input pin interfaces to read Vernier sensor data. In all circumstances appropriate measures were taken to calibrate the sensor data. Use of the ARDUINO microprocessor to collect geo-located sensor data also provided the basic foundation for making the ROVER X2 fully autonomous. Student transitions have slowed these enhancement efforts that are currently ongoing.

Figure 7 c: Temperature data recorded at desired locations

Similar data collection efforts were undertaken with the "Shrimp" running on remote control in water bodies within the UMES campus. However, from the very inception efforts were undertaken to make the Shrimp platform autonomous. To this end, a compass sensor was used in conjunction with the GPS sensor for autonomous navigation. NXT brick used with this configuration was utilized for the trial run in one of the ponds in Ocean City, Maryland, close to campus in the late summer of 2012 as illustrated in Figures 7a, 7b, and 7c. Five GPS points were selected in the pond. The points were connected by straight lines as shown in Figure 7a to describe the desired path. In this trial run, a proportional control was used to turn the rudder depending on the heading error. Figure 7b shows the GPS track actually followed by the Shrimp to get to the desired locations as it fights wind, current, and other disturbances. Although path followed is not accurate, the desired locations are reached, and temperature data are collected at appropriate locations as shown in Figure 7c.

Geo-located sensor data could be conveniently displayed using the cloud based GPS Visualizer software which is available online free of charge [7]. Participating students could easily use the tool with minimal instructions.

The ROVER X2 successfully negotiated the coastal waters in the Assateague Bay under remote control. Interested readers can watch the video footage at the URL: http://www.youtube.com/watch?v=9yUGZkYGhQ&feature=youtu.be.

Complete autonomous operation of the ROVER X2 using ARDUINO board is one of the key aspects of future plans. Due to limitations in the NXT sensor ports it was not possible to log more than one water quality variable using the only available sensor port during the initial autonomous runs of the Shrimp. Efforts are now underway to appropriately interface a suitable multiplexer to the available port attach upto four Vernier water quality related sensors to the Shrimp platform. Efforts are also underway to improve the control algorithm for the autonomous navigation of the Shrimp.

IV. CONCLUSION

Intense STEAM courses particularly in engineering, mathematics and, the sciences fail to inspire students. The informal out-of-classroom setting of projects such as AIRSPACES allows students to see how various components of the curriculum fit into real world problem solving endeavors. Enforcement of turf lines in academia, are often promoted by school and departmental administrators from motivations that are not necessarily "student-centered" or "learning-oriented" but rather driven by ease of "bean-counting" and limits confined by perceived/imposed "reach of authority". NASA personnel routinely perform "science driven" missions that integrate intense mathematical analysis, safety considerations, and, engineering design and problem solving that help diffuse traditional disciplinary lines that can form artificial boundaries in academia. Involvement of NASA and other federal agencies in cross-disciplinary projects such as AIRSPACES, involving undergraduate students promote dimensions of learning through co-curricular activities that cannot be addressed in a typical formal curriculum. Annual surveys developed in consultation with collaborators assess academic and life-skill outcomes and document student feedback and comments.

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Integrating design and bridging activities of the engineering and the design college:

Merging language cultures, creativities, and perspectives

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Abstract – **This paper describes a unique and an innovative pedagogical experiment conducted between engineering and design faculty. The goal of the experiment is to create innovative bridges between student design and creative activities and projects that would converge and unify two different approaches: Engineering and Industrial Design. In this class, third and fourth year students from Material Engineering and Electrical and Computer engineering are teamed up with the students from the graduate level Industrial design studio. Together the teams are assigned to a major industry sponsored design project. This paper discusses the class concept, execution, outcomes, reflections, surprises, and will provide discussions on designing, implementing, and modifying such classes. This work mixes students with different academic levels from three departments of the engineering college together with the first year graduate students in the college of Design. They are all working on a semester long industry sponsored design activity. The paper describes the goal of the experiment, the implementation, and the unique findings of the experiment. In particular, this paper focuses on early results of this pedagogical experiment. Discussions are provided about the issues of implementation, identification of the hurdles, difficulties, and the commonalities. Possible approaches and paths to make such classes possible in diverse environments and cultures are provided. Faculty, students, and industrial client reflections and observations are included. Finally attempts to bring about some guidelines for initiating, conducting daily activities, project planning, and ways for bridging the cultural gaps between the seemingly separated fields are described.**

Keywords – Engineering design, multidisciplinary work, studio

I. INTRODUCTION

One of the most important characteristics of engineering and industrial design education programs is the systematic approach to design. The role of design and design experience is of essential importance in both of the programs. Both of the programs emphasize problem solving, system level thinking, and practical components (studios, labs, and design elements) of the curricula. Students are ideally taking many classes that would build the foundations of their thinking, problem solving, methods, tools, and analysis. Then in addition in the design labs, studios, and similar platforms students are supposed to learn the practical knowledge integration. The design elements will help synthesize their learning. Working on projects helps achieve that with many interacting elements such as teamwork, collaborate learning, research, planning, implementation, testing, documentation, and presentation.

The faculties involved in the programs have always realized that each approach (the engineering and the design approaches) is valid. The two seem to have constructive overlaps, and huge complementary relationship. At our school this has been testing in more than a few cases. We have tried invited lectures from design program in engineering classes (especially capstone) and have engineering faculty lecture for the design classes. In all of the trials the interaction helped to excite the students and enhance their perspectives. Consequently, the natural step would be trying to see how both approaches could coexist in the same class. That is how this experimental class was initiated. The question was how to create overlapping classes that would meet and interact, play, learn, and create in the same environment. Our main focus was to empower the student. The students, their experience and their growth have always been the focal point for curricular development in our perspectives.

The main purpose of this experiment has been to enrich the experience of the engineering and industrial design students, as well as the faculty involved. Each program has unique capabilities and approaches focusing on slightly different points of the design process. By combining the engineering and the industrial design approaches and sharing the process, we would enrich the students' experience of the overall design process.

II. THE MAIN PERSPECTIVE

The process of design is a multistep synthetic process that starts from an idea (from thought) and ends up with an implemented design (to a thing). In this creative, convoluted, and multifaceted approach students will learn different aspects of the journey from thoughts to things that encapsulated multiple aspects of what design really encompasses [1-4].

Students from different programs were brought together into this shared studio environment. Each group maintained their own assignments, reporting, and developments, as well as their respective design classes. However, they were required to work together in the studio, interact, and share their experiences. The students also were encouraged to attend the lectures of the different groups. For the common shared studio experience, the three leading faculty were actively engaged in presentations, discussion, and consultations.

The shared experience of the class was set up as a studio. There were three groups of students who participated in the experiment.

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The first was a group of graduate students taking a six credit studio in the Industrial Design Department at the design college. By training, the graduate group had the most intensive study and depth in defining products and functionalities. So, naturally they would be the engine that would lead and derive this experiment. There were two international visiting students (from Denmark and Sweden) from design schools in Europe who were in the graduate class. Their perspectives and approaches also helped all of us see even another side of the culture of design and synthesis.

The second group was Electrical Engineering students taking a 2 credit junior level engineering studio class (the first studio in college of engineering at our school). These students were working on practical data collection methods based on LABVIEW environment and sensor integration for their studio class. They were also required to do a major design experience. This group was strongly advised to attend all of the lectures that were presented in the graduate class for the Industrial Design experience. The students were strongly encouraged to do that at the beginning. After few weeks, they would look forward to the lectures and presentation and would invite other student friends from other classes to also attend and participate in the lectures and presentations. They truly believe the perspective for the industrial design enhanced their maturity of understanding of the process of analysis.

Finally we had another group of engineering students who were taking multidisciplinary senior design (capstone class) for 3 credits. These students were senior in Material Engineering program. Their project for the class was the one that was the main project for this experiment. This group of students was also encouraged to attend as many studio activities. At the beginning they were very reluctant but later in the term they were spending more time in the common activities. They also believe the activities presentations and interactions enriches their experience, but they also had many demanding classes during the term, which would naturally reduce their available time. However, during the last part of the term they became active participant in the synthesis and analysis process.

The class was set up with the main lecturer from the industrial design program. In addition two collaborator faculties from Electrical Engineering and Mechanical Engineering were also involved.

A. Defining a Unifying Project

In order to make a valuable shared platform experience, a focused and central collaboration platform was needed. We decided to have a common final design requirement. A project with practical and challenging requirements with meaningful purpose and deadline was needed. Consequently, the team decided to work on an industry-defined project that was provided by one of the nationally known collaborators.

The idea was developing clearly. While going through this experience by mixing the lectures, applications, discussions, and collaborations, we would also work with a major industrial partner that would require realistic outcomes. In this case the partner was a major culinary kitchenware company that has very close and good working relationship with the Industrial Design program. Their product managers suggested the project. They created the project definition and were excited to see our team with mixed, multidisciplinary, multilevel, and multitalented group. In particular the managers were excited to see the collaboration between the design and engineering students.

The project was to evaluate some of the existing products and identify changes, modification, and future designs for the company's major electrical line of products. The company's specific requirement was to have a solid product definition, with valid market study, gap analysis, and engineering inputs for the product ideas and modifications. In addition the teams had to identify a design for a whole new product for them. To help, the company shared many of their documentations to our team. The managers were also available for questions, suggestions and idea evaluation at all times. We also decided to have periodical evaluation and discussion sessions with the company. For the final presentation the company would bring few of their managers and visit us on campus.

B. First stage: products and definition

The industrial design students had more experience in product definition and market analysis, they led the project by setting up task analysis, user feedback system, and product definition. At this early stage the engineering teams would work as observers and collaborators. They would attend discussions, lectures, and work sessions that were led by the industrial design team to do market research, define product evaluation rubrics, conduct some consumer surveys and test the products. The engineering team would help the design team to understand the engineering specifications, major electrical, material, and mechanical definitions, questions and possibilities and would also take part in the testing of the product as users. At the end of this stage a meeting was set with the industrial/commercial partner. Ideas were shared and thoughts were presented. Good feedback was generated to help the team focus on to the company's needs and possibilities.

C. Second stage: Systematic product analysis

After the students used the product and understood how the product and 2 to 3 of the competitor products were used, they had to look deeper in the product. The products engineering specifications, power, heat, efficiencies, materials, manufacturing issues and all the details were carefully analyzed. The engineering student led this and the industrial design students would be helping, observing, and asking very well thought and specific questions. During this stage the heating surfaces were analyzed for temperature distribution, infrared imaging of all products were obtained. The basic electrical components were examined and motors and displays were opened up and carefully characterized by the engineering students.

This process helped all students. In particular, the industrial design students used this opportunity to identify the needs and market gaps and started their ideas of future needs, developments and future modifications for a better product definition by the company.

D. Third Stage: Idea generation, specifications and definitions

In this stage all teams, led by the industrial design students, worked together to identify the requirements, engineering possibilities, and modifications that would help the company with their current products as well as future product lines. The Industrial designer team would generate functionality charts and product definitions. They would provide ideas, requirements, and product sketches. The engineering team would help identify what is possible as well as what are efficient and good engineering decisions. Based on the discussion, presentation, ideas generations, and product definition, a possible set of specifications were created by the whole group.

E. Fourth Stage: Finalizing concept creation, suggested modification, documentation, presentation

In this stage the team worked together to document their findings and ideas. Product sketches, possible specifications, possible current and future engineering developments and modification were identified. The industrial design team led the documentation and sketch generation as well as the presentation. The engineering teams provided the support of the ideas, specifications, and engineering considerations.

This synthesis was the most amazing process for all of us to observe. At the end when the teams would suggest a modification for the current products, they would provide reasons and possibilities from a broad aspect of the product perspective. This included, usage, user perspective, engineering possibilities, material and manufacturing possibilities, future product sketches, and specifications.

III. The Challenges and Observations

One of the most important parts of this experience has been observing how the different engineering groups and the industrial designers interact and convey information.

Generally speaking, a typical engineering design in an undergraduate program starts with specifications and teams need to deliver a system that would satisfy the specifications. This project was different, since the final deliverable item was product definitions and ideas. The main activity in this detailed and time consuming collaboration was a process of identification, examination, and characterization of products, specifications, and functionalities. This posed many challenges for all engineering students. The experience helped all of the teams profoundly understand and appreciate the design aspect and importance of this type of synthesis.

The electrical and computer engineering team understood the importance of the lectures and discussions led by industrial design team very early on and tried to be present in all of them to get to know the right perspectives and approaches used. Consequently, the electrical and computer team became a useful resource from early on. The material engineering team eventually became used to the process. They were great resource and provided valuable detail material analysis and suggestions. By the end of the term, the final report and presentation included a comprehensive array of elements that spanned all aspects of design, aesthetic, functionality, and specifications that is required by a good product design process. The team that was the main communicator and managed the process the most effective was naturally the graduate design students.

IV. Some Reflections

Based on the feedback from faculty reviewers, industrial partners, and students' reflections, our experiment was very useful for all patrons. Engineering students realized a better process of careful and creative definition of a product and coming up with specifications and industrial designers understood the engineering detail, rigor, and implementation. Consequently, this experience was of great value.

However, it did not have much of detailed traditional engineering design elements. We spent most of our time in the left side of the product development continuum. The Electrical and Computer Engineering team recognized the lack of traditional design, however, they valued the experience and their contribution as essential part of the design process.

The Material Engineering students were more comfortable with their role in this project. We believe it is due to the fact that their area is much more closely associated with the material science where the development process is of great value and the detail product specification and delivery is not the only guiding light. Consequently, this did become a more valid design experience for that material engineering team.

Though there were still some technical questions unaddressed, the overall quality, fidelity and detail of the resulting work was a notable improvement over studio design projects that do not include interdisciplinary involvement. The engineering teams introduced new resources and insights that allowed the design students to advance the quality of their thinking and execution. The resulting documentation (technical drawings, animations and computer models) was very high caliber.

V. The Final Remark

Students of all teams did believe that they had a great and rich experience working with many different perspectives and associating with an active and creative industrial partner. The client was very happy and indicated that they were pleased with the major contributions of each group. They would like to continue these types of projects and idea and product definitions with the team at our program. The client also clearly identified the value of these types of projects for the engineering students.

In conclusion, this experiment has enhanced our experience regarding broad possibilities of integrating students from different backgrounds to focus on a systematic collaboration in a synthesis/design project. Having the different perspectives and celebrating and enhancing them, together with team teaching and coaching by various instructors have a great potential to be a versatile and effective platform for a true inquiry based collaborative learning and critical thinking as well as knowledge integration.

It is important during this process to have very effective and frequent feedback process and make sure that each group of students have faculty coaching and guidance as a group as well as within the whole class settings.

As usual the challenge of any diverse design team would be to make the deliverables in small pieces with frequent deadlines in the early stages, and more challenging and integrated pieces at the later stages.

During such efforts, the leadership of the project is of utmost importance. Our experience shows that on the left side of the cycle the leadership needs to reside with the Industrial design and on the right side of the cycle with the engineering team.

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Integrating International Students' Contests with Software Engineering Courses

Lessons Learned and Best Practices

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***Abstract*— There are many general computer contests targeting undergraduate and graduate students. The prizes vary from cash, trip, fame, conference participation and others. Contests can be class, school, national, regional or global.**

This workshop aims to share the knowledge and experience of different educational institutes of integrating students' contests with academic software engineering courses. The main goal is to identify, discuss and promote best practices to properly benefit from such integration.

Keywords*— *Teaching Software Engineering.

I. Background

There are many computer contests that can be integrated with software engineering courses [3]. Such integration leads to solving some of the typical problems in courses that include software development projects like capstone and software engineering courses [3]. It can be argued that this integration results in raising the quality of the projects developed in such courses (when properly aligned with the time-line and learning outcomes of the courses). Contests that can be integrated with software engineering classes include Microsoft Imagine Cup, Google Apps Developer, IBM/IEEE Smarter Planet and Score [3].

II. The Goal of the Workshop

The main goal of the mini workshop is to identify, share and discuss possible contests that can be integrated with software engineering course.

The following are some of the possible topics:

- Evaluation of available software engineering related contests.
- Best practices for integrating contests with software engineering courses.
- Teaching software engineering using contests.

III. Anticipated Audience

The workshop is intended for faculty members who desire to gain experience in integrating contests with software engineering courses. The model can be applied to other science and engineering courses as well. The workshop is open to all researchers and industrial practitioners interested in teaching software engineering. The attendees have to be registered in the conference. The expected number of participants is 10-15.

IV. Learning Outcomes of the Workshop

Attendees of the workshop will gain an insight about different computer related contests and how they are integrated with software engineering courses. They will share experiences with educators from different countries and cultures about the benefits, challenges and logistics of such integration.

V. Workshop Activies and Agenda

The following is the initial agenda of the workshop:

- Goals, background and workshop framework (15 minutes). The organizer will briefly present different samples of computer contests that can be integrated to software engineering courses. He will also present his experience in integrating one of the contests with academic programs [2]. A suggested framework to evaluate contests will also be presented [3].
- Attendees will be divided into groups. Each group will consider one contest and how it can be integrated (30 minutes).
- Important findings by attendees will be shared by short presentations. Duration per group will depend on number of participants (40 minutes).
- Wrapping up session (5 minutes)

VI. Post Workshop Activities

Interested attendees will be invited to co-author a paper about the findings of the workshop. The findings can lead to

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suggest changes and modifications to existing contests. The suggestions will be delivered to contests organizers as recommendations. This can lead to improve the quality of related contests and eventually will encourage more participants to join.

VII. BIOGRAPHY OF ORGANIZER

Dr. Amir Zeid is an associate professor of computer science at the American University of Kuwait (AUK). He has above 60 publications in international conferences and journals. Dr. Zeid's research interests include: global software engineering, cloud computing, gender-issues in computing and using technology to promote environmental sustainability. In addition, Dr. Zeid is interested in research about creative methods in computer education. He received numerous research funding grants and international awards. Throughout his career at AUK, Dr. Zeid has been working on encouraging student innovation. He led three teams of AUK students to win the prestigious Microsoft Imagine Cup Competition for the Gulf region in two different categories. He is a member of ACM and IEEE.

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Individual Sustainability: Preliminary Research

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***Abstract*—All societal change begins with the individual. One cannot do for a community what one cannot do for one's self. The topic of Individual Sustainability is a controversial one, as students often appear to be unable to align their demonstrated behaviors with their admirable values related to sustainability. Individual behavior creates the foundation for action in social, economic, and environmental sustainability, and potentially guides our ability to work with one another to make life-affirming decisions. In short, it is a matter of aligning our day-to-day behaviors with our well-stated values that will result in greater sustainable community action.**

The general objective of this research is to help students align their behaviors with their values. This change is a necessary precursor to demonstrating sustainable community behavior. We believe that creating a "cognitive dissonance" between an individual's values and behaviors tends to encourage individuals to balance more effectively the self-knowledge that motivates intentional personal development towards more sustainable behavior. While most students indicated they believed their behaviors consistently reflected their values, the students' broad range of responses and survey responses revealed behaviors quite in conflict with their values.

Keywords—sustainability, individual sustainability, systems theory, cognitive dissonance

I. Introduction

All societal change begins with individual change. One cannot do for a community what one cannot do for one's self. The topic of Individual Sustainability is a controversial one, as students often appear to be unable to align their demonstrated behaviors with their admirable values related to sustainability. Individual behavior creates the foundation for action in social, economic, and environmental sustainability and potentially guides our ability to work with one another to make life-affirming decisions. In short, it is a matter of aligning our day-to-day behaviors with our well-stated values that will result in greater sustainable community action.

This research, funded by two National Science Foundation grants (IEECI Grant #0933948 and EEC Grant #1158728, E. Pappas, P.I.), is one of more than a dozen projects we are conducting on Individual Sustainability (also referred to as Sustainable Personality), which we define as follows:

Sustainable individuals are characterized by creating harmony, interconnection, and relatively high levels of self-awareness in their values, thoughts, behaviors, and actions as well as cultivating continued individual growth in their physical (health), emotional, social, philosophical, and intellectual abilities.

Individual sustainability includes possessing a well-developed and demonstrated value system that acknowledges the importance and interconnectedness of all global biological and social systems, and our appropriate place within them.

Nearly 250 students in an undergraduate science and technology course were given a 50-item multi-source feedback online survey (on PersonalityPad.org) that assessed individual sustainability in the following contexts: emotional, social, health, economic, and intellectual. Following a post-test, reflective essays, and a later follow-up survey, results revealed that most students found their behaviors related to individual sustainability did not always align well with their well-stated values.

II. Objectives

We believe that creating a "cognitive dissonance" between an individual's stated values and demonstrated behaviors tends to encourage these individuals to balance more effectively the self-knowledge that motivates intentional personal development towards more sustainable behavior. In other words, students experience a cognitive dissonance when they realize their behaviors related to sustainability do not reflect their values. We expected students would work to align their behaviors with their values.

This research had the following three primary objectives meant to encourage students to change their everyday behaviors:

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1) to facilitate individual sustainability awareness;

2) to study the cognitive dissonance that occurs when students realize that their behaviors related to physical, emotional, social, economic, and intellectual sustainability do not align with their stated values; and

3) to determine, when faced with this inconsistency, if and how students' behaviors motivated individual change.

III. LITERATURE REVIEW: INDIVIDUAL SUSTAINABILITY

An important context missing from most discussions of sustainability, especially within academia (or society in general), is individual sustainability. Living a sustainable lifestyle includes creating harmony, interconnection, and relatively high levels of awareness in one's values, thoughts, and behaviors, as well as maintaining an increasing control over one's physical, emotional, social, philosophical, environmental, and intellectual life. The general dispositions that support individual sustainability are awareness, motivation, and the ability to engage in intentional self-development. As well, individual sustainability includes possessing a well-developed and demonstrated value system that acknowledges the interconnectedness of all global biological systems and our appropriate place in the Natural World.

A considerable number of psychologists, educators, philosophers, and engineers have noted the complex nature of what constitutes personality and how it manifests itself, and some have indicated that these characteristics (or skills) are dependent upon each other in order to produce a highly functioning individual. What these writers have in common is the understanding that personality is related to a variety of factors, and that these factors comprise a complex system.

If one understands the complexities and interconnectedness of one's own individual sustainability contexts, then he or she might well transfer this systems understanding to address community environmental, social, and economic problems[1,2,3]. Such growth may be difficult for some, and the challenges to individual development may be hindered by personal, career, family, and psychological issues, as well as a dysfunctional relationship with time or technology [4].

The are countless historical roots here. Bertrand Russell [5], in his lecture on *Belief*, outlines the mutually dependent components of a holistic intellectual life which consists of "beliefs, reasoning, theories of knowledge, and metaphysics...out of which our philosophical outlook evolves" (p.139). Hegel [6] views the "whole" of existence as a non-self-contradictory complex system. His philosophy always considers Reality as a whole. James [7] delineates the constituents of the self as "the material self, the social self, the spiritual self, and the pure ego" (p.292). These factors, he says, provide the human foundation for self-seeking and self-preservation, an understanding of one's self in the broadest sense.

Dewey [8] refers to consciousness as composed of "natural and social operations" (p.244) and is a "connected course of experience" (249). Further, he proposes the synthesis of human processes "in which elements combine into complex wholes and series" (p.245). He notes "knowing, willing, feeling [are the] name states of consciousness" (p.252), and acts and attitudes all found in experience. He later refers to consciousness as a "system of truth" (p.257). A few years later, Dewey outlines a similar system guiding successful education: "Education, we received from three sources—Nature, men, and things"…that the "concurrence of three kinds of education is necessary to their completeness (p.108). Each kind of education, he stresses, determines the success of the other two.

Maslow [9] describes the 13 characteristics of a self-actualized individual as follows:

1) Superior perception of reality
2) Increased acceptance of self, others, and of nature
3) Increased spontaneity
4) Increase in problem-centering
5) Increased detachment and desire for privacy
6) Increased autonomy, and resistance to enculturation
7) Greater freshness of appreciation, and richness of emotional reaction
8) Higher frequency of peak experiences
9) Increased identification with the human species
10) Changed (the clinician would say improved) interpersonal relations
11) More democratic character structure
12) Greatly improved creativeness
13) Certain changes in the value system

He notes these characteristics as a path to "a fuller knowledge of, and acceptance of, the person's own intrinsic nature, as an unceasing trend toward unity, integration, or synergy within the person" (p.25).

Rogers [10], a decade of so later, notes the "Qualities of a Person of Tomorrow," twelve characteristics of a highly functioning and balanced individual, a list clearly reminiscent of Maslow's and characterized by "a world in which the mind, in its larger sense, is both aware of, and creates, the new reality" (p.352). They are as follows:

1. Openness
2. Desire for authenticity
3. Skepticism regarding science and technology

4. Desire for wholeness
5. The wish for intimacy
6. Process persona
7. Caring
8. Attitude toward Nature
9. Anti-institutional
10. The authority within
11. The unimportance of material things
12. A yearning for the spiritual

Capra [11] offers his systems view of personality "based on awareness of the essential interrelatedness and interdependence of all phenomena—physical, biological, psychological, social, and cultural" (p.265). He notes that there is no established framework for such an approach, either conceptual or institutional, that would accommodate paradigm change, but that individuals, communities, and networks develop their own approaches to such growth. In addition, Capra notes that "systems thinking is process thinking, form becomes associated with interaction, interrelation with interaction…" (p.267). Csikszentmihalyi [12] takes a similar interactive approach and reflects on the complexity of consciousness, stating that knowledge or intelligence need be in harmony with feelings and actions—"to create harmony between goals and desires, sensations and experiences" (p.207).

Some writers, like Thoresen [13] delineate a sustainable personality, what she considers responsible citizenship, from the perspective of "empathy, relationships, critical skills, co-operation, self-awareness, equality, feeling concerned" (p.8)—individual attributes that would increase our chances of survival. She groups over two dozen human behaviors and values into three general areas: "Biological determinants, Social expectations, and Moral imperatives." While Thoresen's approach is not quite as expansive and inclusive as Maslow, Rogers, or Capra, her approach does cover an extensive variety of intellectual, affective, and ethical skills and dispositions as well as provide a foundation for instruction in higher education.

Encouraging curriculum change in higher education to foster individual sustainability, Kagawa [14] suggests problem solving skills, creative and critical thinking, and self-reflection as necessary components to encourage sustainable development and points out "And what kind of development do we want to sustain: social, cultural, political, spiritual and/or economic? (And are these separable?)" (p.325).

Education for sustainably should foster learning new attitudes, perspectives, and values that guide and impel people to live their lives in a more sustainable way" (p.63), according to Gadotti [15]. Feeling, simplicity and quietness, identity, justice, and a culture of peace characterize sustainable societies, notes the author, who further encourages political and social revolution based on an "anthropocentric and individualistic view of humanity's well-being" (p.96). Stone's [16] approach to curricular change includes instruction in "cognitive, emotional, active, and connectional" (p.44) topics, similar to integrating approaches to personality in Goleman, Barlow, & Bennett [17]. Employing a similar structural format, Lowenstein, Martusewicz, and Voelker [18] focus on a social approach related to the discourses that shape our modern industrial cultures.

Three methodologies inform this work. First, this research employs a *systems theory* methodology (which stresses that the interrelationship of factors in a unified system depend upon the unpredictable nature of the relationship of these individual factors). Second, we consider *values*, whether they be corporate, government, community, or individual, as the principle guiding force for defining and solving sustainability problems [19]. Third, following years of researching and teaching sustainability, we understand it is an individual's demonstrated *behaviors and skills*, not simply his or her *knowledge* of, or *attitudes* toward, sustainability that support and promote sustainability. It appears that offering the opportunity to learn about sustainability does not necessarily lead to more sustainable behaviors [20]. We recognize that developing an individual's values may provide motivation to behave in a manner more congruent with sustainability principles [21]. This transformative process employs instructional theory and methodologies that offer students greater insight into, and understanding of, sustainability problems...far greater than traditional instruction that focuses on increasing "student knowledge" or learning basic laboratory skills.

Creating a "cognitive dissonance" between an individual's values and behaviors tends to encourage individuals to balance more effectively the self-knowledge that informs decision making and problem solving [22].

A topic we find missing in many of these works is significant discussion of reciprocal influences among the factors noted by authors, that each factor influences the others in unpredictable ways (See Discussion).

IV. METHODOLOGY

This study utilized a unique multi-source feedback platform developed by three James Madison University faculty members: Morgan Benton, Jesse Pappas, and Eric Pappas. Personality Pad (www.PersonalityPad.org) is a fully automated on-line experience in which participants generate and interpret individual sustainability feedback based on their values, as well as several friends' and/or family members' external perspectives on their (the participants') values and behaviors, in order to engage in intentional self-development in the direction of sustainable thought and action [23]. The site offers five sources of multi-source feedback based on methods commonly used in organizational settings for professional development. Research has consistently shown that, when conducted effectively, the multi-source feedback process can lead to greater evaluative accuracy and higher levels of participant acceptance compared to single source evaluation alone [24]. It is also more likely to increase motivation and lead to specific developmental actions [25].

In a critical thinking General Education class, nearly 250 undergraduate students in a wide variety of majors participated in the study; 80% were first-year students. These students were given a 50-item survey that assessed individual sustainability in the following contexts: emotional, social, health, economic, and intellectual using a seven-point Likert scale (strongly agree—strongly disagree).

Sample questions:

I am a person who

...feels the need to have a lot of material possessions (Economic context)

… demonstrates openness, acceptance, and respect in my relationships (Social context)

…actively seeks new knowledge (Intellectual context)

…frequently experiences significant stress in my life (Emotional context)

…actively pursues good physical health habits and activities (Health context)

"Friends and Family" responses were phrased in this manner:

(*Student's name*)…actively pursues good physical health habits and activities.

Following the survey, students were directed to reflect upon their responses and write short reflective essays to the following questions: 1) Do you think the values expressed in the survey are relevant to your personal life? and 2) Do you demonstrate these values in your daily life? Five weeks later, a ten-question follow-up survey and narrative required students to assess whether the previous surveys and reflections resulted in any changes that helped them align their behaviors and their values related to individual sustainability. Each student was asked to list up to five behavioral changes she experienced due to participating in this study (if, indeed, she had experienced any changes).

Study students were awarded a small amount of course credit (equal to two homework assignments) for simply completing the study, regardless of their investment in the study or quality of their participation. In general, students seemed interested in the study since the focus was on personal development. For this reason, we consider students' responses and narrative essays mostly authentic. The study was conducted with no class discussion, apart from clarifying the instructions.

While most students initially indicated they believed their behaviors consistently reflected their values, the students' broad range of responses on the seven-point Likert scale and reflective responses revealed behaviors quite in conflict with their values (and sometimes disruptive to personal lives). Most students in this study noted at least three areas (three of the questions for which they received feedback) in which the imbalance was substantial or disturbing.

Summarizing the 50 responses, the post-test, and follow-up survey here for 250 students will be limited to the most salient trends related to the objectives of this research. The cognitive dissonance and behavioral changes reported by students were greatest when their individual perceptions of themselves were compared to the perceptions of five of their "Friends and Family" (in which friends and family responded to the same 50 questions— evaluating *the student's* individual sustainability). This multi-source feedback was especially valuable, considering the friends and family feedback was anonymous, offering these friends and family members the opportunity to honestly evaluate the participant.

V. RESULTS

In general, 97% of students agreed that "this survey addresses skills and habits you generally consider to be valuable," while 89% believed that they "demonstrated (in your daily life) the skills and habits noted in the survey that you consider valuable."

On the follow-up survey, 75 percent of students agreed to the following statement: "Based on the personality feedback I received during this study, I have some personal changes in mind that I would like to pursue."

Similarly, Table 1 and Table 2 show the follow-up survey responses related to individual development and students' intention to make personal changes.

TABLE 1: On a scale of 1-10, how much did you learn about yourself (overall) by participating in this study?

I didn't learn anything about myself.	0%
2	2%
3	6%
4	6%
5	12%
6	24%
7	27%
8	15%
9	6%
I learned a whole lot about myself.	3%

TABLE 2: On a scale of 1-10, how likely are you to pursue a personal change based on what you learned about yourself?

Not at all likely	1%
2	1%
3	7%
4	5%
5	15%
6	18%
7	29%
8	15%
9	5%
Extremely likely	5%

Overall, 81% of students reported actively working on behavioral changes due to their participation in the study. Of this group, the average number of changes reported was 2.4 per student. Common changes reported included emotional changes (reducing stress, improving relationships, worrying less); academic changes (organizing more effectively, improving time and study efficiency, being more open); and self-image changes (being more confident and outgoing, being more empathetic, eating better, working out).

Surprisingly, when asked (on the follow-up survey) about who had a more accurate perception of their (students') overall individual sustainability, 66% reported that their friends and family did, while only 34% of students indicated that they, themselves had a more accurate perception. Almost 89% of students agreed that "periodically reviewing external feedback about myself (e.g. from friends and family) could help me make productive personal decisions."

VI. DISCUSSION

It is clear from this research that, before participating in the study, students generally did not consider whether their behaviors reflected their values, or if they did recognize this, they refrained from intentionally attempting to align these factors. As well, only after the study do students report considering aligning behaviors and values an issue related to personal integrity or authenticity.

Our results in this study are encouraging, and we continue to research these effects. If students' self-reports are to be believed, this study has yielded significant personal behavioral change in students. Many students reported that their relationships, study behaviors, time use, and relationship with technology have improved. As well, because they experienced some success in these improved behaviors (that is, behaviors aligned with their values), students' narratives reflected an improved sense of personal integrity and self-esteem. In particular, many students reported a decrease in stress and anxiety, as they tended to improve their behaviors in family and friends' relationships. It is true here, perhaps, that if a change in one's behaviors improves daily life, then those behaviors tend to be repeated and perhaps become a personality characteristic [26].

Short educational interventions, such as the one described in this paper, may be of particular value to educators. The current study required no more than two hours of a student's time (at home), very little or no classroom time, and yielded what we consider significant educational results. More research, of course, is needed. In the two next years, we will conduct longitudinal studies involving the now 1200 students who have already participated in Personality Pad research.

One of the major challenges to this systems approach is that the five sustainability contexts influence each other in complex ways, and understanding these interactions requires increased awareness. It appears that determining individual sustainability depends upon the careful and complete *assessment and evaluation* of a range of human factors. As noted earlier, because sustainability factors comprise a *complex system*, a change in one sustainability factor is likely to result in an unpredictable change in the others. It is quite possible that one context in sustainability will be quite in conflict with another—that is, that making a positive change in one factor may produce some unwanted effects in another. Too little work has been done to understand and assess the reciprocal influences this complex system creates.

VII. CONCLUSION

Measuring educational outcomes using behaviors is the central objective of our efforts. We believe that student behaviors, more than content knowledge or attitudes, measure learning more thoroughly and effectively (especially long-term). The fact that successful behaviors may tend to become personality characteristics drives our research and experimentation. Our research indicates that students' desire for integrity and individual value consistency tend to move them to align their values and behaviors.

We fully recognize the limits of self-report, especially when a study is conducted in an academic class, but the overwhelming positive responses related to improved behavioral change are encouraging and support our ever-evolving work in this area. We recognize, as well, that these changes may be temporary, hence we will conduct longitudinal research in the semesters to come.

We further recognize that the Sustainable Personality Survey is in a developmental stage; hence, the results could be questioned. But, as we have developed the survey (this is the second iteration of published results), our results are remarkable consistent. Our next version of the survey will be considerably improved.

VIII. FUTURE WORK

Two substantial National Science Foundation grants have afforded us the means for conducting nearly a dozen studies related to individual sustainability, and values and behaviors, over the past two years. Our work developing the multi-source feedback platform, Personality Pad, and the *Sustainable Personality* survey (here referred to as Individual Sustainability), continues, and following further reliability and validity tests, we plan to have a version suitable for wide distribution in 2015. The Personality Pad platform will be ready for more widespread use in 2014 and will provide multi-source feedback in a wide variety of applications, both in academia and, as well, for government organizations, non-profits, and other organizations that measure growth and success in terms of human productivity rather than profit.

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Associations of Students' Creativity, Motivation, and Self-Regulation with Learning and Achievement in College Computer Science Courses

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***Abstract*—The need for more post-secondary students to major and graduate in STEM fields is widely recognized. Students' motivation and strategic self-regulation have been identified as playing crucial roles in their success in STEM classes. But, how students' strategy use, self-regulation, knowledge building, and engagement impact different learning outcomes is not well understood. Our goal in this study was to investigate how motivation, strategic self-regulation, and creative competency were associated with course achievement and long-term learning of computational thinking knowledge and skills in introductory computer science courses. Student grades and long-term retention were positively associated with self-regulated strategy use and knowledge building, and negatively associated with lack of regulation. Grades were associated with higher study effort and knowledge retention was associated with higher study time. For motivation, higher learning- and task-approach goal orientations, endogenous instrumentality, and positive affect and lower learning-, task-, and performance-avoid goal orientations, exogenous instrumentality and negative affect were associated with higher grades and knowledge retention and also with strategic self-regulation and engagement. Implicit intelligence beliefs were associated with strategic self-regulation, but not grades or knowledge retention. Creative competency was associated with knowledge retention, but not grades, and with higher strategic self-regulation. Implications for STEM education are discussed.**

Keywords—motivation; self-regulation; engagement; STEM learning; goal orientation; emotion; perceived instrumentality

I. INTRODUCTION

The need for more post-secondary students to major and graduate in STEM fields is widely recognized as in the National Academies report "Rising above the gathering storm: Energizing and employing America for a brighter economic future" [1]. Substantial funding is provided for enhancing instruction in STEM fields [2]. A relatively low percentage of students major in STEM fields, and despite attracting students with generally better academic preparation and aptitude, students in STEM fields experience higher attrition than those in other post-secondary majors [2].

Students' strategic self-regulation has been identified as playing a critical role in their success in STEM learning [3,4], but how students' use of strategy, metacognitive self-regulation, and engagement impact different types of learning outcomes is not fully understood. Also, despite considerable past research, including recent work reported in prior Frontiers in Education conference proceedings [5, 6, 7], theory and research have not completely described the dynamics of student motivation for pursuing productive strategic self-regulation and engagement. Our goal in this study was to investigate how motivation and strategic self-regulation, together with creative competency, were associated with course achievement and long-term learning of computational thinking knowledge and skills in introductory computer science (CS1) courses.

II. THEORETICAL FRAMEWORK

A. Motivation and Affect

Motivational variables in this study were drawn from goal orientation [8, 9, 10], future time perspective (FTP) [11], implicit belief theory [12, 13], and emotion/affect [14, 15, 16]. These aspects of motivation have been shown to be associated with higher academic achievement, greater engagement, and more strategic self-regulation [17].

Goal orientation concerns the types of goals students set. Goals exist at different levels of specificity. Consistent with Elliot *et al*. [9], there are goals for specific tasks and assignments anchored in the context of doing or evaluating the task and, at a more general level, students set goals for their courses [9, 10]. In this study, we used a framework proposed by Shell *et al*. [18] and Shell and Soh [4] that examines course goals in three dimensions (learning, performance, and task) with each dimension having an approach and avoid component. Learning-approach goals are goals directed at learning new knowledge or gaining competence consistent with most past formulations of learning or mastery goals [8, 10]. Learning-avoid goals are deliberate goals to avoid learning of course material. Think about the old saying *you can lead a horse to water, but you can't make it drink*. This reflects the Shell *et al*. [18] notion of learning avoidance. A student might complete all assignments and do enough to get a score on a test or a grade in a class, but not put forth the additional effort to really learn the material.

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Performance-approach goals reflect a desire to obtain favorable judgments of one's abilities by others or perform better than others in the class and performance-avoid goals reflect the desire to avoid negative judgments of one's ability or do worse relative to others in the class [10]. Performance-approach and avoid goals have been found to motivate very different behaviors. Approach seems to be positive for increasing effort and positive self-regulation; avoid seems to be detrimental, decreasing effort and self-regulation [4, 10].

Task- or work-avoid goals reflect a desire to get through the class with as little time and effort as possible [20, 21, 22]. Task-approach goals reflect wanting to perform well on course assignments and tests [4]. They differ from performance goals because they are about doing well without reference to normative performance or gaining positive or avoiding negative evaluations evaluation of competence. They also differ from learning goals in that students can have a goal to "do my work to the best of my ability" without any expectation that they will learn anything.

Perceived Instrumentality (PI), is defined as a person's perception of how useful a present task is for a future goal [4, 24, 25]. Endogenous instrumentality reflects instrumentality for personally meaningful future goals and outcomes. Exogenous instrumentality reflects a utilitarian connection between task results and future outcomes. Past literature indicates that an individual's perception of instrumentality positively affects learning in the classroom [4, 7, 24, 25]. Students with high perceived instrumentality can see the connection between their current class activities and their more distant future academic, career, and life goals leading to increased motivation for their present learning in school [4, 7, 11].

Implicit beliefs about intelligence have been shown to impact students' goals, motivation, and achievement [12, 13]. Students who believe that intelligence is malleable and changeable through effort, learning, and practice set learning goals, achieve better, and engage in better strategic self-regulation. Students who believe that intelligence is fixed and unchangeable are more likely to set performance-avoid goals and be at risk for learned helplessness [12, 18]. Research has found that 50% of engineering students held an entity view of fixed intelligence [26].

Affect/emotion involves students' general feelings and reactions to the class [15, 16]. Positive emotions have been shown to increase students' engagement in academic work and support more adaptive self-regulation [4, 16, 21]. Negative emotions have been found to decrease motivation and lead to maladaptive self-regulation [4, 21].

B. Strategic Self-Regulation and Engagement

Four aspects of student strategic self-regulation in classes have a long history of research. The first is general metacognitive self-regulation. Students who are self-regulating engage in active planning, monitoring, and evaluation of their learning and apply general learning strategies to accomplish their goals. [27, 28]. They are what Pressley *et al*. [29] called good strategy users. The second aspect comes from the knowledge building approach to learning proposed by Bereiter, Scardamalia, and their colleagues [30, 31]. Central to the knowledge building approach is the idea that meaningful learning involves the production of knowledge rather than the reproduction of knowledge. This knowledge building is accomplished by an in-depth study of a topic that goes beyond simple factual or recall learning. Learning is tied to personally meaningful goals and includes examination and connection of new knowledge to existing knowledge and coursework in other classes.

The third aspect of strategic self-regulation concerns more dysfunctional self-regulatory strategies [8, 22, 32, 33]. Lack of regulation [4, 21, 32] describes students who are confused, have difficulty studying effectively and self-regulating, and also need support from others. Lack of regulation has been shown to be negatively associated with grades [4, 32] and is a key component of learned helplessness in classes [4, 21].

The final aspect is student engagement with the class as reflected in active participation and effort. Engagement concerns student study time and effort for the class [4, 21, 34]. Engagement also considers the extent of student active course involvement as indicated by question asking [4, 21, 35]. Students who are more engaged tend to have more positive experiences in the class and higher achievement [14, 16].

C. Creative Competency

Epstein's Generativity Theory defines creativity as a process integral to human intelligence, which can be exercised within any context and can be practiced, encouraged and developed [36, 37]. Epstein [36, 37] has identified four core cognitive competencies involved in creative thinking: (1) *broadening* by acquiring information and skills outside one's current domains of study and expertise; (2) *challenging* established thinking by engaging in difficult, ill-defined problems and tasks where new behaviors and approaches must be tried; (3) *surrounding* oneself with new people and environments that require one to look at things in new ways, and (4) *capturing* by recording novelty as it occurs. Epstein has substantiated the validity of his core competencies in numerous laboratory and applied studies [36, 37]. His core competencies have a solid anchoring in contemporary cognitive and neuroscience research on learning and cognition [18].

III. The Present Study

The goal of this study was to investigate how students' motivation, strategic self-regulation, and creative competency, were associated with course achievement and long-term learning of computational thinking in introductory computer science (CS-1) courses. This study was part of a larger NSF-funded effort to improve learning of computational thinking and better incorporate computational thinking principles into the disciplines through integration of computational and creative thinking [38, 39]. Courses included one for CS majors, one for a combined business/computer science honors program major, one for engineers with content tailored for engineering, one for a mix of CS, engineering, and general science majors, and one for humanities and journalism majors. The courses are all required within the students' major field of study (e.g., engineering, physics, computer science, etc.).

IV. METHODS

A. Participants and Proceedures

Participants were 175 students who consented to participation (151 men; 24 women; 78 freshman, 49 sophomores, 32 juniors, 13 seniors, 3 other/unknown) from five courses in a suite of required introductory computer science course (CS-1) at a large Midwestern state university. Core content was the same for all courses, but courses were tailored for different majors with different programming languages and lab exercises. Participants completed all survey questionnaires on Survey Monkey in approximately 30 minutes during a single proctored course laboratory period in the final week of classes.

B. Strategic Self-Regulation Measures

Strategic self-regulation was assessed with three scales from the Student Perceptions of Classroom Knowledge Building instrument (SPOCK) [4, 21, 32]. All questions were answered on a five-point Likert scale from 1 (*almost never*) to 5 (*almost always*). Scores were computed as the mean score of the scale items. Coefficient alpha reliability estimates for the self-regulated strategy use, knowledge building, and lack of initiative scales were respectively .82, .86, and .69.

Self-regulated strategy use (5 items) assesses the extent of participant planning, goal setting, monitoring, and evaluation of studying and learning (e.g., "In this class, I tried to monitor my progress when I studied"). *Knowledge building* (5 items) assesses the extent of student exploration and interconnection of knowledge from the class [30, 31] (e.g., "As I studied the topics in this class, I tried to think about how they related to the topics I have studied in other classes"). *Lack of regulation* (4 items) assesses participants' lack of understanding of how to study and need for assistance and guidance in studying (e.g., "In this class, when I got stuck or confused about my work, I needed someone else to figure out what I needed to do").

C. Engagement Measures

Engagement was assessed with four measures. Two scales from the SPOCK assess the extent of question asking in class. *High-level question asking* (3 items) assesses the extent to which students ask questions that extend or expand on the basic information being provided in the class (e.g., "In this class, I asked questions to more fully understand the topics we were learning"). *Low-level question asking* (3 items) assesses the extent to which students ask questions to obtain or clarify basic course information ("In this class, I asked questions to be clear about what the instructor wanted me to learn"). Scores are computed as the mean of the items in each scale. Coefficient alpha reliability estimates for high-level and low-level question asking were respectively .87 and .86.

Two scales assessed self-reported studying [4, 21, 32]. Study time was assessed by asking participants to indicate the average number of hours per week they spent studying for the class on a 1–7 scale from 1 (<5 h per week) to 7 (over 30 h per week). Perceived study effort was assessed by asking participants to indicate their perception of the effort they put forth studying relative to most students on a 5-point Likert scale from 1 (*much less effort*) to 5 (*much more effort*).

D. Goal Orientation

Participants' goal orientation was measured with an instrument adapted from that used by Shell and Soh [4]. Scales were shortened to two items due to administrative time constraints. Participants rated goals on a 5-point Likert scale from 1 (*very unimportant*) to 5 (*very important*). Scores were computed as the mean score of the items in each scale. Reliability cannot be statistically estimated accurately for 2-item scales, however, coefficient alpha estimates for the parent scales [4] were .89, .88, .78, .87, .91, and .82 for the learning approach, learning avoid, performance approach, performance avoid, task approach, and task/work avoid scales respectively.

Learning-approach goals (2 items) assess goals for developing long-term, deep understanding of information and skills learned in the course (e.g., "Learning new knowledge or skills during the class just for the sake of learning them"). *Learning-avoid goals* (2 items) assess deliberate avoidance of long-term learning or retention of course information ("Getting a grade whether you remember anything beyond that or not"). *Performance-approach goals* (2 items) assess normative performance relative to other students and favorable assessments of ability by the instructor for ego protection (e.g., "Doing better than the other students"). *Performance-avoid goals* (2 items) assess avoiding negative performance evaluations and unfavorable assessments of ability by others (e.g., "Keeping others from thinking I am dumb"). *Task-approach goals* (2 items) assess efforts to achieve highly and do well on class assignments and activities without reference to normative comparisons (e.g., "Doing my best on course assignments and tests"). *Task-or work-avoid goals* (2 items) assess deliberate intention to put forth minimal effort in the course (e.g., "Getting through this course with the least amount of time and effort").

E. Perceived Instrumentality

Students' perceived instrumentality was measured with the Perceptions of Instrumentality Scale [4, 25]. The scale measures both endogenous instrumentality (4 items. e.g., "What I learn in this CS1 will be important for my future occupational success") and exogenous instrumentality (4 items. e.g., "The only aspect of this class that will matter after graduation is my grade"). Participants indicated their agreement with each question using a 5-point Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*). Scores are computed as the mean of the items in each scale. Coefficient alpha estimates for the endogenous and exogenous scales were respectively .94 and .92.

F. Implicit Intelligence Beliefs

Students' beliefs about intelligence were measured with the Implicit Theories of Intelligence Scale [12, 13]. The scale measures incremental beliefs (4-items) that intelligence is changeable (e.g., "No matter how much intelligence you have, you can always change it quite a bit") and entity beliefs (4-items) that intelligence is fixed (e.g., "You can learn new things, but you can't really change your basic intelligence"). Participants indicate their agreement with each question on a 6-point Likert scale from 1 (*strongly disagree*) to 6 (*strongly agree*). Scores are computed as the mean of the items in each scale. Coefficient alpha reliability estimates for the incremental and entity scales were respectively .95 and .94.

G. Course Affect

Participants' course affect was measured by a modified version [4, 21] of the Positive and Negative Affect Scale (PANAS) [40]. Participants rated the frequency with which they experienced 10 positive (e.g., excited, inspired, determined) and 10 negative (e.g., nervous, distressed, upset) emotions on a 5-point scale from 1 (*a few times or none*) to 5 (*most of the time, 80%-100% of the time*). Scores were computed as the mean of the items in each scale. Coefficient alpha reliability estimates for the positive and negative scales were respectively .92 and .90.

H. Creative Competency

Creative competency was measured with the Epstein Creative Competencies Inventory [37] administered at the Web site "mycreativityskills.com." The percentage score (0-100) for total creativity was used.

I. Computational Thinking Knowledge Test

Students' retention of computational thinking knowledge and skills from the course was measured with a computational thinking knowledge test developed by CSCE faculty [4]. The test contained 13 conceptual and problem-solving questions for the core computational thinking content common to all CS-1 classes. The coefficient alpha reliability estimate was .76.

V. RESULTS

A. Associations of Strategic Self-Regulation, Motivation, and Creative Competency to Grades and Retention

We used Pearson correlations (*r*) to examine how students' strategic self-regulation, motivation, and creative competency were associated with course grades and retention of core course content as indicated by the computational thinking knowledge test. These are shown in Table 1. Course grades and retention of course content were only moderately associated ($r = .350$), suggesting that students can achieve high grades without necessarily retaining much of the information from the course.

Student grades and knowledge retention were associated with similar but not identical patterns of strategic self-regulation, engagement, motivation, and creative competency. Both were positively associated with self-regulated strategy use and knowledge building, and negatively associated with lack of regulation. Engagement measures had considerably smaller correlations with grades and retention than strategic self-regulation measures with only study time associated with higher knowledge test scores and only study effort associated with higher grades. These findings suggest that the quality of strategies and self-regulation employed makes more difference in student achievement than general levels of active engagement.

Learning-approach goal orientation was positively associated with both grades and retention; conversely, learning-avoid goal orientation was negatively associated with both. Task-approach goal orientation also was associated with higher

TABLE I. ASSOCIATIONS OF STRATEGIC SELF-REGULATION, MOTIVATION AND CREATIVE COMPETENCY WITH GRADES AND KNOWLEDGE

Variable			***Course Grade***	***Knowledge Test***
	M	***SD***	***r***	***r***
Course Grade	2.72	1.35	--	.350**
Knowledge Test	7.60	3.40	.350*	--
SPOCK Self-Regulation	3.30	.74	.220**	.206**
SPOCK Knowledge Building	3.10	.84	.255**	.135*
SPOCK Lack of Regulation	2.82	.78	-.249**	-.305**
SPOCK Question Asking Low	2.88	.93	.140	.127
SPOCK Question Asking High	2.85	.98	.103	.061
Study time	3.19	1.55	.001	.144*
Study effort	3.05	.92	.147*	.071
GO Performance Approach	3.01	.94	.118	.120
GO Performance Avoid	2.70	1.03	-.178*	-.005
GO Learning Approach	3.99	.90	.197*	.211**
GO Learning Avoid	2.62	1.03	-.146*	-.171*
GO Task Approach	4.25	.93	.176*	.270**
GO Task Avoid	2.58	.99	.023	-.122
PI Endogenous	3.71	.99	.217*	.322**
PI Exogenous	2.26	1.03	-.258**	-.337**
Positive Affect	3.10	.84	.252**	.269**
Negative Affect	2.10	.79	-.407**	-.213**
Incremental Intelligence Belief	4.19	1.12	-.136	-.057
Entity Intelligence Belief	2.67	1.15	.051	.087
Creative Competency	56.80	15.02	.055	.139*

*$p <= .05$, **$p < .01$

grades and knowledge retention. Consistent with prior research [4,10], performance-avoid goals were negatively associated with course grades confirming that focusing on goals to avoid low achievement and negative judgments of ability is detrimental to achievement.

Perceived instrumentality was associated with grades and knowledge retention. Endogenous instrumentality was associated with higher grades and knowledge retention; conversely, exogenous instrumentality was associated with lower grades and knowledge retention. It appears that students who focus on only the utilitarian value of grades do not achieve or learn as well as students who focus on more personally meaningful instrumentality.

Positive emotional/affective reactions to the class were associated with higher grades and knowledge retention, and negative emotions/affect in the class was associated with lower grades and retention. Unlike prior studies [12, 13], implicit beliefs about intelligence were not associated with either grades or retention. Dweck [12] and Shell *et al.* [18] have argued that implicit intelligence beliefs operate by influencing goals. To test this, correlations between implicit beliefs were examined. Consistent with theory [12, 18], incremental intelligence beliefs were associated with higher learning-approach ($r = .24$) and task-approach ($r = .17$) goal orientations and lower performance-avoid ($r = -.17$) and task-avoid ($r = -.20$) goal orientations. Entity intelligence beliefs were associated with higher performance-avoid ($r = .25$) and task-avoid ($r = .22$) goal orientations and lower learning-approach ($r = -.16$) goal orientation, suggesting that impacts of implicit intelligence beliefs on achievement and learning are likely indirect.

Studies have not examined how Epstein's creative competency [37] might be related to STEM course achievement and learning. Overall creative competency was significantly associated with knowledge retention but not grades, suggesting that creativity may be associated with deeper learning and building of expertise, but may not be related to course achievement.

B. *Strategic Motivation, Self-Regulation, and Engagement*

Because students' strategic self-regulation and engagement were associated with their course grades and retention, we were interested in what motivated students to engage in these behaviors. We again used Pearson correlations (r) to examine how students' strategic self-regulation and engagement were associated with their motivation, affect, and creative competency (Table 2).

Students' self-regulated strategy use and knowledge building strategies were associated with similar patterns of motivation, affect, and creative competency. Both were associated with higher performance-approach, learning-approach, and task-approach goal orientations and lower learning-avoid and task-avoid goal orientations. These associations are consistent with prior research on goals [4, 9, 10]. Self-regulated strategy use and knowledge building were associated with higher endogenous instrumentality and lower exogenous instrumentality similar to findings in prior studies [4, 7, 24, 25]. As in prior research [4, 21], positive course affect had a large correlation increasing self-regulated strategy use and knowledge building; and negative affect was associated with lower levels of these. Implicit intelligence beliefs were not associated with self-regulated strategy use, but incremental beliefs were positively associated and entity beliefs were negatively associated with knowledge building. Interestingly, creative competency was positively associated with both self-regulated strategy use and knowledge building, suggesting that creative competency can enhance positive strategic self-regulation.

TABLE II. ASSOCIATIONS OF STRATEGIC SELF-REGULATION, MOTIVATION AND CREATIVE COMPETENCY WITH GRADES AND KNOWLEDGE

Variable	*Self-Reg. Strategy*	*Know. Building*	*Lack of Reg.*	*Study Time*	*Study Effort*
	r	*r*	*r*	*r*	*r*
GO Performance Approach	.19**	.20**	-.21**	.07	.13*
GO Performance Avoid	-.11	-.08	.12	.05	-.07
GO Learning Approach	.31**	.44**	-.20**	-.04	.05
GO Learning Avoid	-.27**	-.36**	.21**	.03	.06
GO Task Approach	.21**	.17*	-.19**	.16*	.19*
GO Task Avoid	-.27**	-.24**	.11	-.15*	-.16*
PI Endogenous	.46**	.60**	-.20**	.16*	.07
PI Exogenous	-.41**	-.43**	.28**	-.07	-.04
Positive Affect	.54**	.62**	-.34**	.22*	.14*
Negative Affect	-.13*	-.24**	.48**	.23*	.05
Incremental Intelligence	.07	.14*	-.10	.01	.01
Entity Intelligence	-.10	-.15*	.09	.04	-.03
Creative Competency	.32**	.29**	-.07	.08	.01

*$p <= .05$, **$p < .01$

Lack of regulation was associated with almost the reverse pattern of motivation and affect. Learning-avoid goals were associated with increased lack of regulation. Performance-approach, learning-approach, and task-approach goals were all associated with lower lack of regulation. Exogenous instrumentality and negative affect were associated with higher lack of regulation, and endogenous instrumentality and positive affect were associated with lower lack of regulation. These associations are consistent with prior research [4, 21, 33] suggesting that lack of regulation is a function of negative emotional/affective reactions to the class coupled with a utility-based instrumentality for the course and learning-avoid goals.

Study time and perceived study effort both were associated with higher task-approach and lower task-avoid goal orientation and with positive affect. Additionally, study time was associated with higher performance-approach goal orientation and endogenous instrumentality. Higher study time also was associated with negative affect, suggesting that engagement may possibly be motivated by both positive and negative reactions to the class. Perhaps those experiencing negative emotions make themselves study and persist more to compensate. This aspect of motivation for studying needs more study.

VI. DISCUSSIONS AND CONCLUSIONS

Recent theorizing in the fields of motivation and self-regulation [4, 16-18, 21, 27] has emphasized the complex links among motivation, affect, and students' strategic and self-regulated behavior in classrooms. The need to consider how multiple aspects of motivation influence a broad constellation of strategies, engagement, and self-regulation to advance course achievement and learning is increasingly recognized. Because motivational and self-regulatory constructs have emerged within different theoretical and research traditions [17, 27], research and discussion have tended to focus on only one (or a few) constructs and strategic behaviors at a time. Our findings show the need to consider how multiple aspects of strategic self-regulation and engagement produce higher grades and retention and how achievement and effective strategic self-regulation are motivated by different facets of students' goals, beliefs, and emotional reactions.

We found that course grades and retention of course content were associated with classic cognitive and metacognitive self-regulation [27, 28, 29] and active engagement [4, 16, 21, 34]. But, achievement and knowledge retention also were associated with a knowledge building approach [30, 31]. These findings suggest that high achievement and long-term retention require both effective studying and self-regulation and in-depth examination of course content through personally meaningful knowledge building. Findings also suggest that STEM educators need to pay attention to students who are not being effective in their studying and self-regulatory efforts, as we found that lack of regulation was associated with lower grades and knowledge retention. Prior research [4, 21] has implicated lack of regulation as a key component in learned helplessness [8] that can potentially lead to disengagement and failure.

Effective interventions to enhance student strategic self-regulation have been reported [28]. These typically involve special courses in study skills [28] or other outside-of-class interventions. Referral to these resources may help alleviate lack of regulation difficulties. Instructors themselves can help students manage time and prioritize by being clear about assignment time demands. They can encourage students to ask questions when they do not understand course material or assignments. Interventions in classrooms to foster knowledge building have been described [18, 30, 31]. Collaborative activities, especially those involving Computer Supported Collaborative Learning (CSCL), have been shown to increase knowledge building [30, 31, 32].

We found that similar patterns of motivation and emotion/affect were associated both with grades and knowledge retention and with higher strategic self-regulation and engagement. These findings support theoretical views that motivation and emotion work through their impact on strategic self-regulation and engagement [14, 15, 17, 18]. Learning-approach goal orientation has been singled out as critical to effective learning and building of expertise [18]. Our findings supported the association of learning-approach goal orientation with increased achievement, knowledge retention, and strategic self-regulation. Our findings also suggest the potential for learning-avoidance goal orientation to undermine these, as they were negatively associated with grades, knowledge retention, and strategic self-regulation and were positively associated with lack of regulation. Shell *et al.* [18] discuss a number of strategies for helping students adopt learning-approach goals. Instructional strategies such as worked examples and models that focus on learning as opposed to solving problems or producing products have been found to be especially effective by directing students to attend to learning rather than outputs [41].

Task-approach goal orientation also is necessary to motivate the self-regulation and engagement needed to study and practice enough to build knowledge and skill [18]. Our findings supported this linkage, as task-approach goal orientation was associated with achievement, knowledge retention, self-regulated strategy use, knowledge building, and engagement while task-avoid goal orientation was associated with decreased self-regulated strategy use, knowledge building, and engagement. But, task-approach goals need to be balanced by learning-approach goals. As noted by Bereiter and Scardamalia [19], students often approach school as a series of tasks to complete rather than as an opportunity to learn. Instructors need to be sure that students are focused on learning the content and not just focused on getting the assignments completed.

Perceived instrumentality has been identified as crucial to student motivation in STEM [4, 7, 18, 25]. Our findings supported this connection as endogenous instrumentality was positively associated with achievement, knowledge retention, self-regulated strategy use, and knowledge building and negatively associated with lack of regulation. Utility-based exogenous instrumentality, on the other hand, was negatively associated with these. These associations suggest that seeing "getting a grade" as the only important outcome of the class does not necessarily lead to effective strategic self-regulation and learning. Students need to see the endogenous instrumental connections between the course and personally meaningful future goals [11, 18]. Research suggests that students do not necessarily see these connections [4, 39], so STEM educators may need to be very explicit about how course material links to the students' major and career aspirations. Endogenous instrumentality can be impacted by classroom intervention, such as providing videos of past students talking about how they used the course content in their other courses [7].

Having incremental intelligence beliefs has been shown to be important for setting learning-approach goals and for fostering knowledge building strategies. Our results supported this prior work as we found a positive association between incremental intelligence beliefs and knowledge building and a negative association between entity beliefs and knowledge building. Numerous studies at all educational levels have shown that incremental intelligence beliefs can be fostered by instructor feedback focusing on how ability and skill can be improved through study and practice and by specific interventions such as having students read a passage about brain plasticity [13].

Our findings that positive emotions were associated with higher levels of achievement, knowledge retention, strategic self-regulation, and engagement and negative emotions were associated with lower levels of these were consistent with much prior research [4, 14, 15, 16, 21]. Research [4, 39] suggests that students in STEM courses that are required but not specifically in their major often have very negative emotional reactions to the course as a whole and to specific assignments designed to enhance deep learning. Establishing a learning-approach climate in the class and fostering higher perceived instrumentality are thought to increase positive affect [15], but there is limited research on how to overcome strong negative emotions in the class [15].

This study is one of the first to look at the role of creative thinking in STEM course achievement and student strategic self-regulation. The Center for Computational Creativity research team has proposed that that using Epstein's [36, 37] model, creative competency can improve learning of computational thinking [39]. The findings provide support for this contention. *Creative competency was not associated with grades, but was associated with higher retention of course material.* Also, *creative competency was associated with higher self-regulated strategy use and knowledge building*. These results suggest that creative competency may enhance the strategic learning strategies associated with building new knowledge and understanding that lead to greater long-term retention and development of expertise. This suggests that enhancements to creative competency may be a valuable instructional tool [39].

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An Evaluation of Freshman Engineering Persistence Using Expectancy-Value Theory

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***Abstract*— As we engage in an increasingly complex and quickly progressing world, the development of science, technology, engineering, and mathematics (STEM) students will be increasingly important to the continuation of the United States' competitiveness. However, the overall number of STEM students earning a degree will not be able to meet the increasing demand for practicing professionals especially within historically underrepresented groups such as women and minorities. One way to tackle this problem is to increase the retention of STEM students by studying the processes that influence persistence to completion of a STEM degree. Retention is critically important to the field of engineering as over 10% of all engineering majors will switch to other STEM degrees and even more will not persist within STEM fields at all.**

The focus of this paper is to utilize Expectancy-Value Theory to determine how freshman engineering students (both those who persisted within the major and those who switched out of the major) perceive engineering. Research was conducted at a predominately undergraduate liberal arts institution with a medium sized engineering program. Interview data was examined for 11 entering freshman who stayed with the engineering program (persisters) and 10 entering freshman who switched to different majors (switchers).

Keywords—EVT; Engineering; STEM; Persistence; Expectancy-Value Theory; Attitudes; Beliefs

I. Introduction

With innovation accounting for over half of the documented economic growth within the United States over the last 50 years, the ability to provide students with the opportunity to succeed in science, technology, engineering, and math (STEM) fields is increasingly important [1]. STEM occupations are expanding at a faster rate than their non-STEM counterparts, but even with this increase in demand, many STEM fields are barely keeping pace with the rate of degrees awarded in other fields. STEM bachelor degrees have dropped from a high of 24% in 1985 to 18% by 2009, while masters have declined from 18% to 14% during the same period [1]. This phenomenon is especially troubling in the field of engineering, where the National Science Foundation's (NSF) Science and Engineering Indicators for 2012 show that 10% of all declared engineering majors will switch to earning a mathematics, physical science, or computer science degree [2].

Another concern is that many of the STEM degrees being awarded within the U.S. are going to foreign students, who might take their skills back to their home country, leaving positions still unfilled domestically. The U.S. Congress Joint Economic Committee indicates that the share of degrees going to domestic students has dropped from 74% to 54% and the NSF's Science and Engineering Indicators for 2012 indicate that foreign students have continued to increase at the graduate level particularly within engineering and computer science [1].

It is also troubling to note that many traditionally underrepresented groups still struggle to break into certain STEM fields. The NSF indicators for 2012 show that while women make up approximately 57% of bachelor degree earning students, they are still a minority of the students who are awarded degrees in engineering, computer science, and physics. These statistics also indicate that the proportion of women within these fields has not changed significantly in the last 10 years [2]. Racial and ethnic groups have witnessed a small increase in the number of STEM degrees awarded but no more so than the overall increase in total degrees awarded. These increases have also failed to close the gap concerning employment within STEM fields as Hispanic and African American workers only account for 6% of all STEM positions, which is disproportional to their overall percentage of the population (Hispanics make up 14% of the overall population while African Americans make up 11%). These trends have left us trailing behind some of our global international competitors in both diversity and competitiveness and have led some to call into question the ability of the United States to maintain its economic leadership [1, 2].

These worrying trends have led to a new emphasis on research which focuses on factors that affect recruitment and retention. Educators have begun to focus their efforts on identifying what factors influence students to choose STEM majors and what factors influence their decision to persist with a STEM degree, with the hope that once these factors are identified tools can be developed to capitalize on them in order to increase the total number of students graduating with STEM degrees. Within this paper, we will focus on how Expectancy-Value Theory (EVT) influences engineering student's motivation to persist or switch out of an engineering degree. By analyzing how students' motivation is influenced by a variety of factors, major motivational markers can be identified

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which will serve as the foundation for further exploration of a predictive tool to increase overall retention within engineering, and other STEM majors, to provide the opportunity for targeted analysis to solve for underrepresentation of specific groups within STEM fields.

II. Literature Review

Over the past decade researchers have begun to question the effectiveness of traditional lecture-based methods for teaching students which has led to the development of alternative student-centered learning environments. This push for novel pedagogical practices has led to the study of both external and internal factors and how they influence retention within the classroom.

Researchers have studied how external factors influence students' retention and motivation within classrooms through experimenting with alternative teaching styles. Prince reviewed 168 studies on retention and found that collaborative learning, which relied on group work, was able to increase student performance and decrease minority attrition by 22% [3]. Yusof, Hassim and NMA have demonstrated that Problem-Based Learning (PBL) which promotes smaller group based project work is also able to influence retention through external factors. They found that PBL was able to increase student problem-solving, directed learning, motivation, confidence, and team cohesion within a Process Dynamics and Control Course for chemical engineers [4]. Bernold, Spurlin, and Anson found that engineering students could be categorized into four main learning styles (WHY, WHAT, HOW, and WHAT-IF), which corresponded to specific desires for external classroom environments. They found that traditional lecture-based courses only catered towards WHAT and HOW learning styles which desired verifiable data, individual assignments, straightforward tasks, and measurable products. Without relying on alternative teaching styles WHY and WHAT-IF groups demonstrated lower performance and retention rates due to their desire for an environment that fostered creativity, innovation, abstract application, and cooperation with other students [5].

Other researchers have focused on how internal factors have influenced student retention. Attitudinal research is one such area of study which seeks to examine the intersection of attitudes and beliefs. An attitude is commonly defined as a learned consistent response to an action or object [6]. This is different from a belief, in that a belief is an individual's pre-existing knowledge [7]. Self-Determination theory (SDT), a subset of attitudinal research, seeks to determine how the strength of certain motivations (deemed autonomous or controlled) influence a person's decision making processes [8]. Amelink and Meszaros used SDT to show how different internal and external frames of reference influenced male and female students' evaluations of situations and affected their decision to remain within engineering [9]. Beam et al. demonstrated that a student's self-conceptualization of identity and its alignment with their conception of being an engineer could also be a factor that influences the likelihood of a student persisting within the major [10].

Expectancy-Value Theory (EVT) builds off the foundation set by previous works in attitudinal research and seeks to explain how attitudes and beliefs influence expectancies and values. It seeks to measure how external stimuli and factors are internalized into internal reactions to explain retention. Lawler defines EVT as "the strength of a tendency to act in a certain way depends on the strength of an expectancy that the act will be followed by a given consequence (or outcome) and on the value or attractiveness of that consequence (or outcome) to the actor" [11].

EVT originated in the work of John Atkinson in his 1957 publication, "Motivational Determinants of Risk-Taking Behavior." His laboratory studies focused on how expectancies and values influenced an individual's performance, motivation, determination, and objectives [12]. Expectancies are defined as preconceived ideas concerning the likelihood of an outcome to occur and can be divided into ability beliefs (broad beliefs about competency in a domain) and expectancies of success (beliefs about competency at a specific task) [7, 13]. However as research has expanded beyond laboratory environments where variables can be isolated and manipulated, researchers have found that in real-world situations both types of expectancies are highly interrelated and thus not statistically different. This has led many researchers to referring to expectancy as a singular unit [12].

Value is defined as the amount of worth a person assigns to a task and has been categorized into four main components by Eccles and colleagues: intrinsic value (enjoyment gained by finishing the task), utility value (usefulness of completing the task), cost (things given up in exchange for doing the task), and attainment value (importance of success) [13-14]. Trautwein et al. later confirmed this division of value in a study of 2,508 upper secondary students. In this study researchers found that, while there was a high correlation between many of the value dimensions, any model which did not combine the value dimensions was able to account of more variance than those that did combine one or more of them. [12].

Eccles and colleagues developed a framework which combined the internal factors of expectancies and value with research into attitudes and beliefs, serving to interrogate how internal and external factors interact [14]. Their studies on domain specificity of knowledge and the development of expectancies and values as children age have demonstrated that beliefs about a task, a person's perception of their past performance, beliefs about other people's attitudes, cultural influences, and personal history all effect both expectancies and values, which in turn influence their performance, persistence, and choices [13].

Jones, Paretti, Hein, and Knott in 2010 and Matusovich, Streveler, and Miller in 2010 both applied EVT research to the field of engineering education and retention studies [15-16]. Jones, Paretti, Hein and Knott found that value dimensions were better predictors of career choice than expectancies when analyzing data collected from freshman students [15]. Matusovich, Streveler, and Miller found that high attainment value (i.e. identity correlates strongly with being an engineer) was highly correlated with persistence, and indicated that students demonstrating low attainment values offer an opportunity for educators to influence the persistence process. They also found that low/moderate attainment or interest when combined with high utility can produce persistence when costs remain low and that low attainment, interest, and utility with high costs produced situations where students were less likely to persist [16]

This paper seeks to expand upon previous research into EVT and engineering retention by focusing on how costs influence other value dimensions specifically as it applies to persisters and switchers in order to understand how different students can view the same event from different value frames. By understanding how these events are internalized through motivational structures, alternative pedagogical practices can be adjusted to accommodate student learning and increase the likelihood that students will persist within the major. The ultimate goal of this research is to build the foundation for the development of a predictive tool that can serve as an aid to both high school and college counselors to assist them in identifying motivational strategies to inspire students to become engineers and remain within engineering programs.

III. Methodology

All data used within this study was part of an ongoing research project aimed at understanding engineering retention produced by Beam et al. and Pierrakos et al. [10, 17]. Data was originally collected from 45 interviews and focus groups conducted with freshman students (STEM and non-STEM) at a large predominately undergraduate liberal arts institution during the Fall of 2008 and Spring of 2009 [17]. Because of the scope of this research, information was limited to the 21 students who entered the university's medium sized engineering program as freshman [10]. Eleven of the interviewees planned on staying in the engineering program at the post-interviews conducted at the end of their freshman year (labeled as persisters) and ten of the interviewees switched out of the program (labeled switchers). Students were recruited through e-mail requests and those who consented were interviewed orally by proctors using a semi-structured format for 30-50 minutes. Each interview was recorded for transcription and analysis [17]. The overall goals of the interviews were to evaluate: influences that led students to choose engineering, students' knowledge of what an engineer is, a students' sense of being prepared, a students' sense of community within engineering, and influences to a students' professional identity [17]. Because these goals align closely with factors that influence expectancies and values, the data when analyzed by EVT provided relevant results.

Based on the research done into the multi-disciplinary application of EVT and specifically EVT's effect on retention in engineering education, three categories were developed to analyze: expectancies, beliefs, and values. After these categories were identified, several of the interviews were analyzed to identify common themes deemed relevant given previously evaluated literature and their relation to the predetermined categories.

From this analysis, thirteen themes were identified as common to many of the interviews and were incorporated into the coding process. The division of these themes has been represented graphically below in Figure 1. The expectancy themes identified included: expectancies of success (degree that a student feels they will do well on a particular subject matter related to engineering), evaluation of prior knowledge of engineering (degree of certainty that a student feels about whether their evaluation of what engineering is, was accurate), ability beliefs (degree that a student feels they will do well in the discipline of engineering), perception of inclusion in the community (degree of belonging to the engineering community and sense of acceptance by faculty and peers), and perception as an engineer (degree of identification with being an engineer). The belief themes included: prior knowledge of engineering (level of correct perceptions about engineering), beliefs about how others perceive engineering (degree of perceived positive reactions by others to the engineering discipline), and previous engineering experience (level of involvement with activities that relate to engineering prior to survey as evaluated by experts opinion of field). Finally the value dimension included: intrinsic value (degree of value based on enjoyment of activities related to engineering), utility value (degree of value based on perceived usefulness of activities related to engineering), cost (degree of value based on perceived opportunity costs or negative consequences of activities related to engineering), and attainment value (degree of value based on perceived importance of succeeding at engineering).

A team of three researchers was assembled to code the data for presence of each theme. Each interview was assigned to two researchers who coded the analysis independently on a scale of zero to three. A score of zero represented that the researcher did not think that the theme was present at all within the interview. One indicated a presence at low value, and three represented a theme was present at high levels.

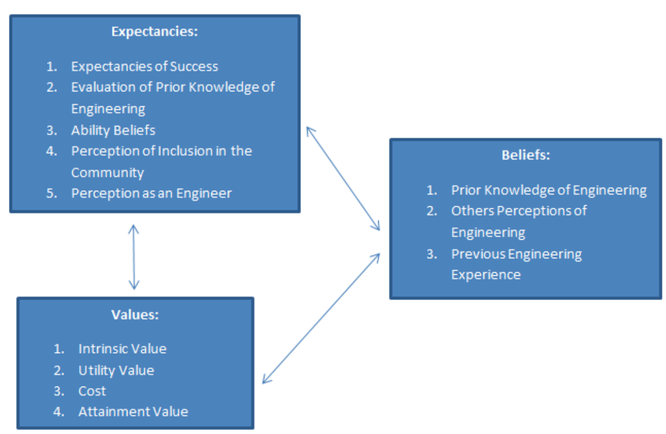

Figure 1: Breakdown of Themes by Category

For example, a three in the category of costs represented that the interviewee clearly and strongly indicated that engineering caused them to miss out on opportunities or provided them with opportunity costs that outweighed the values of engaging in engineering.

Some limitations exist with the application of EVT to the data analyzed within this paper. EVT is generally applied to situations in which people are asked to predict their responses or beliefs about certain situations; whereas the data collected for this research utilized interviews which expressed passed feelings and recollections. While this does introduce some error in the application of EVT, the data still provides valuable insights into motivations of STEM students. Future research into the development of an assessment tool to aid in counseling for retention can increase their applicability of EVT by gathering data explicitly for the purpose of EVT analysis and phrasing questions to capitalize on the predictive nature of EVT variables.

Finally, the inter-rater reliability and generalizability of our coding method was tested by using two raters with high levels of familiarity with EVT literature and one rater who did not have previous experiences with EVT. Rater 1 and 2 were both involved in the developent of the EVT coding framework and both possessed previous experience with EVT literature, while rater 3 was not involved with the process until the coding began. When the raters average scores and the standard deviations for their averages were compared, no significant differences could be discerned between the different raters as shown in figure 2 below. This indicates that the coding rubric developed for describing and ranking themes provided an adequate introduction to the topic of EVT and the specific themes being examined. As the goal is to eventually develop a tool to help counselors identify areas to address retention in engineering, this finding was encouraging.

Figure 2: Reliability Between Raters

IV. Results

This paper began by examining the differences between persisters and switchers to determine which themes would prove the best indicators for differentiating between the two groups. Our initial hypothesis was that people who switch out of engineering would show significantly higher scores in the area of cost, while persisters would demonstrate higher scores in all other themes analyzed. We further hypothesized that value themes would prove better indicators for persistence then either expectancies or beliefs. This hypothesis was corroborated by the data collected.

The average of the two coders' scores for each theme from all of the persister and switcher interviews has been depicted below in figure 3. Using this data, a Cohen's D analysis was performed to directly compare the significance of the differentiation between persisters and switchers. Through this analysis it became evident that students who persisted past the first year in general showed large effect sizes in all themes except for "others perception of engineering" and "utility".

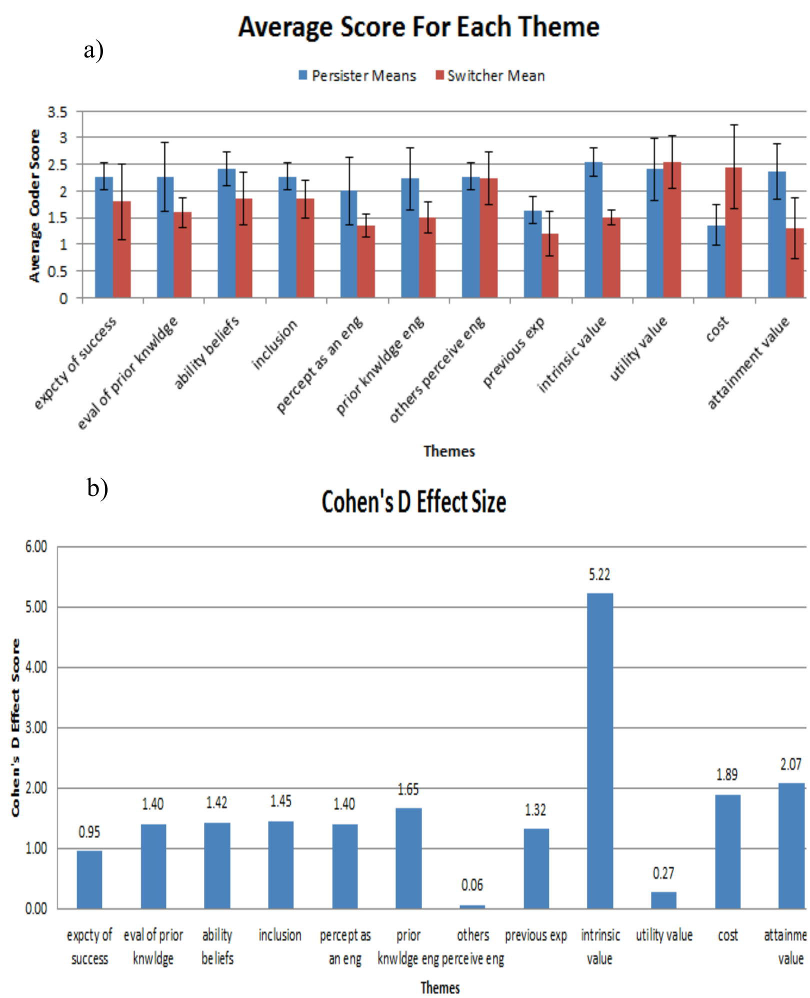

Figure 3: Thematic Analysis. a) is the average of the two raters scoring for all of the persisters and switcher presented for each theme b) is the Cohen's D effect size calculated for each theme.

A. Expectancies

As highlighted in Figure 3, students who demonstrated higher levels of expectancy were more likely to persist within engineering then those who did not. One explanation for this trend is that people who expect to do better will view problems as a challenge to overcome and will put in more time and effort to succeed in the task at hand. If students doubt their ability to succeed it can lead to a self-fulfilling prophecy where students do not work as hard as they otherwise might. One switcher described this feeling as, "I was really like pumped about the engineering program like, I loved all of the professors, ... I feel like I have that much more of a disadvantage with this calc[ulus] because everyone else is like on the track… I just don't like going into something, not being sure that I can do it." When this view is contrasted with a persiter who in Table III indictates that the math requirement was a necessary challenge to overcome and not a disadvantage, the data shows that differing expectancies can lead two different students to view the same task from different viewpoints such as one viewing it as a cost while the other views it as a benefit. In this case, a low expectancy score led the switcher to view math as an insurmountable obstacle to continuing engineering even though they also indicated that another math teachers might have been able to relay the necessary information if they took the course again.

The students who were interviewed came from a broad background with different skill levels and even switchers who indicated that they were not struggling with the skills portion of the classes demonstrated these overarching principles. Table I illustrated that students isolated issues ranging from not fitting in, to fear of being stuck at a desk, and even the idea that engineering is too individual oriented as opposed to group oriented, as reasons why they felt their personal background and identity did not set them up to succeed within the environment that they perceived engineering to be. This also shows that expectancies, beliefs, and values are interrelated. The switcher in this case encountered a situation that influenced his/her expectancies which influenced his/her values of engineering, which will over time influenced his/her belief structure.

TABLE I.

	Examples of Responses		
	Themes:	Definitions:	Examples:
Expectancies	**Expectancies of Success**	Degree that a student feels they will do well on a particular subject matter related to engineering	• "I've always been good at math and physics" • "Yeah, I'm confident that I've been well prepared"
			• "My physics class from high school wasn't very good and everyone dropped out of my calculus class so it was kind of tough going into here when I didn't really know any calculus because they dropped the program at my high school" • "poorly on math placement"
	Evaluation of Prior Knowledge of Engineering	Degree of certainty that a student feels about whether their evaluation of what engineering is, was accurate	• "I used to work for an actual firm…it was for civil engineering, we helped design a project for a new stadium" • "I took engineering in high school"
			• "I just really didn't have any clue how you know difficult it would be once I got here" • "I don't want a job where you know working by myself…maybe engineers interact more than I perceive them to but as far as the studying and work you do in class, that's certainly all individual work"
	Ability Beliefs	Degree that a student feels they will do well in the discipline of engineering	• "I knew being an engineer would be tough, but I'm not really worried" • "Do you think you're background has prepared you….? Yes"
			• "I just wasn't that interested and then the difficulty of the courses themselves, I just couldn't, couldn't do it" • "Really unprepared when it comes to science"
	Perception of Inclusion in the Community	Degree of belonging to the engineering community and sense of acceptance by faculty and peers	• "pretty accepted in the science classes" • "I feel like I belong because all of our personalities are similar"
			• "my lab partner, was actually my roommate so like, I got along with him, but the other people were just there" • "I never felt like I really like fit in with everybody else who was doing it"
	Perception as an Engineer	Degree of identification with being an engineer	• "I don't feel like an engineer as in like that's my job; I feel like an engineer as like being a student with the classes and everything" • "I like telling people I'm an engineering major and people are like WHOA"
			• "Do you feel like an engineer? Not really yet in many ways, might be because I have so many different areas of interest" • "I haven't really felt like an engineer yet"

[a.] Higher scored responses denoted in grey and lower scores denoted in white

B. Beliefs

The data highlighted in figure 3 also indicates that prior beliefs followed similar trends to that of expectancies, in that persisters consistently scored higher in each belief theme then switchers. The largest Cohen's D effect size was prior knowledge of engineering, which indicated that students who knew more about what they were getting themselves into were less likely to be surprised by the course load and work involved with the program. As Table II demonstrates a number of students came into the engineering program with little knowledge of what an engineer does or the requirements that they had to meet. This lack of knowledge left some students shocked or distressed by the amount of and type of work that they were expected to do which contributed to their decision to leave. One switcher when asked if they felt prepared coming from high school said, "I thought I was prepared. I took physics, I didn't take AP because I figured it was the same thing, and I found out it wasn't." In general students indicated that they expected to take hard math and science courses but beyond that had difficulty describing what is involved within an engineering curriculum.

Students who had participated in activities like those listed on Table II such as engineering summer camps, engineering school courses, or who had expereience with engineers through their family or work were more likely to persist then students who scored lower in this category. Interestingly, figure 3 indicates that others' perception of engineering represented the lowest Cohen D's effect size. A majority of students thought the community views engineers positively whether they persisted or switched. This theme proved the least beneficial indicator of intent to switch or persist.

C. Values

Finally, values proved to be the best indicator of persistance, a finding consistent with previous work by Jones, Paretti, Hein, and Knott [15]. Within the themes for value, intrinsic value, followed by attainment and costs were the best indicator which differs slightly from Matusovich, Streveler, and Miller's findings that attainment value is the best predictor of persistance [16]. As figure 3 demonstrates, all three themes produced large Cohen's D effect sizes, while utility produced only a small effect size.

The high significance of intrinsic value, is indicative of the need to enjoy a subject to be able to persist through the challenges that a student faces. Students who found enjoyment in the classes they were taking were much more likely to persist in engineering then those who viewed engineering

TABLE II.

	Themes:	Definitions:	Examples:
Beliefs	**Prior Knowledge of Engineering**	Level of correct perceptions about engineering	• "I knew being an engineer would be tough" • "engineering is in my family (dad works with missiles"
			• "Hands on (there is behinds the scenes deskwork?) ….stereotypical "ocean miners" and whatever they do"
	Beliefs about how Others Perceive Engineering	Degree of perceived positive reactions by others to the engineering discipline	• "overall quite supportive, everybody needs engineers" • "parents/grandparents/family have always been supportive"
			• "the people in the engineering program, or course there's like nerdy kids, like ok, stereotypical" • "the actual workers who have to put together, they think that engineers are idiots, I kid you not they always talk about how they hate engineers and how they screw up things because they never make anything practical"
	Previous Experiences	Level of involvement with activities that relate to engineering prior to survey as evaluated by experts opinion of field	• "IB program" • "governors school in field ecology"
			• "Any experiences…that led you into engineering?...Not really because I didn't really enjoy physics and stuff" • "did a summer camp thing"

[a.] Higher scored responses denoted in grey and lower scores denoted in white

TABLE II.

	Examples of Responses		
	Themes:	Definitions:	Examples:
Values	**Intrinsic Value**	Degree of value based on enjoyment of activities related to engineering	• "like building/designing things" • "they put a high emphasis on sustainability, environmental aspect, and that's, that was a big like role play in what I wanted to do"
			• "I didn't want to go into business" • "I didn't really want to be stuck in an office"
	Utility Value	Degree of value based on perceived usefulness of activities related to engineering	• "yeah it's a very prestigious job" • "I chose it because like it would be financially stable"
			• "I haven't really thought that far"
	Cost	Degree of value based on perceived opportunity costs or negative consequences of activities related to engineering	• "considered music (violist), also considered physics" • "I guess just the amount of time you have to put into it, and that fact that you know it's not really creative in any way"
			• "Math is necessary in engineering but I like a challenge"" • "You could major in bio, but then you'd just do bio and have to specialize, etc. If you get an engineering degree there's a lot you can do with just that"
	Attainment Value	Degree of value based on perceived importance of succeeding at engineering	• "I like the saying that engineers "make things better," they don't invent, they improve upon things and I would like to be a part of that improving upon" • "I have pretty high expectations for being able to solve really hard problems when I'm like out of school, senior year, being able to come up with creative solutions"
			• "I've never really thought about what kind of ideal job I wanted" • "I wasn't that dedicated to engineering, but…you need to be, they've told me and I've understood that like you need to be determined to do that"

[a.] Higher scored responses denoted in grey and lower scores denoted in white

solely based on its utility. In fact students who presented high utility without moderate to high intrinsic or attainment value were more likely to switch to a major they "enjoyed" more. One switchers response to the question why are you leaving engineering was, "I was an exchange student in Germany last summer, and that's where I really, really developed an interest for it and when I came here I found out that I couldn't continue studying it…I knew then, if I'm sacrificing something that I really love for something that I don't love as much, there's something wrong." Students who changed majors based on enjoyment often indicated that no change to the program or counseling structure could deter them from leaving.

The second best indicator was attainment value, which represents how important success is to the student. The data suggested that students who wanted to succeed independent of skill level were more likely to persist. In general, it appeared that these students were more likely to view obstacles as a challenge as opposed to a cost. Usually students who ended up switching out of the major indicated that the opportunity cost was too high for them to be able to continue. As Table III indicates students often indicated they would prefer to take other classes, be able to join a club, or wanted to expand their social life. What was concluded from this information was that the difference between a student who switched and a student who persisted was not a result of a physical time difference (i.e. that these students took longer to complete the tasks assigned to them) but was often a result of the perception of the student with regards to the task.

V. Conclusion

While expectancies, beliefs, and values all provided evidence of their ability to serve as indicators for persisting or switching, values were by far the best indicators with intrinsic value serving as the most indicative of a persons intention to switch or persist. The large Cohen's D effect size for intrinsic value indicates that those who enjoy what they are doing are more likely to persist and view tasks as an opportunity for betterment rather than a cost. This correlation also makes sense with respect to the results for attainment. Many people who scored high in the attainment value category viewed situations that arose as part of the process for attaining their goals as opposed to costs. Finally, utility value showed a slight negative correlation with persistence, as money or prestige was often not able to overcome a lack of intrinsic value.

Expectancies followed by beliefs were the next best indicators, and illustrated consistent properties between both categories due to their interrelatedness. Our pre-existing beliefs influence our predictions on whether we think we will succeed just as our predictions for success may color our memories about beliefs. The significant anomaly was the category of others perception of engineering. This category represented a small difference between persisters and switchers, as most people believe the community views engineers with respect. This serves to limit this theme's ability to serve as an indicator for future development of aids in predicting persisters or switchers.

VI. Future Research

While most research on EVT focuses on intrinsic value, attainment value, and utility, this study has indicated that in fact cost can often play a role in students' intention to persist in engineering or switch out of the field. The way that students view a situation and the frame of mind that they use to evaluate consequences significantly influences how they approach different tasks. It is possible that if counselors or teachers were able to identify students who had a negative frame of mind then it would also be possible to build learning opportunities to change these students' perceptions about engineering and the process of becoming an engineer. EVT through its analysis of attitudes, beliefs, and motivations, provides a unique tool capable of examining previously unexplored motivations behind retention of students within STEM fields, and if a framework for development of evaluation tools can be developed, it provides the opportunity to train individual instructors to identify and react to different motivational and learning structures to produce targeted advancement for recruitment and retention.

Research still needs to be expanded in the development of evaluation tools for identifying these themes within students. Research will need to focus on incorporating processes that allow for a predictive identification of the themes as opposed to past recollection and should be expanded to understand the differences between motivational patterns for underrepresented groups. Research should also be expanded to include how EVT intersects with other types of attitudinal research. Vansteenkiste, Lens, De Witte, & Feather have produced studies which indicate that applying both Self-Determination Theory and EVT at the same time is able to account for more variance within the data then either alone [8]. Looking at the intersection of multiple attitudinal research types could provide a more nuanced evaluation of the data collected within future EVT research. Finally in relation to retention, EVT should be used to inform practices involed with the applicaiotn of alternative pedagogies such as PBL and cooperative learning. Motivational sturctures can inform classroom pedagogies to increase the effectiveness of both as we move towards a more inclusive learning environment.

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First-Generation Engineering Transfer Students:

A Qualitative Study of Social and Cultural Capital

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Abstract—**We present the preliminary results of interviews with 18 first-generation engineering transfer students at two institutions. We employ a unique method for categorizing students according to generation status and then examine whether their experiences differ from one another. We then describe the different experiences of transfer students based on parental education status, with a focus on negotiating the transfer process, involvement in extra-curricular activities, the use of study strategies, and assistance received from families. Our early results suggest that it is useful to make finer distinctions between the various levels of parental education (i.e., use three rather than two categories).**

Keywords-transfer student; first-generation student; social capital; cultural capital; persistence; STEM

I. Introduction

There has been much discussion about the needs, expectations and experiences of first-generation college students. Some studies focus on operationalizing the definition of "first-generation," while others look at the differences in the social and cultural capital of first-generation versus non-first-generation college students (students for whom one or both parents attended college and/or earned a college degree). [1]

This paper is the second in a series investigating the influence of various forms of social capital on transfer student outcomes and thus attempts to fill a gap identified in research on transfer students (those who attend more than one institution during their academic careers).[2] An earlier paper reported preliminary findings on how social, cultural, and transfer student capital interacted with institutional student orientation and advising efforts.[3]

II. Literature Review

In this paper, we seek to better understand whether the parental education status of transfer students is related to transition experiences. First-generation students are a growing segment of the college student population and the transfer pathway holds promise for expanding the diversity of higher education in general and engineering in particular. Given that parental education is related to both socioeconomic status (SES)[4] and race/ethnicity,[5] it is important to better understand how parental education influences student educational pathways.

From a theoretical perspective, parents can be an important source of various forms of student capital, including social capital,[6] cultural capital,[7] and transfer student capital.[8]Taken together, these forms of capital refer to the knowledge, skills, networks, and access necessary to successfully negotiate and ultimately graduate college .[9] Since first-generation students' parents did not attend college, those students may have low amounts of capital (e.g., information, access to social networks, etc.), potentially hindering their ultimate success in college. We contend that first-generation transfer students may experience "dual culture shock" resulting from being the first in the family to attend college and from the transfer process itself.

Methodologically, we respond to a call to go beyond the traditional approach of using only two categories of parental education (first-generation vs. non-first generation) to examine the influence of social capital on student retention and outcomes.[2] Since a large proportion of transfer students begin at 2-year colleges, we wanted to learn whether using a three-category definition that includes 2-year institutions would result in a more nuanced understanding of the role of parental education PE on student outcomes. Previous research suggests that such distinctions are important for learning about the "conditional impacts" of different levels of parental education.[10] We posit that including a mid-level of parental education, which includes earning a 2-year degree as the highest level of education, will allow us to capture the unique experiences of transfer students, many of whom transfer from 2-year institutions to 4-year institutions.

III. Research Questions

Theoretically, we investigated: (1) How the experiences of engineering transfer students vary, depending on their parental education (PE); and (2) When adjusting to the new institution, whether students enacted social and cultural capital in different ways, based on their parents' education. In particular, we examine the following dimensions of the transfer student experience: negotiating the transfer process, the use of advising and study strategies, and involvement in extracurricular activities. We also summarize the level and character of support from family members. As described above, methodologically, we expand previous research by including an additional PE level to understand student experiences.

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IV. RESEARCH METHODS

We recruited our students from two large public research institutions, located in the Southeastern United States, that graduate a significant proportion of engineering students. Representatives at the two institutions emailed an invitation to engineering transfer students who had matriculated into the institution in the two years preceding the semester of the interview. Interested students provided demographic and interview scheduling information through an online survey. Participants were selected from six engineering majors (civil, chemical, computer, electrical, industrial, and mechanical). To meet our research objectives, we limited our study to those students who were seeking their first bachelor's degree (unless they were in a 3+2 program through which students attend one four-year institution for approximately 3 years before transferring to another institution, ultimately receiving degrees from both institutions). Students were diverse in terms of gender, ethnicity and PE. Selected students were interviewed in Spring and Fall of 2012. Interviews ranged from 19 to 65 minutes; the average length was about 37 minutes. Participants were paid $20 after the interview. Interviews were audio-taped and then transcribed verbatim and verified. We used a constant comparative coding method to elicit major themes related to our research questions concerning the influence of PE on transfer experiences.

Based on previous research [10], we categorized students based on whether: (1) both parents' highest level of education was graduating high school or lower ("low parental education" - LPE); (2) both parents graduated high school and one or both parents attended college and/or earned an associate's degree ("mid-level parental education" - MPE); or (3) both parents' highest level of education was a bachelor's degree or higher ("high parental education" - HPE).

For the current analysis, due to time constraints and the exploratory nature of this paper, we randomly selected six interviews in each category from among a total of 39 interviews at the two institutions.

V. INITIAL FINDINGS

A. Negotiating the Transfer Process

LPE students were more likely to describe their strategy for applying to the receiving institution as self-initiated. They had to "take the bull by the horns" to figure out the logistics of applying and determining which courses would transfer. They reported disappointment in the lack of support at both the sending and receiving institutions; they expected help but did not get it. The one LPE student who reported a more positive experience with the transfer process was part of a 3+2 program.

MPE students were more likely than LPE students to report meeting with counselors to learn more about the transfer requirements. They consulted individuals at both the sending and receiving institution. HPE students were most likely of the three groups of students to describe the transfer process in positive terms as "not so bad" and "smooth." One student said she felt confident about applying to the receiving institution "after taking courses [at the sending institution] and knowing what college is like." Another HPE student, who had attended two prior institutions, described using a variety of strategies to ensure her credits would transfer, including visiting the MIDFIELD institution, calling her major department, and utilizing the transfer credit equivalency website.

B. Advising and Study Strategies

There were distinct differences in student descriptions of their advising experiences. LPE students were most likely to describe their advising as "self-initiated" or as inadequate, especially at the sending institutions. The one exception was for a student who was a part of a 3+2 program; she reported that her advisor (at the sending institution) was quite helpful. MPE and HPE students were both more likely than LPE students to report using personal networks to obtain advice about coursework and succeeding at school. For example, an MPE student reported that the dean at his sending institution provided in-depth assistance in obtaining a scholarship. All HPE students reported receiving in-depth support from their advisors. For example, a student described receiving specific suggestions from his advisor for succeeding at the receiving institution: "My advisors told me to take easier classes and take a lighter load…he told me that most transfer students don't do well their first semester. So I should take a lighter load."

Respondents used a variety of survival strategies to ensure a smoother academic transition. LPE students were more likely to describe themselves as independent enough to "figure it all out"; others indicated they were still trying to navigate the system. MPE students also participated in a variety of study strategies, with one saying that he sought help "every day, every night" and another who attended all the tutoring hours, similar to an LPE student who said he went to supplemental instruction "as much as humanly possible." While HPE students also engaged in a variety of study strategies, they were more likely to indicate that they sought help from professors than did the other students.

C. Involvement in Extracurricular Activities

Extracurricular activities can be an important source of social and cultural capital for first-generation students who are negotiating a new academic environment.[10] All LPE students said they were very involved with extracurricular academic and social groups, with one saying she got involved "right off the bat." They did so for a variety of reasons: to reinforce classroom learning, network with others, and to ease the transition to the new schools. MPE students were also involved with student groups, with one indicating it was important for "engineering students to stick together" to get through the major. While HPE students were more likely to indicate they joined a variety of groups, they did not describe taking an active role in these organizations to the extent that MPE and LPE students did. For example, one HPE student said he really didn't see a need to join a group for transfer students; rather, he relied on friends that he knew from high school to learn how to succeed at the receiving institution.

D. Assistance from Families

Students from all three groups described receiving moral, emotional, and financial support from their families; however, LPE and MPE students used stronger adjectives to describe such support (e.g., "My parents are extremely proud of me";

and “They don’t want me to quit.”). An LPE student reported feeling immense pressure being the first in his family to attend college; he said he was “heartbroken” after receiving a failing grade on an engineering test, knowing this would disappoint his parents. An HPE student reported receiving practical and logistical support from parents in applying to school and negotiating the transfer process; for example, one student indicated relying on his parents to complete financial aid forms. In direct contrast, an LPE student indicated that, “you have to have the initiative… Because nobody…you don’t have your mom fill out those applications. My mom didn’t do that…frankly, she’s lucky I did it on my own.” Another LPE student commented that he sought academic advice from other adults who had earned a 4-year degree. MPE and LPE students often contrasted their own educational experiences with their parents’ educational experiences, which is not surprising. However, these comments allude to some potential challenges posed by the “cultural divide” with their parents. For example, one MPE student described himself as being the “black sheep” in his family for attending college, saying “I’m the smart one.” His family often teases him by calling him “Professor.” This same student reported “starting my own family tradition” by being the first in his family to go to college. Several LPE and MPE students said their parents could not at all relate to the logistical and practical challenges posed by both the transfer process and majoring in engineering.

VI. Future Research

Our research expands knowledge about the differential experiences of engineering transfer students based on parental education level. Early results suggest that LPE students were more likely to feel isolated upon arrival. They were more likely to report getting moral support from their families for attending college and for their choice of engineering major. However, of the three PE levels, LPE students described receiving less support from the institution for navigating the complex transfer and higher education pathways. This finding supports previous research on the relationship between parental involvement and parental education.[4] MPE students had similar experiences and were more likely to identify as “first-generation” even if one or both parents had college experience (attended college or earned an associate’s degree). HPE students relied on parents for practical assistance, but were equally as likely as LPE and MPE students to utilize a variety of study strategies.

Overall, our results support using a more nuanced definition of PE that includes a mid-level of parental education. This is especially important given that this level incorporates the distinct experience of attending a 2-year college. It should be noted that our research is based on student reports of their parents’ educational status; we did not ask the students about the experience of their siblings. That is, a respondent may have had an older sibling or other close relative who had attended college and given them advice about how to succeed.

In future papers we will analyze 86 interviews conducted at five large research institutions to learn more about the influence of PE on engineering transfer student experiences. These data will allow us to compare across the five institutions to learn how institutional context and individual characteristics mediate the influence PE on transfer experiences. We will investigate to what extent other sociodemographic characteristics, such as gender and race, may shape student experiences.[11] Our previous research suggests that distinguishing between sending institutions (2-year vs. 4-year) merits further investigation as well.[12] Finally, we will ascertain the influence of locus of control, motivation and other psychological factors that are important to consider, especially in the context of understanding how student experiences may vary based on parental education status.[4]

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A New Vision: Changed Engineering Outcome Expectations through EWB-USA

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***Abstract*—With the growing demands for additional and diverse engineers, the atypical gender balance experienced by Engineers Without Borders-USA (EWB-USA) is a unique engineering education research setting. Exploring the gender balance of this organization could assist the field's efforts in better recruiting and retaining female engineers. In this work-in-progress study, a social cognitive career theory framework is used to explore the engineering outcome expectations of engineers both involved and not involved with the organization. Qualitative methods were used to gather outcome expectations of male, female, professional, and student engineers, and initial case-based and thematic coding was performed. Preliminary results suggest that EWB-USA members have unique engineering outcome expectations that are often influenced by their organizational involvement. This study may identify ways in which the larger engineering field can replicate similar alternative expectations, particularly to aid the recruitment and retention of a more gender balanced engineering population.**

Keywords—outcome expectations; EWB-USA; retention

I. Introduction

Shortages of skilled engineers present concerns for future global economic competition [1]. These shortages have caused researchers to search for solutions in creative methods and settings including K-12 initiatives, work-life balances, pedagogical alternatives, mentorship programs, etc. [2], [3]. One unique context to study how to aid the engineering population is the non-profit, engineering organization Engineers Without Borders-USA (EWB-USA), which provides engineering solutions to developing communities around the globe. In its eleven years of existence, this organization has rapidly grown to 12,000 members in both student and professional chapters, and it reports roughly 40% female involvement [4]. Because this organization experiences such a contrasting demographic from traditional engineering settings, which average between 11% and 20% female involvement, this setting provides a unique context for research [3]. The large goal of this study is to explore EWB-USA's gender-balanced membership in order to better understand what can be done to recruit and retain more women in the engineering profession.

The framework for this study departs from social cognitive career theory which has been well studied in the context of math and science fields [5], [6]. This theory describes career choice motivations as based heavily upon both self-efficacy expectations (asking, can I do this?) and outcome expectations (asking, if I do this, what will happen?) [5]. These two factors are the primary drivers for this model of career choice and action. Several researchers have studied the impact of self-efficacy on engineering motivations (e.g. [7]), but very few studies have focused on outcome expectations, which some researchers claim should receive more attention [8]. Therefore, this paper fills the gap to explore the engineering outcome expectations of EWB-USA members.

Because social cognitive career theory proposes that career related interests and choices are dynamic and continuously adapting, this theoretical model offers a framework to show that engaging in EWB-USA can alter the outcome expectations and career goals and actions of an individual. Using this underlying framework, this study addresses the following research questions:

1. What are the engineering outcome expectations of EWB-USA members?
2. Do engineering outcome expectations differ between EWB-USA members and engineers not involved in the organization?
3. How does EWB-USA influence engineering outcome expectations of its members?

II. Methods

Due to the exploratory nature of this research, qualitative methods were used for their strength in rich descriptions. Semi-structured ethnographic-style questions were used to conduct both interviews and focus groups covering topics including motivations, career goals, and expectations of an engineering career. In total 165 engineers participated—105 EWB-USA members and 60 engineers not involved with the organization. Participants were primarily recruited through engineering organizations such as EWB-USA, ASCE, ASME, etc. and were selected purposively for a mix of males, females, students, and professionals. Recordings were transcribed and uploaded into qualitative coding software for inductive case-based and thematic coding.

Analysis is still underway, and thus far two thirds of the transcriptions have been coded using QSR NVivo 10 software. Data has been coded at the macro level for engineering outcome expectations which were recognized in the transcriptions through Bandura's three main types of outcome expectations: social, material, and self-evaluative [9].

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Distinctions between these three types have not yet been analyzed; however, all three were used to operationalize the framework in the coding process. Once transcriptions were coded at this macro level, the resulting coded segments were carefully read by the research team to look for themes and comparisons.

III. Preliminary Results

The results presented here are based on trends from initial coding and are preliminary. Further micro-level coding is continuing to distinguish the types of expected outcomes, to determine the relative frequencies of the response themes, and to explore differences between demographic groups such as students and professionals.

A. Engineering outcome expectations

Initial coding highlights that the engineering outcome expectations of EWB-USA members show hesitancy about the profession. In order to illustrate these hesitancies, some representative quotes from the data are shared. When asked about their expectations of an engineering career, most EWB-USA members expected a disconnect between the workplace and school ("*from the work that I've done in the private sector, I don't think that much of anything will look like going to school here*"); they expected to be bored or feel stuck ("*I don't want to be the type of engineer that is stuck in the office looking at technical sketches all day*"); they expected that it would not be social or impactful ("*the reason that [a lot of my friends] didn't go into [engineering] is because… they wanted to be out in the community and be active and help and do all these things and I don't think it was clear that you could do that in engineering*"); and they expected that they would not be happy and would eventually want to leave ("*I can't see myself being happy actually doing that for the rest of my life*"). While there were some more positive exceptions to these outcome expectations (such as one male's comment, "*so hopefully engineering will help me out somewhere*"), the majority of the engineering outcome expectations from this group were more hesitant than positive.

In comparison, the engineers not involved with the organization had more positive engineering outcome expectations. Some engineers were excited about the money or job security that they expected in engineering, ("*the reasons for [me] being an engineer is job security because that's obviously important right now*"); and they expected to be able to pursue their interests ("*I prefer the hands-on practicality, so that's why I'm an engineer").* In some ways their responses were similar to the EWB-USA members in that they were unsure how much their engineering curriculum would align with important on-the-job skills ("*[at work] you are not doing the problem just to solve a problem, you are not doing it just to get a grade, you are doing it to make money*"). While some engineers in this group showed hesitancies about their engineering outcome expectations, many more engineers in this group seem to be positive about the outcomes they expected from their engineering career.

B. EWB-USA influencing engineering outcome expectations

These contrasting engineering outcome expectations suggest that those engineers in EWB-USA are less likely to pursue engineering than engineers not in the organization. Yet in taking a case-based approach at answering the third research question, how EWB-USA influences its members' engineering outcome expectations, we start to see four pathways emerge, each of which will be described briefly here with a case. For each of these pathways, the research team used a low level of inference in order to identify influence based on participants' direct language.

1. Some members "see the light" in a traditional engineering career through EWB-USA as it helps them expect to be able to balance their multiple interests. For example, one female student said that "*I think the interpersonal aspect of EWB and working with the communities solidified the fact that you don't just need math and science to be good in engineering. … It made me think that I'd made the right decision… that I could survive engineering*."

2. Other members show that they have "found their niche" in engineering through EWB-USA by seeing a unique type of engineering that they can expect. As another female student said, "*I really want to do engineering but not like smartphone engineering, I wanted to do a different kind of engineering… I don't want to work in a process plant, that is not why I am studying engineering… and I get comfort from being in EWB because I have kind of stopped doubting that engineering was the right thing*."

3. A third pathway shows other members who, through EWB, have seen that they do not like the outcomes that they expect in their careers and plan to "readjust". One female professional member claimed, after witnessing the careers of people in EWB-USA, "*I am probably going to go back to school for a master's degree and probably just refocus my engineering career because… I had been able to see that what I am doing now isn't what I want to be doing long term*."

4. A fourth pathway comes from those members who have come to expect, through EWB, a mismatch between their interests and their careers. Those on this pathway plan to stay in the engineering profession for a limited time in order to "use the profession" for some valued outcome such as technical skills or salary. As one woman said, "*[EWB] sort of kept me in engineering… I don't find joy in designing a tank… I'm staying to make sure I can truly be the best engineer… I sort of go through every spring wanting to leave*." Members on this path are considering leaving engineering for a better match elsewhere, but are persisting for a certain gained value from the profession.

While each of the examples in the four pathways above quotes a woman involved with EWB-USA, some men show similar responses, such as one male who "found his niche" in unique engineering positions. He said of EWB-USA engineers, "*we're going to be pretty hard to impress with business as usual, status quo engineering*." Similarly, a woman not involved with EWB-USA talked about changed engineering outcome expectations through research she did as an undergraduate, "*it was all about helping kids in India… and for me that was just the kind of boost that I needed in the midst of the misery of engineering school, knowing that what we do is great*." This woman showed how her research experience changed her outcome expectations to help her "see the light" in engineering.

These examples highlight that there may be other men in EWB-USA who follow these pathways, or that there may be other engineers not in the organization with changed engineering outcome expectations through alternative activities; however, the majority of cases where engineering outcome expectations changed came from the EWB-USA members, particularly the female members. These pathways suggest that EWB-USA influences the engineering outcome expectations of its members in varying, yet significant ways.

IV. CONCLUSIONS

So far, the results from coding suggest that EWB-USA members have different engineering outcome expectations than engineers not involved with the organization. As their stories show, these differences can arise from the influence of the organization; EWB-USA influences what these engineers expect from an engineering career by altering their perceptions of its related outcomes. Based on a preliminary, case-level of analysis, four general pathways of these outcome expectations have emerged—some keeping EWB-USA members in engineering and some encouraging their exploration of alternatives. Theoretically, these results add to the application of social cognitive career theory, particularly in the call for extended understanding of outcome expectations and their link to choices and actions. Practically, these findings suggest that EWB-USA could act as an important link to engineering for those with traditionally less presence in the engineering field by giving them an opportunity to pursue their diverse interests (e.g. "*a different kind of engineering*") and explore their fit in engineering, even if for a short time. These practical results suggest that universities and workplaces should encourage the creation of this link between engineering and diverse interests through organizations like EWB-USA; however, they should also be aware of the potential struggles when enthusiasm is unmatched by a supportive culture [10].

Continued analysis for this project will solidify these pathways and quantify the results. The results presented are limited to a first, macro-level coding scheme based on emerging trends. Because this study is not longitudinal, results are also limited to participants' retrospective interviews where outcome expectations are interpreted through participants' use of direct language. Final results could impact the ways that the engineering profession addresses recruitment and retention of engineers, particularly females, by altering engineering outcome expectations.

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Expectations of Computing and other STEM Students: A Comparison for different Class Levels, or (CSE $\neq$ STEM - CSE)$|_{Course\ Level}$

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***Abstract*—Students begin each new course with a set of expectations. These expectations are formed from their experiences in their major, class level, culture, skills, etc. However, faculty and the students are often not on the same page with respect to expectations even though faculty provide students with course syllabi. It is crucial for faculty to understand students' expectations to maximize students' learning, satisfaction, and success. Furthermore, it would promote classroom transparency. There would be no hidden unstated expectations; disappointments during the course can potentially be minimized. We present the results of a survey focused on understanding student expectations. Specifically, we focus on examining the differences in expectations of the students of Computer Science and Engineering (CSE) courses and non-computing STEM courses. We present our analysis and observations of the results using aggregate data for all students at all class levels. We observe various differences and similarities among the STEM fields. Identifying differences is crucial since many non-computing STEM majors are enrolled in computing courses, especially in the lower level courses. We provide a detailed comparison among sophomore and senior level courses in computing, biology and chemistry courses. We also compare sophomore and senior CSE courses. Finally, we discuss the importance of paying attention to all students' needs and expectations. Armed with this knowledge, faculty members can increase transparency in the classroom, student satisfaction, and possibly student retention.**

I. Introduction

Education is a national interest and President Obama has said "If we want America to lead in the 21^{st} century, nothing is more important than giving everyone the best education possible from the day they start preschool to the day they start their career" [16]. The President's Council of Advisors on Science and Technology (PCAST) in its 2012 report to the president put forth an ambitious goal of producing one million additional college graduates with degrees in the different Science, Technology, Engineering, and Mathematical (STEM) fields [17]. Computer and Computational Sciences and Engineering have a significant impact on almost all other STEM fields. It is a vital and crucial foundation to be built upon in other STEM fields [27]. This translates to a desire to push for multi-disciplinary connections between computing fields and other STEM fields. Projects such as *Engaging Computer Science in Traditional Education* (ECSITE) [8], [9], which developed curricular units that are embedded into non-computing $K-12$ classes to introduce computing to $K-12$ students, and the special session chaired by U. Wolz and L. Cassel to promote and discuss interdisciplinary computing [4] are two efforts that show the existence of initiatives in improving and introducing computing to curricula at different levels and stages. These initiatives originate from the reality that, all over the world, computational technologies have become an integral part of our daily lives. Other efforts that aim at improving science education such as Anderson *et al.* [2] have made recommendations for general science education, including adopting techniques already proven to increase learning.

The two thrusts above, namely, the need and importance of integrating computing into current and future curricula in the $K-12$ realm and at colleges and universities as well as the goal of producing more STEM graduates, mean that there are a larger number of students who are expected to be enrolled in colleges in STEM fields and that they will have more exposure to computing. If these efforts succeed, Computer Science & Engineering faculty should expect more students from other fields, specifically other STEM students, in their classes. It is important to understand and address the needs and expectations of this new category of students not only for their own growth, but also for the future of computing in general. Understanding, contemplating, and acting upon students' expectations will ultimately maximize the efficiency of the time that students are in the classroom and will increase the likelihood that learning goals are achieved. We may even entice a good portion of students to transition to a computing degree or to add computing as a second major. Without spending time in understanding our students and their expectations, it will be very difficult to move forward or to achieve these goals.

In this paper, we introduce a survey conducted with 816 students in 25 different STEM courses that addresses the need for examining the students' expectations at the beginning of any individual course. Results are presented alongside data from two specific computing courses. The rest of the paper is organized as follows: Section 2 discusses the related work and provides an overview of literature on student expectations. Section 3 describes the development and content of the survey tool we piloted (the survey can be found at [10]). Section 4 presents the results from the pilot with a variety of breakdowns. Section 5 is a discussion of the impact such a tool can make. Section 6 describes future directions of research.

II. Related Work

Understanding students and their expectations is not a new idea; a large volume of work exists in the literature that

TABLE I. A SUMMARY OF THE SURVEY CATEGORIES, QUESTIONS AND SELECTIONS

Categories	Questions	Available Choices	
	Which of the following do you expect in this course?	Learning Management Systems	PowerPoint
(1) Technology	Rank the three most important components in	E-Textbooks	Social Media
	this course for your learning	Clickers [Lecture]	
	Which of the following do you expect in this course?	Demonstrations Textbooks	Chalkboard/Whiteboard
(2) Learning	Rank the three most important components in	In-class Discussions	Small discussion groups
Activities	this course for your learning	Study guides [Lecture]	Non-Textbook readings
	Which of the following do you expect in this course?	Group Projects Homework	Individual Projects
(3) Learning	Rank the three most important components in	Essay-based Exams	Multiple Choice Exams
Assessments	this course for your learning	Written Papers [Lecture]	Class participation points
	Which of the following do you expect from the	Interact with students in class	Be accessible
(4) Faculty-Student	instructor of this course?	Know students' names	outside office hours
Interactions		Hold office hours Other	None of the above
	How soon do you expect your instructor to:	Immediately	Within 24 hours
(5) Timeliness	Respond to email and phone calls, post grades,	Within 2 days	Within a week
of actions	return assignments, be available to meet	[Longer than a week] Never	N/A

investigates this ideas. For example, Tricker [24] looks for the reasons behind changes happening in student expectations over a period of three decades. The most relevant, closest, and most prominent work is the National Survey of Student Engagement (NSSE) [12]. NSSE assesses how students are engaged in learning, what practices affect this, and several other measures. With a focus on institutional-based measures, it collects data only from freshmen and graduating students. Likewise, Sander *et al.* [19] introduces a survey called University Students' Expectations of Teaching (USET), measuring incoming students' hopes, dislikes, and expectations for teaching and learning methods. These learning methods are general pedagogical choices such as regular formal lectures, group work, and private study. The limitation of Sander's work is shared with NSSE's. Both aim for comprehensive curriculum design but are cumbersome and lacking the detail necessary for an instructor who wants to address a specific class. Another limitation with Sander's work, compared to our work, is that courses surveyed are only in business, psychology, and medicine.

Trudeau and Barnes [25] focus on identifying and ranking the 'teaching dimensions' that students value the most and the least. These dimensions, taken from regular course evaluations, again address ideas like "Knows Material" or "Instructor Availability", without giving concrete knowledge about what students expect exactly to happen in a course. Furthermore, it does not give the students a space where they can freely express their views, limiting response choices to content in course evaluations. Several studies aim to determine the effects from cultural differences in international [22], first-generation and traditional students [5], or working-class students [14]. Additional studies focus on the expectations that surround technology [7], [15].

Reflecting a general concern over graduating students computing capabilities, numerous recent research and teaching initiatives have been devoted to increasing enrollment in CSE courses. Adams and Pruim [1] recognize the lack of supply of graduates with advanced computing skills and suggest ways to encourage non-CS majors to take CSE courses. They present strategies to attract science students to take additional CSE courses.

Our work is complementary since we are trying to provide and illustrate the differences and similarities between the expectations of computing majors and non-computing STEM majors which can be used to adapt computing courses to non-computing STEM students. In other publications, [20], [21] we consider different aspects of our expectations study, which we conducted at UMD as part of a year-long fellowship. In [21], we discuss the survey and its class-specific use in biology courses. In [20], we tangentially address some of the issues pertaining to computer science versus STEM in terms of expectations.

All in all, there is a significant volume of work on expectations. However, we did not find work that is focused enough to clarify why something is not perceived well or to be used in redesigning courses.

III. DEVELOPING THE SURVEY (METHODS)

A. Motivation

To guarantee both success and satisfaction for students in a course, we have to understand expectations of our students. A mismatch between student expectations and what happens in the classroom can have serious negative consequences [11]. Lang in "The Chronicle of Higher Education" [13] discusses classroom transparency, where openness is a key factor in mutual understanding and success between faculty and their students. The University of Illinois, Urbana-Champaign has developed an initiative [26] to increase transparency in the classroom. The initiative provides a platform for collecting results from testing different course changes, but only analyzes the effect at the end of a semester. It is important to increase transparency and close the gap of mismatched expectations between faculty and the students.

Our goal in this work is to create a resource for faculty that could inform them of what students were expecting in a course and to open a dialogue with our students about what faculty themselves expected and planned to utilize in a course. The survey was created as an adaptable, customizable, portable, and generic tool that can be used in any course on any university campus. In addition, we believe that excessive length can adversely impact survey participation and completion. We decided to make the survey as short as possible while still determining course expectations. The design goal was to create something that would take only a few (5 – 10) minutes to finish. In summary our design goals were: 1. Collect information directly related to a specific course; 2. Examine course components that were applicable to any course; 3. Focus

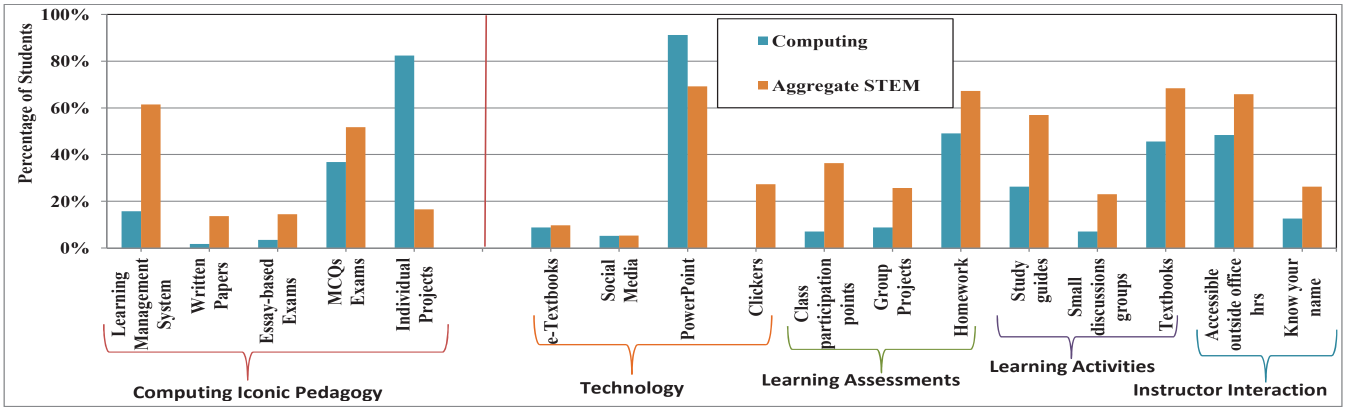

Fig. 1. A selected subset of the aggregate data for students' expectations in courses

survey content to be easily and quickly completed, yet still relevant for instructors.

B. Survey Structure

To satisfy our above stated design goals for the survey, we divided the survey questions into two groups. The first was a set of five demographic questions to provide context and classification for the results and to help us understand the make-up of the student population. The second was designed to gauge the expectations of the students to help faculty in planning, classroom management, assignments, and interactions with and among students. This second set of questions fell into five pedagogical and learning categories: 1. Technology and its Use; 2. Learning Activities; 3. Learning Assessments; 4. Faculty-Student Interactions; 5. Timeliness of instructor's actions.

Table I (adapted from [20] with some modifications) has a concise summary of the second group of our survey. The table outlines each of the five subcategories with the questions being asked and the choices the students can make for each question. The actual complete survey can be found here [10]. The last question we asked (not included in Table I) was an open-ended question which gave the students the opportunity to elaborate on their previous responses – "What misconceptions do you believe faculty have about students?"

C. Deployment & Updates

We deployed the survey in the early Spring 2012 at the University of Maryland, College Park, an R-1 state university. After the deployment, feedback was solicited from instructors whose students participated in the study. We received many useful suggestions and were able to modify our survey based on these insights. Notably, because of feedback from the instructors, in the "timeliness of action" category we added a new choice, namely "longer than a week" to address a gap between "within a week" and "never" in the options originally provided (Table I). We also added "lecture" as a selection option for the first three categories 1–3. Table I includes the suggested changes indicated by square brackets around them. We also clarified some of the questions. We do not believe these missing items jeopardize the validity of our results nor weaken our conclusions, especially in the case of the missed "lecture" option. As for the timeliness, we do not report any of this category's data in this paper. The edited and updated survey consisted of the three relevant demographic questions and six learning related questions. The survey is freely available via a creative commons license through the Center for Teaching Excellence [10]. The Department of Family Science is adopting this idea and thus, the department will deploy the tool in all of its undergraduate curriculum starting Fall 2013.

IV. Results

A. Participation

Instructors from across a wide range of departments were solicited for the study with 27 instructors opting to participate. This provided data from 25 different courses in 8 different departments across campus. Students from all 13 undergraduate colleges and schools at the university are represented in this sample. The final sample included 816 undergraduate students enrolled in STEM courses. Within this comprehensive data-set, there were two Computing courses surveyed, which we will discuss in greater detail: Introduction to Computer Systems (CMSC 216) and Programming Language Technologies and Paradigms (CMSC 433). The responses included 42 from CMSC 216 and 15 from CMSC 433.

The remainder of this section will present selected highlights of the aggregate data including a comparison to computing courses, a breakdown by class status, a breakdown by course level, and a STEM vs. Non-STEM comparison. We present two detailed case study comparisons of four 200-level courses from three STEM departments: Computer Science, Biology, and Chemistry, and three 400-level courses from Computer Science, Biology, and Bio-Chemistry. The complete results are available upon request.

B. Aggregate vs. Computing

Figure 1 presents a large series of comparisons between the aggregate data from all STEM courses including Computing courses and the average result of the two Computing courses surveyed. A few categories with minimal differences have been omitted for brevity. However, the majority of component categories ($\sim$ 75%) did have differences. Several of these results can be expected from iconic pedagogies historically used by computing courses, like programming projects. They are shown in the first section of Figure 1, and are presented to remind instructors that Non-Majors may not be expecting the level and volume of individual projects in a computing course.

The difference in Learning Management Systems points out another trend that is challenging to address. Students from other majors frequently expect professors to utilize university-wide course management systems. However, instructors that are accustomed to an in-house, department-specific, or non-standard learning management system often struggle or refuse to do so. This can create dissatisfaction in students as the information and interactions they have come to take as standard are not available to them.

Within the technology components, several unexpected results appeared. First, while many educators are exploring how to utilize e-Textbooks and social media, students themselves seem to expect very little use of them with only 10% and 5%, respectively, supporting the claims of low technology expectations by Lohnes & Kinzer [15]. This suggests that either the instructors are not using these techniques since they are relatively new in the classrooms or students did not see them in their past experiences and thus are not expecting them. Even though students are not expecting such technologies, there is work in some classrooms and some fields to develop such techniques to improve the learning process [23]. The question will be whether the students will see enhanced learning using these techniques. Instructors will need to take a step-by-step approach when introducing such technology. If instead these technologies are proving even marginally beneficial, it would make sense to spend time experimenting with them to find their rightful place in the classroom alongside other well-documented and researched pedagogies such as active learning [18].

Meanwhile, PowerPoint is highly expected, more so than in other STEM courses. The need to present pre-written code might explain this, however caution should be used since Craig and Amernic [6] have evaluated a significant body of literature related to PowerPoint usage and come to a very 'clear' ambivalence about the success of PowerPoint in enhancing learning. Alternatively, clickers, which several studies have shown to be effective for enhancing learning, are not being used or expected within Computing, even in the larger CMSC 216 course, simply because the instructors in the courses surveyed did not use that technology whereas in lower level CMSC courses clickers are used heavily. In other STEM courses, clickers are clearly expected.

The differences shown in Learning Assessments for Homework and Group Projects reflect a significantly higher expectation of Individual projects in Computing in general. However, the very low expectation of Group Projects is not unexpected since most instructors in lower level undergraduate computing courses opt to use individual projects and not group projects. This probably should be balanced, given the prevalence of team projects in industry, and raises the question of whether we are realistically preparing our students for their future jobs. Finally, class participation points are shown as something instructors should be aware of, and make explicit for students who might have other expectations as it can create an immediate mismatch between reality and expectations (as explained in [11]) for interdisciplinary courses.

The three Learning Activities components with significant differences perhaps harken again to the different pedagogical style inherent in Computing, though these are certainly less prevalent than the components already identified as inherent. Both study guides and small discussion groups highlight areas where instructors might easily introduce important learning activities that will increase student engagement with materials. While study guides are frequently a source of contention, discussion groups are a successful and proven method to help students process materials in class.

The final category of instructor interaction highlights two areas for focus, especially in higher-level interdisciplinary courses. Students from other STEM disciplines fully expect instructors to be accessible (66%), while Computing students have a noticeably decreased expectation (48%). They also have more than twice the expectancy for an instructor to know their name. Both these aspects reflect that a more personalized approach and availability are expected from non-Computing students. This might suggest that we have to build a better rapport with non-Computing students, which might make them more interested in computing and more willing to seek our help.

C. Breakdown by Class Status

Within the comprehensive 816 responses, we had a nearly equal distribution among class status, 29% freshmen, 20% sophomores, 28% juniors and 23% seniors. This provided the opportunity to identify trends in expectations as a student progresses in his or her collegiate career, such as an increase in expectations of discussion, essay-based exams, and group projects (not shown). Nearly all of these match trends are identified in other literature or are generally expected. We do, however, want to highlight one surprising result, which is of particular interest to computing: the overall expectation of technology usage, shown in Figure 2. A mean technology expectation was found by averaging the number of components each student expected in the category of "Technology". The mean technology component expectation for all students was 1.73 with the specific value for each class status shown in Figure 2. This indicates that most students only expected one or two technology components in a course and freshmen expected even less ($p < 0.001$). This data is in-line with the results of Lohnes and Kinzer [15] but challenges initial intuitions.

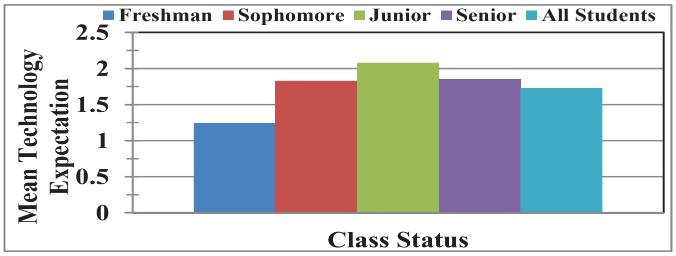

Fig. 2. Mean technology expectation by class status

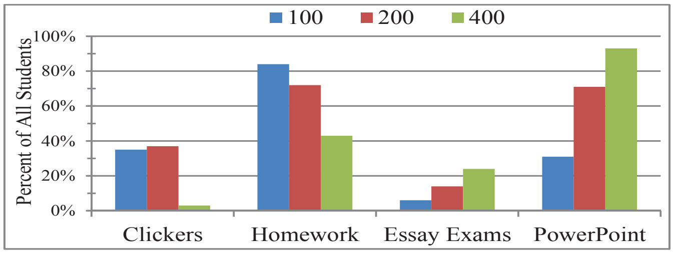

Fig. 3. Expectations in 100, 200, and 400 level courses in selected categories

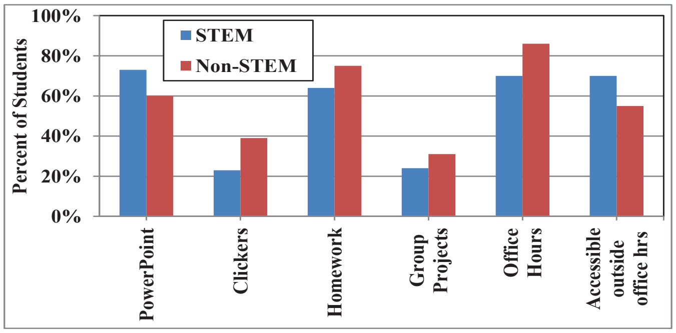

Fig. 4. Selected expectations of STEM/Non-STEM students

D. Breakdown by Course Level

When we break the results by course level, we found that only a small portion of the data came from 300-level courses, mainly from one course. Specifically, the breakdown distribution was 20% from 100-level, 53% from 200-level, 4% from 300-level, and 23% from 400-level courses. Therefore, Figure 3 contains only results for 100-, 200-, and 400-level courses from which meaningful statistical comparisons can be made. While many of the trends present in the breakdown by class existed in the course-level breakdown (essay exams and PowerPoint are shown), the results in clickers and homework expectancy bear particular attention. There is a clear break between larger, introductory courses and their expected use of clickers (used heavily in one of the biology classes surveyed) and smaller more individualized senior-level courses. The expectation for homework also fell, even though other individualized work increased.

E. Breakdown by STEM vs. Non-STEM

Our final breakdown is the expectations of STEM and Non-STEM students. In our data set, 73% of the students belonged to STEM colleges and 27% to Non-STEM colleges. All of the data comes from STEM courses, however, since many of the courses surveyed satisfy general education requirements, a significant portion of the students belonged to Non-STEM colleges and programs.

In Figure 4, there are three pairs of comparisons: technology, assessments, and instructor interactions. Within technology, the difference in PowerPoint is certainly worth noting. Students coming from non-STEM majors expect it noticeably less and may find classes frequently utilizing PowerPoint less interactive. The increased expectation of clickers is clear, but may be an artifact of a larger portion of Non-STEM students in large biology and chemistry general education courses where clickers are heavily used.

Within assessments (category 3 of Table I), we found an overall trend of Non-STEM students having higher expectations than STEM students, of which the most pronounced were group projects ($p < 0.05$) and homework ($p < 0.01$) as shown in Fig 4. The only choice from the assessments category in which they expected less was essay-based exams (not shown). This trend may indicate that Non-STEM students are generally used to and more comfortable with a wider range of assessments. Alternatively, it might suggest that Non-STEM students are less sure about which types of assessments will be utilized in a STEM course.

Finally, there are statistically significant differences between STEM and Non-STEM students in two categories of interaction with the instructors. First, STEM students show a higher expectation of accessibility outside office hours. This may reflect a better understanding of how STEM instructors spend their time or their responsiveness to emails. Contrary to that, Non-STEM students have higher expectations that instructors will hold regular office hours. This discrepancy is worthwhile to consider when scheduling and publicizing availability for students early in the semester. One way of explaining this gap is that non-STEM students are used to getting individualized help because they are coming from writing and art, where such instructor-student interaction is the norm.

F. Breakdown of Computing by Course Level (200 vs. 400)

Presented for completeness, we compare the two Computing courses in Figure 5. Most categories did not show a significant difference. In the five categories that did, most are exactly what we might have expected, representing a shift to more individualistic and interactive learning, which is a global conclusion we saw in the previous breakdowns. Specifically this can be seen in the increase in discussion groups and non-textbook readings, with the corresponding decrease in whiteboard usage. The other two categories most likely reflect individual course decisions made by the instructors and explained in their syllabus. Future studies with a broader sampling of Computing courses will illuminate these trends more clearly.

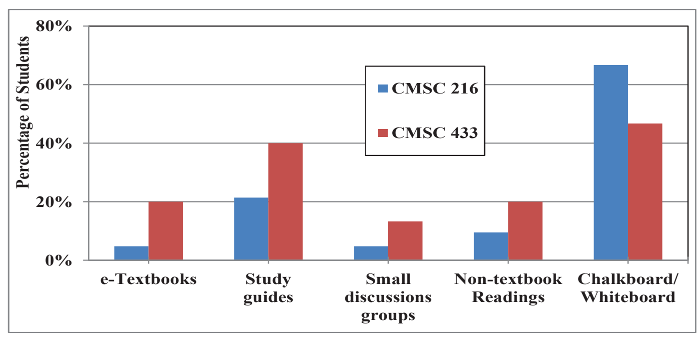

Fig. 5. Comparison of the 200 and 400 CS courses

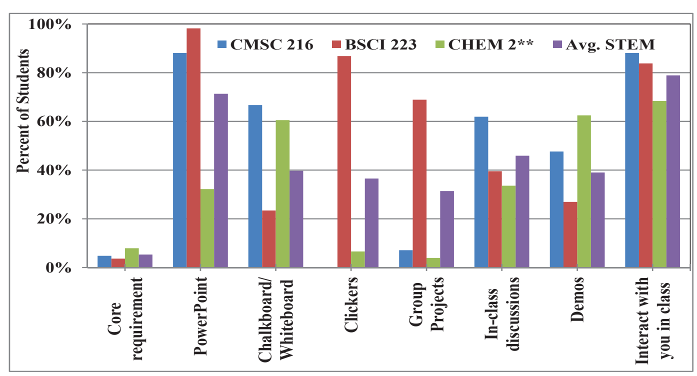

Fig. 6. Comparison of 200-level courses in Computing, Biology and Chemistry

G. Comparing Computing, Biology, & Chemistry Courses

1) Case Study 1: 200 Level: As our first case study, we consider four different 200 level STEM courses: General

Microbiology (*BSCI 223*), General Chemistry (*CHEM 232*), and Organic Chemistry (*CHEM 271* and *CHEM 272*)), and Introduction to Computer Systems (*CMSC 216*). As can be seen in Figure 6, only about 5% of the students were taking the course to fulfill a core requirement, with the Chemistry courses being slightly higher. This low percentage indicates that the expectations in the course are not obscured by students taking the course from a widely varied background (of colleges at the university). The results presented can give us a closer view of how different majors think, remembering that *CMSC 216* is taken by CSE majors only.

While students in chemistry courses did not expect projects, both *CMSC 216* and *BSCI 223* students did, but of very different types. Furthermore, the greater than 20% differences in expectations of homework (Figure 1) need careful consideration. Are the expectations we have for Computing students sufficiently high? When we offer courses to Non-majors are we challenging them to perform at their best?

Differences existed in nearly every category we examined, many of which were similar to the comparison of Computing to the aggregate data. Several unique differences, however, also existed between the courses with the most pronounced shown in Figure 6. There is evidence of different teaching methods with higher expectations of PowerPoint from CMSC and BSCI students and higher Whiteboard usage in CMSC and CHEM students. We see a higher clicker expectation in *BSCI*'s $> 85\%$, since the course requires clickers. We also see a dramatic difference in group projects for BSCI, similar to CMSC's high individual projects in Figure 1, demonstrating two different realms. Our final observation is that CMSC had the highest in-class discussion and interaction (the course has a discussion section in addition to regular lecture), suggesting that, even though all the courses are large, the CMSC course by design pushed for active participation and engagement with the students.

2) Case Study 2: 400 Level: Our second case study, shown in Figure 7, compares three senior level courses in Computer Science (*CMSC 433*), Biology (*BSCI 440*), and Bio-Chemistry (*BCHM 463* and *BCHM 464*). With the higher expectations of study guides and textbook usage, students from Biology or Bio-Chemistry may be unprepared for the learning styles of interdisciplinary courses such as Bio-Informatics. This is further exacerbated for the biology students by an expectation for a very different classroom style involving participation points and various forms of discussion. The Bio-Chemistry students, on the other hand, had very similar expectations of classroom learning activities to computing courses. Also, it seems that both Bio-Chemistry and Biology students expect to have a more personal interaction with their instructors. They expect the instructors to know their names and be accessible outside of office hours. Finally, students outside of Computing have a significantly higher expectation of accessibility outside of office hours as seen in Figure 7, but did not differ significantly in any of the timeliness categories (not shown).

V. Discussion

A. Impact on Curricula

The survey was originally designed to help instructors improve their courses by beginning discussions to increase

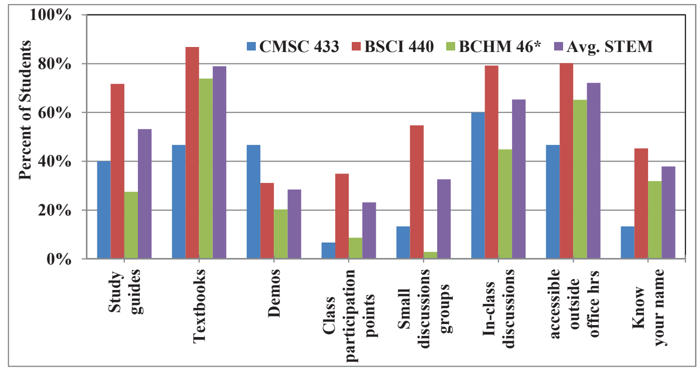

Fig. 7. Comparison of 400-level courses in Computing, Biology and Chemistry

classroom transparency (as discussed in Sect. 3a). While the results in Section 4 point out several interesting trends, we are looking for a greater impact. We started by examining the increasing necessity of computing in all STEM courses as well as beyond STEM disciplines. As more students take introductory courses, these courses can be designed to capitalize on the different expectations that Non-STEM students have, for example by incorporating more group projects or homework. Further, if departments choose to offer courses specifically designed to interest non-majors, as suggested by Adams and Pruim [1], or to offer higher level interdisciplinary courses as suggested by Anthony [3], the courses can be tailored in such a way that the students will leave with a higher satisfaction and thereby increase learning according to James [11] and Lang [13]. Beyond simple adaption, understanding expectations lets instructors address why specific technologies and techniques are used in-class and how they can help students better learn required skills and knowledge. It is vital to remember that while the students might be novices in Computing, they are not novices in the classroom. As one student responded to the open-ended question: "[Faculty believe] [t]hat we don't want to learn – if we show up to class, we are there to learn – it is not hard to "skip" a class. In that vein, if we are in class, please do not baby us, do not mock us for asking questions, and do not waste your time or ours going into information that is irrelevant…" Other important impact areas are retention rates, increased satisfactions, and, if we pay more attention to the expectations of women and minorities, increased diversity.

B. Study Limitations

While the reported results produced several interesting insights and conclusions, there are some issues to address. The instructors administered the survey after the first week of classes and the syllabi had been distributed and presumably discussed. Thus, we would expect students to have a decent idea of what to expect in the course. However, in many courses, categories were often not "expected" 100% or 0% by students. This suggests that even though students had jointly experienced a course there was no unanimous expectations for or against some common things. This may be a self-reporting problem, or perhaps confusion on the students' part. Another limitation is that the data was only collected at a large R-1 school. It would be very exciting and interesting to analyze the expectations at smaller colleges and universities. Another limitation is that a large sector of STEM is missing from our results. Not many Engineering courses were included in the survey, although we did have some Engineering students participating.

VI. Future Work

We are convinced that we have touched the surface of a large area of research that we hope to further work on in the short-term. One faculty member even responded on their feedback form saying: "I thought this survey was great at getting a cross-section of what my students expected from a class…I was surprised at some of the expectations…" To capitalize on this work, we must first understand how data from the survey will influence courses. This is particularly important since we do not anticipate faculty simply meeting students' expectations, but rather discussing survey results to help students better understand the learning process they are involved in (meta-thinking).

However, since this study was the first, faculty members were not able to get the results quickly enough to implement changes to their courses. With the survey now publicly available and ready for use (see [10]), turn-around time in future deployments will not be an issue.

The data we collected dealt only with STEM courses. We would want to do a similar study for Non-STEM courses. It would be interesting to see how the expectations of STEM students would be in non-STEM courses and how they differ from their expectations in STEM courses. Intuition suggests that the expectations in Humanities courses will differ. Another aspect that would be intriguing to add is a longitudinal study – similar to the medical and pharmaceutical studies – tracking the change of student expectations from the day they step into college until the day they graduate to observe the evolution of their expectations, similar to the NSSE tracking.

Conducting a direct extension of this work would be administering this survey across multiple colleges and universities, and comparing both CSE and other STEM students across liberal arts colleges, small or large, teaching and research institutions. A nation-wide study is our more ambitious goal. We would expect such future research to have a large impact on policies and on our understanding of the different institutions and their students.

Acknowledgment

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Teaching Software Maintenance with Open Source Software: Experiences and Lessons

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***Abstract*—Software Engineering (SE) careers are overwhelmingly devoted to the maintenance and evolution of existing, large software systems, where the key challenge is code comprehension especially in the face of inadequate documentation and support. SE courses must thus prepare students to meet this challenge. Open Source Software (OSS) furnishes a valuable source of realistic, sizeable projects for inculcating the appreciation and skills involved in code comprehension and evolution. This paper describes experiences and lessons learnt in using OSS projects to teach an introductory, sophomore/junior-level SE course with an emphasis on comprehension, maintenance, and evolution. Students' reactions and undertakings, acquired through participant observation and homework assignments, suggest that OSS can meaningfully illustrate comprehension and evolution difficulties. Finally, it describes the characteristics of OSS projects that are conducive to highlighting maintenance challenges.**

I. Introduction and Motivation

The dramatic growth of the software industry has intensified the need for skilled and talented software engineers. To respond to this need, most institutions now incorporate a mandatory Software Engineering (SE) course in their curriculum. This SE course must prepare students to handle industrial challenges, which arise from an imminent and pervasive need to comprehend, maintain, and evolve legacy systems [1]. Comprehension and evolution of legacy systems, however, is difficult and cumbersome because these systems may be: (i) subject to many fixes and modifications; (ii) poorly written; and (iii) sparsely documented. It is thus imperative to train students in the skills necessary for efficiently and effectively maintaining software systems. It is also critical to cultivate students' attitudes towards rigorous and systematic system construction to ease subsequent maintenance and evolution.

SE projects with a "maintenance-centric" focus can illustrate these industrial challenges. Maintenance-oriented SE projects, however, require an easily accessible code base of reasonable volume, complexity, and quality. Without this, laboratory projects involve building a system from the ground up and incorporate very small maintenance and evolution tasks where the students modify their own recently written code. A semester's worth of self code can hardly impart comprehension and maintenance skills appropriate to large bodies of code written by multiple others, nor does it necessarily emphasize the importance of systematic system construction. Therefore, these present projects are inadequate at offering realistic, industry-relevant experience and training.

Open Source Software (OSS) projects can offer a diverse, rich, and extensive code base which could be used as a starting point for designing maintenance-centric SE projects. In this paper, we report on our experiences and lessons in integrating OSS into an introductory sophomore/junior SE course, where through a series of laboratory assignments the students were required to understand, analyze, and extend existing OSS systems. Our objectives were for the students to become acquainted with software maintenance: to comprehend another's software, to modify it for the better, and to appreciate a systematic approach. Without being hindered by sparse documentation and with minimal support, the students enhanced their chosen OSS projects with a range of features, suggesting that OSS can offer extensive opportunities for deep involvement with the code. They also cultivated the ability to exploit and reuse the existing code and learnt to appreciate the overreaching impact of project architecture on the ease of implementing enhancements. Finally, we discuss how architecture, state of implementation, and subject matter of a project can influence its suitability for highlighting maintenance difficulties.

The rest of the paper is organized as follows: Section II lays out the case for using OSS. Section III describes teaching maintenance with OSS projects. Section IV discusses characteristics of OSS projects. Section V compares related work. Section VI offers conclusions and future directions.

II. Promise of OSS

The OSS revolution is having a lasting impact on the way software is developed, disseminated, and adapted. This is evident from the myriad of OSS projects already available, and the pace at which they continue to grow. The revolution has thus created easily accessible and exponentially growing [2] volume of code. Popular OSS repositories such as Sourceforge [3], Freecode [4], CodePlex [5], and W3C [6] host more than 200,000 projects. We use these simply as code sources; students do not contribute back to them.

OSS projects span a variety of domains such as tools for software development, financial analysis, security and networking, data manipulation and visualization, audio and video engineering and text editing, operating and database systems, and games and entertainment [3]. These projects

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target common platforms including Windows and Linux and are written in languages such as C, C++, Perl, Fortran, Python, Java, Tcl, Objective-C, Ada, and Php. Although the OSS development process appears *ad hoc*, many projects are completed successfully with rich functionality and high reliability because their latent social structure allows the projects to grow in an organized manner [7], [8]. Moreover, because most participants of OSS do so to build reputation, or for self-development [9] and altruistic reasons, they may be inherently committed to applying SE principles, which may lead to projects that are carefully designed, engineered, and maintained. The quality of open source code may span a range wider than that of industrial systems; because some code is not good enough to be industrial, while some code having had the benefit of a fresh start, is refined compared to industrial code. Therefore by selection with filtering, we hope to find OSS projects that exhibit characteristics and quality similar to industrial systems, and hence, provide a valuable resource of example code for teaching SE.

III. Teaching Maintenance with OSS

Our objective was to integrate OSS into an early, introductory SE course for sophomore and juniors. Our students had limited experience in Java programming and could write, test, and debug only small volumes of code after having taken a data structures course. Our SE course was designed to be "maintenance-centric," and the laboratory exercises, performed in teams of two on OSS projects challenged students to practice code comprehension, use appropriate tools (source code control systems, reverse engineering) [10], and implement an enhancement of their choice. We manually searched and evaluated about 1000 projects from several OSS repositories to find a collection of 17 projects from Sourceforge [11] that were commensurate with our students' preparation.

These 17 Java projects spanned the application domains of Games, Art, Skills, Indexing, Searching and Client/Server applications [12]. Project sizes ranged from 5,500 to 10,500 lines of code; we believe that smaller projects may not adequately provide comprehension and enhancement difficulties, while substantially larger ones may be beyond our students' capabilities. The projects were reasonably modular to demonstrate best practices that aid maintenance. Modularity was assessed by examining the depth, number and naming conventions of directory hierarchies, number of files, and packages, and average and variances of the number of files within a directory and lines of code in a file. Projects were lightly documented, in case outstanding documentation might not adequately represent comprehension and evolution challenges.

A. Sample OSS Projects

In this section, for each project, we describe the intended functions and attempted enhancement, scoped within the range of feasible extensions.

1) **CarDriving:** This arcade car game had a primitive user interface with no user instructions. A range of enhancements, from advancing the capabilities of the car and the environment through which it is navigated, were possible. Students upgraded the GUI to include a driver's wheel that could be turned. They also improved collision detection and wrote a tutorial.
2) **Coppit:** A board game with a computer player, this project also did not have a very imaginative GUI. The range of enhancements stretched from improving appearance to artificially intelligent players. The students overhauled the interface resulting in a significantly improved interaction experience. They fixed some bugs, and also delved into the selection of players and legal progress of pieces in the game.
3) **Domination:** This project, a "single-shooter" game was quite simple. The students implemented a sophisticated GUI, including a menu of choices.
4) **FourRowSolitaire:** A GUI simulation of a "card game" had a moderately detailed display. A spectrum of enhancements were possible; from user interface to artificial intelligence. The students' enhancement allowed a pleasing display of predictable sequences.
5) **ChessBoard:** This polished game already included an automated opponent, and ambitious enhancements such as advancing the level of play with artificial techniques were possible. The students attempted a cautious one though, customizing the appearance of the game.
6) **JigsawPuzzle:** This game broke a user-selected image into a specified number of pieces and then provided a GUI to assemble these pieces. The enhancement chose to provide a puzzle solving hint upon request, highlighting a piece adjacent to the selected piece.
7) **JugglePat:** This animation project clarified patterns. Advanced modifications such as judging whether a given string represents a legal juggling pattern or inventing new patterns with concatenation could be imagined. The students improved the GUI significantly with coordinated music, making it appealing to an audience beyond the juggling aficionados.
8) **Melosion:** This game accompanied the practice of musical skills with animation. It separated the concerns of interfacing with peripherals such as MIDI and WII over several packages. Students chose a minimal enhancement, being the entry of a new song.
9) **Monopoli:** This project offered very little scope for enhancement while remaining within the rules. The students improved the GUI for rolling the dice.
10) **MusicSkillsCoach:** The implementation of song and activity selection in this project was at an early stage. It allowed for adding the planned functionality such as microphone input and testing pitch for *solfeggio* practice. Enhancements included the ability to play a whole song, to pause and continue to rewind, and an improved GUI.
11) **NocNorade:** This project included an attractive board, but very little implementation of a client/server game of increasingly complex levels. The students implemented one game, devising their own rules and moves.

12) **Picofarm:** This client/server application allowed users to remotely select animals and place them on a farm. The students extended this project to include additional farm animals and placement options such as close to a barn and a pond. Architecturally, they increased the prominence of the local mode over the client/server one.
13) **Puggle:** This project provided indexing directories for search. Although highly polished, it was easily extensible. The students chose to add two document types to the indexed list, which widened the domain instead of increasing its complexity.
14) **SlimeWarrior:** This was a 2D role-playing arcade game with scrolling images and ability to score points. It used sound and simple animations. Possible, open-ended changes included additional characters, scenery and story line. The students enhanced it to allow a user to direct the actions of the warrior, controlling the speed, direction, and height of jumping and scaling obstacles.
15) **vgt-battleships:** This complete but unpolished game offered opportunities for enhancement ranging from user interface, artificial intelligence for the computer player and including more vessels. The students updated the GUI to provide instructions and sound effects. They also put a lot of productive effort into the documentation.
16) **Sudoku:** The students added first level of artificial intelligence to this polished project. Complicated enhancements would include advanced reasoning and hints.
17) **Simulum/Mulumis:** This complete project produced a lovely star field display. The students enhanced it to incorporate star generation, zoom and pan, and associated music as a sound track, whose volume could be modified in accordance with the speed of the display. Many other extensions would have required solving equations governing the motion of celestial bodies.

B. Engagement with Maintenance

We comment on how the projects and their extensions engaged students with maintenance aspects.

1) Enhancement Difficulty: Table I ranks the difficulty of attempted feature enhancements as “Small (S)”, “Medium (M)” and “Large (L)”. We judged difficulty based on our estimate of the extent of impact on the existing code, and the existence of industry standard approaches for the functionality, using our combined programming experience, which exceeded forty years. We also included conversations with students as they were working on their projects. Only two teams chose easy, superficial enhancements, while other extensions were of at least medium difficulty. Updates and improvements to GUIs were most popular, which could be due to the visual feedback and satisfaction that a functional GUI provides. These were followed by incorporating varying degrees of artificial intelligence into the games. A few projects also introduced and coordinated displays with music.

2) Degree of Comprehension: The table also categorizes the degree or the extent to which the students had to comprehend their code in order to implement their enhancements as “Superficial”, “Isolated Modules” and “Thoroughgoing”. This comprehension was focused on two aspects of the code, namely, architecture and data representation. Understanding the architecture involved figuring which classes invoked which others and with what information; in other words, how information was moved and transformed in the system. Understanding the data representation involved checking for validity of input and how data was stored and used in advancing the logic. Examples for each degree are provided below:

- **Thoroughgoing:** Coppit represented an example of thorough understanding; because in order to change the appearance the students had to know its method of presentation. They also had to know how and what data was brought into the system, to change how the GUI asked about the players. In order to repair incorrect enforcement, they had to know how the program represented and used the rules. They added some capabilities for players, so they had to know where and how the program accomplished the different choices about pieces and moves of the players. They left no stone unturned in implementing these enhancements.
- **Superficial:** ChessBoard represented an example of superficial understanding, where the students modified the appearance of the pieces. They discovered that the appearance of displayed objects was provided through style sheets or skins [13], which they added. They also allowed chess pieces to take a set of monster/ogre appearances [13]. Melosion also allowed superficial understanding; the data representation made adding a song so simple, it almost evaded the goals of the course.
- **Isolated:** Puggle was an example of isolated understanding, its layered architecture allowed the students to implement an interface for another file type, with some sense of assurance that the impact of their code change would remain confined; and they need not concern about specifics of modules outside their own.

GUI updates were most popular because students may have expected, albeit incorrectly, that such enhancements could be implemented with superficial understanding. Evidence in the table, however, contradicts any such latent or unspoken expectations as most GUI enhancements needed a comprehensive understanding of both the architecture and data representation. The positive interplay between the difficulty of enhancement and the depth of involvement is also seen. Small enhancements (ChessBoard, Melosion, and Monopoli) could be implemented with either a superficial or an isolated understanding. By contrast, all large enhancements (CarDriving, Coppit, Domination, NocNorade, vgt-battleships, and Simulum) required a thorough understanding of the architecture and data representation. Some medium-difficulty enhancements (FourRowSolitaire, JigsawPuzzle, JugglePat, Picofarm) necessitated detailed understanding, whereas others used only isolated comprehension.

3) Impact of Architecture: We learnt about the students' conceptions of architecture by listening to their discussions in

TABLE I
SUMMARY OF ENHANCEMENTS

Project	Enhancement	Difficulty	Aspects	Degree
1. CarDriving	GUI Tutorial	L	Architecture Data Representation	thoroughgoing
2. Coppit	GUI Game rules Bug fixes	L	Architecture Data Representation	thoroughgoing
3. Domination	GUI	L	Architecture Data Representation	thoroughgoing
4. FourRowSolitaire	GUI Game Rules	M	Architecture Data Representation	thoroughgoing
5. ChessBoard	GUI	S	skins	superficial
6. JigsawPuzzle	GUI	M	Architecture Data representation	thoroughgoing
7. JugglePat	GUI Coordinate Music	M	Architecture Data Representation	thoroughgoing
8. Melosion	Entry of a new song	S	partial data representation	superficial
9. Monopoli	GUI	S	Architecture	isolated modules
10. MusicSkillsCoach	Play, pause, rewind GUI	M	Architecture Data Representation	isolated modules
11. NocNorade	Game rules	L	Architecture Data Representation	thoroughgoing
12. Picofarm	GUI	M	Architecture Data Representation	thoroughgoing
13. Puggle	Add document types	M	Architecture some Data Representation	isolated modules
14. SlimeWarrior	GUI	M	Architecture Some Data Representation	isolated modules
15. vgt-battleships	GUI Documentation	M/L	Architecture Data Representation	thoroughgoing
16. Sudoku	Rules	M	Data representation	isolated modules
17. Simulum	GUI Coordinate music	L	Architecture Data Representation	thoroughgoing

the laboratory. Many students learnt to appreciate the impact of architecture in facilitating the implementation of their enhancements. The Puggle team consulted with us on whether it was really permissible to "just add new document types" given that this addition did not require knowledge of all the other aspects of the implementation. The JigsawPuzzle team realized that the project's architecture was brittle, compelling them to change its underlying structure to complete their extension. The Picofarm team checked whether it was enough to change the architecture to handle local representations of animals, without also exercising the remote server portion. JugglePat's modular architecture followed the Model, View, Controller (MVC) pattern [14], which eased its modification. The Melosion team agreed that separating peripheral types into packages helped them narrow their attention. Finally, the NocNorade team stated that having documentation of the planned architecture helped them orient their thoughts.

4) Code Reuse: The students were specifically asked to explore code reuse, and to connect new code for their enhancement to the original code. Coppit and Domination teams reused the overall structure of their respective games, yet renovated almost all of the parts. A developer familiar with the original project would recognize the activities, control flow, events, and objectives, but would find richer, more correct implementation with more options. Earlier designers of CarDriving, by contrast, would notice the addition of new modules and an improvement of previous ones. The original designers of Picofarm would see that what they had imagined had been greatly extended. The emphasis on client/server interactions had been reduced, and GUI interaction that had been minimal had been made more feature rich. Original designers of Monopoli would see that a change of limited impact made use of all of their work. This limitation of impact was even more pronounced in the case of ChessBoard, where the architecture of cascading style sheets made it possible to change dramatically the appearance of the game without modifying the code very much at all. The Puggle team reused code by implementing an already existing interface.

5) Availability of Documentation: Most projects offered very minimal documentation; CarDriving, Coppit, Domination and NocNorade included web sites with ancillary information, but nothing directly about the code. JugglePat, ChessBoard, Puggle, and Simulum included some documentation via HTML and Readme files. vgt-battleships included comments and variable names in Polish. SlimeWarrior included rare remarks in Dutch, however, these did not hinder the students.

6) Additional Skills: Students needed to acquire many additional skills to implement their enhancements. GUI enhancements required AWT and Swing, menus and event handling, bounding boxes, 2D and 3D graphics, buffered I/O streams, file I/O, obtaining resource location via URLs. Specific enhancements called for additional skills: geometry, trigonometry (CarDriving, JugglePat, Simulum), random number generation (Coppit), sockets, TCP/UDP/IP, servers, IP addresses and ports, multithreading (Domination, Puggle, SlimeWarrior), affine transformation (JigsawPuzzle), XML and DOM (JigsawPuzzle, JugglePat, Puggle, Coppit), GIF animations (JugglePat), Newtonian physics for position, velocity, acceleration (JugglePat), permutations and symmetry (JugglePat), linear algebra for matrix transformations (JugglePat, Simulum), grammars and parsers (JugglePat, NocNarcade, Puggle), encryption, password protection (Puggle), MP3 handling (Puggle), archive extraction (Puggle), Rich Text Format (Puggle). The students as a whole learnt a broad range of skills; each team learnt at least what was called for by their own project, in a small amount of time, closely mimicing how software engineers need to make up for deficiencies in skill and knowledge under severe time constraints.

Overall, the students' initial frustration was replaced with a healthy sense of pride, accomplishment, and self-achievement, as they navigated through the code and completed their chosen extensions with a new set of skills under their belts. Survey results [15], [16] showed students' appreciation that software maintenance and evolution was: (i) challenging, resource intensive, and time consuming; (ii) significantly aided by documentation and comments; and (iii) greatly eased by good architecture, but dramatically hindered by a brittle one.

IV. Suitability of OSS Projects

We observed that OSS projects could meaningfully engage students with various aspects of maintenance. However, not all projects could offer these opportunities equally. Therefore, we noted three characteristics of a OSS project that makes it particularly conducive for teaching maintenance.

1) Project Architecture: We wished students to approach the code in a top down manner, rather than habitually seeking lines of code using a debugger with a step capability. Therefore, we chose modular projects and exploited evidence of architecture. Architectures with horizontal infrastructure layers with a top layer of variations upon a type of object were readily extended, because students could build new variations, using the one or more top layer objects as examples and points of departure. Once the students discovered these layers after examining the code, they did not have to comprehend all of the code at the granularity of lines. They could implement the extension by expanding the domain of objects over which the code operated, without changing the architecture. Students working on these projects also benefited from exposure to a good design. For example, Puggle followed a layered architecture and the students easily added indexing for two more types of documents. Although layered projects may be low risk from the perspective of permitting extensions, because the students only need a local understanding and they do not have to struggle with an architecture that is resistant to change or with damaged modularity, these projects may not adequately represent maintenance difficulties.

2) Project State: The project state should provide a set of possible enhancements of varying difficulty. Students can then begin with enhancements that are not overly difficult, and progress throughout the semester, as noted by Rajlich *et al.* [17]. A state of polished completion seems less helpful. Projects were classified as incomplete (works in progress) and complete based on the extent to which planned features were already implemented. Thus, projects that rendered a game board but did not provide a game, or projects whose menus included options that, when chosen, did not result in any usable situation were regarded as incomplete. It was useful to differentiate between projects that were incomplete because of a lack of intended functionality and those where the extension capacity of the implementation was exhausted or was no longer adequate. For example, extending a fixed size data structure with no unused bits (capacity exhausted) was very different than extending it by converting unused bits into used bits. Similarly, in an architecture where peripherals were separated by types, whether a new peripheral was a small variation of an existing one, or a new kind of peripheral was a judgement call. Deciding that a peripheral was new would have had more resource impact than deciding that it was a small variation, because the latter might not warrant a whole new package, but the former would, to be consistent with the architecture. For example, JigsawPuzzle used a two-dimensional array to store information on puzzle pieces. It was an integer field. When additional information was desired, such as the current location of "my neighbor" pieces, the students were initially at a loss for how to extend or expand this data representation to hold this information. Similarly, Picofarm required some changes to move the animals around; and though originally they could be one place or another, our students allowed for rotation and scaling by expanding the animal data structure to incorporate these attributes.

The students were most gratified with projects that were incomplete or works in progress, yet showed enough organization of functionality into packages with documented intent. For such projects, being able to discern the architecture from the code or documentation was important as it provided the students with a good example and a starting point. Although incomplete projects offered much liberty for extension and completion, students working on these might deserve a lot of support to make up for the absence of exemplar modules as in the layered architecture. In our collection, NocNorade, MusicSkillsCoach, and Picofarm were incomplete and followed different architectural styles. Picofarm was implemented with interfaces supporting extensions to additional animals. In this project, the code was significantly extended because the architecture was not limiting. However, incomplete projects providing many avenues of improvement might also allow students to opt for only easy modifications and some method of counteracting timidity or at least ensuring that timidity did not inhibit progress might be warranted. In NocNorade, students showed initial timidity but followed it with a substantial change resulting in a game. The initial timidity in Melosion, on the other hand, was followed by procrastination resulting in a very minimal enhancement.

Thoroughly polished projects that also did not suggest obvious functionality improvements might be less satisfactory. Chess and Monopoli belonged to this category and the depth of involvement was not very high. To implement medium or large enhancements in these projects, the students would not only have to learn the software organization but also how to include new modules, incurring significant effort. For complete projects, it also mattered whether the students examined the architecture before or after choosing the enhancement. Students chose appreciable enhancements when they considered a use case perspective without first examining the architecture, which sometimes led to an in-depth investigation of and struggle with the architecture. Melosion was examined late but because its architecture was organized with each peripheral in its own package the students did not have to struggle as much. JigsawPuzzle was also examined late, which caused a review of options. JigsawPuzzle team knew that they could make a destructuring but relatively easy change, or they could revise the structure. Ultimately, its brittle architecture inhibited deep involvement. On the other hand, when the students investigated the architecture early as in Chess and Monopoli and restricted their choice of enhancement to match what the architecture facilitated, they chose superficial enhancements and did not have to struggle as much implementing their change.

3) Subject Matter: Students cared about the value of the program and the undertaken enhancements from the perspective of users, consistent with the appropriateness of authenticity mentioned by Clear [1]. They derived a measure of enjoyment or other meaning from the domain of the projects be it games, music, general productivity or humanitarian. The subject matter also seemed to have a curious effect on the students' creativity. For example, students did not turn Chess, Monopoly and Coppit into some other game, such as Chinese Chess, or a Monopoly with different cards to be drawn, or other improvements on property. Thus, invisible boundaries restricted students' creativity, and hence, less well-known games and activities might not be as inhibiting. Finally, projects with trustworthy representation of industry practice, such as inclusion of test modules, were appealing.

A summary of these characteristics is as follows:

- Projects with layered architectures can be extended easily, but may not adequately illustrate maintenance difficulties.
- Projects that are incomplete or works in progress but well planned, although initially daunting, offer greater flexibility for creative extensions and prove gratifying compared to the polished projects.
- Students prefer projects with enhancements ranging in difficulty. Also, extensions chosen without examining the project architecture tend to be meaningful and beneficial.
- Projects with useful domains, clear purpose and perhaps an industrial tilt may have higher appeal.

V. Related Research

OSS has been used to teach SE activities such as design, testing, quality assurance, maintenance, and usability [18]–[26]. It has also been used to teach basic and advanced programming and software development concepts [27]–[31]. Some of these works allowed students to choose their own projects [18], [27], [31], while in some courses faculty chose from a few familiar [22], [23], [30], [32], or popular ones such as Apache and Mozilla [21], drawing, editing and file management programs [17], JUnit [19], software studio [32], or pertaining to specific domains such as Web and Web 2.0 [25] or tools [20]. Some used software written by their students [26], [28], [33], while some solicited projects from academia and industry [24].

We easily found works evaluating OSS projects before choosing them for a specific purpose; however, works evaluating the suitability of projects after use for achieving the course objectives are limited. Ghapanchi *et al.* [34] noted a lack of literature exploring the software development process considerations to predict OSS project success. Fox *et al.* [35] chose software as a service cloud-based applications to increase student productivity and their appeal to the employers. Papadopoulos *et al.* [36] considered the maturity of OSS projects to allow students to act in specific roles such as requirements analyst and tester. Purcel *et al.* [37] evaluated OSS projects for student participation based on maturity, stability, potential growth and support for learning objectives. MacKellar *et al.* [38] selected projects by interacting with real-world users, which highlighted requirements analysis and acceptance testing. MacDonnell [39] selected a humanitarian project to alleviate the criticism that the school is disconnected from software development in the real world. Damian *et al.* [30] selected their project based on the learning objectives of global collaboration, and working with a real client. Barr [40] chose projects specifically to illustrate well-designed structure to the students. Zhang *et al.* [41] used business applications for a contest in which they chose to compete using a "small scale time intensive web" project and exposed a Scrum/Agile process to the students. Stamelos [42] reported that Tigris.org focused specially on projects suitable for students.

In summary, our literature search has yet to find reports on an experience using quite a few open source projects at once, that have been chosen and groomed for the students' use by the course staff. What literature review has shown, for courses starting with existing code, is: (i) courses using one carefully selected project; or (ii) a project that agreed with a real customer; or (iii) using many open source projects at once, but selected by the students from the forges. The present paper, in reporting the experiences and lessons from a specific collection of OSS projects, while abstracting generic insights that can guide future project selection fills this void.

VI. Conclusions and Future Research

This paper reports on integrating OSS into an introductory SE course to emphasize software maintenance and evolution. Our experiences suggest that OSS projects can allow a range of enhancements of varying level of difficulty, and hence, can offer meaningful opportunities for deep involvement with the code. They can readily illustrate several facets of comprehension and maintenance, namely, difficulties arising from sparse documentation, importance of the role of architecture, exploring and exploiting code reuse, and learning and acquiring new skills under time constraints. However, not all OSS projects are equally capable of illustrating these challenges, and project suitability hinges on its architecture, state and subject matter.

Our future research is involved with developing a systematic approach for efficient selection of projects from OSS repositories subject to the above three characteristics.

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Mathematization in Teaching Pumping Lemmas

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***Abstract*—Theory of Computation provides students of the computing disciplines with understanding that some problems are not solvable, and that there is a range of complexities of problems, in terms of significant resources, including but not limited to time and memory. Theory of Computation acquaints students with reasoning processes by which they can know (for some cases) the complexity class of a given problem, and by which they can, for some problems they might find in the future, determine the complexity. People formulate these reasoning processes in symbols, and use logic with quantifiers; an example of this is the application of the pumping lemma for regular languages.**

We categorized the errors students made in applying the pumping lemma for regular languages, to develop an understanding of the possible misconceptions, in turn, to improve teaching.

I. Introduction

Problem solving by computer is core to the computer science curriculum. A subset of problems, decision problems, e.g., “Should I apply the brakes now?”, but not ”When should I apply the brakes?”, can be represented by set membership. For infinite sets, the expressiveness required by the description of the set membership function is unsurprisingly mirrored by the discriminatory power required of the process which decides whether an object is or is not a member of the set. This range of expressiveness, equivalently particularity, is subdivided into classes, e.g., regular, context free, etc. Theory of Computation includes the idea of classification of how difficult problems are. Computer scientists need to be aware of these classes.

One such class is the set of regular languages. Due to the simplicity of this class, i.e., its lack of power to discriminate between certain strings, the membership of a string s in a regular language, when the length of s exceeds a certain length p, implies membership of a countably infinite number of strings related to s. Stated formally, we have the pumping lemma for regular languages, which we take from Sipser’s text [1](p. 78):

> **Pumping lemma for regular languages** If A is a regular language, then there is a number p (the pumping length) where if s is any string in A of length at least p, then s may be divided into three pieces, $s = xyz$, satisfying the following conditions:
> 1) for each $i \geq 0, xy^iz \in A$,
> 2) $|y| > 0$, and
> 3) $|xy| \leq p$

For an aid to intuition, see Figure 1. We recall that there is an alphabet from which letters in the string are taken, and that a string is processed one letter at a time in sequence, and that, prior to any letter having been processed, the machine corresponding to the language is in its (single) start state. The processing of each letter executes a transition from a state to a state, therefore, by Dirichlet’s pigeonhole principle, when the number of letters in the string equals or exceeds the number of states, a state must be revisited during string processing.

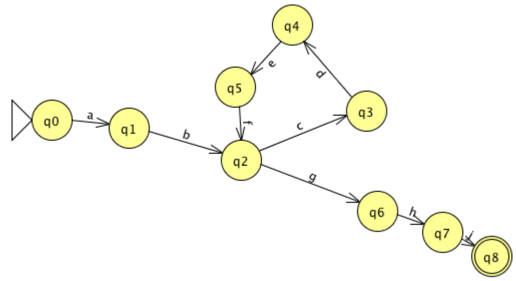

Fig. 1. Example deterministic finite automaton, a machine corresponding to a regular language. Segment x (in this example, ab) is a substring whose processing involves following transitions from the start state to a reused state. For a string with as many, or more, letters (transitions) than there are states in the machine, a cycle must have been followed. This example cycle contains four transitions; one or more transitions returning to a state constitute a cycle. A substring z (in this example, ghj) takes the machine from the last reused state to an accept state. A substring processed by a cycle is denoted y (in this example, cdef). The machine cannot keep count of the number of times the cycle is traversed. From 0 to as many times around the cycle as you please, to the machine, it is all the same.

The pumping lemmas are applied in proofs that a given problem is more difficult than a class (regular and context free, respectively), thus we wish students to understand the pumping lemmas well enough to apply them.

The research question that guided this study is: **Which proof skills, needed in applying the lemma, do students still lack at the end of the course?**

Section II-A describes the background of the study. Section II-B describes the course. Section III describes the methodology. Section IV describes the data obtained. Section V describes the analysis. Section VI discusses the results. Section VIII gives our conclusions. Section VII relates this to some prior work. Section IX describes extensions we would like to carry out.

II. Background

A. Theoretical Framework

Proofs, according to many sources, e.g., [2]–[4] are arguments that are convincing to the mathematical community, but there are other views, e.g., see Reid and Knipping [4].

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Consistent with social-constructivism applied to learning, we believe that discussion, including formulating questions and expressing opinions, helps students learn [5]. Though interested in Moore's method [3] of teaching students about proof, we did not use it during lectures. We applied example and discussion for helping students advance through Bloom's taxonomy [6] towards comprehension of proofs and perhaps further, to application of proofs.

B. Course Description

1) Scope: We taught the course from Sipser's third edition [1], using chapters 1 through 5 and 7. The pumping lemmas were given emphasis in class, help sessions and tutoring, in homework, exams, and in review. We treated the pumping lemma in the context of logic, emphasizing the inversion of quantifiers. We discovered that some students seem to tire of attending to statements with more than one quantifier, consistent with Devlin [3]. We also treated the pumping lemma with diagrams of machines from Sipser's book [1].

2) Policy: We encouraged student collaboration on all learning activities, including homework. We used only known individual work (exams) for their grade. To encourage active learning [7] beyond using the classroom response system, we assigned participation in a discussion of a specified question, weekly. We discovered that students preferred to have their contributions to these discussions be anonymous to other students.

3) Website: To supplement the text and overheads, we offered additional sources on a class website. A mid-semester survey revealed that the 20 students (approximately half the class) who responded to the survey did not avail themselves of the supplementary material. A question area on the website was much used; several different questions might appear on any given day. The assigned problem discussion area was supported on this website.

4) Lectures: From Peer Instruction to Lecture Pacing: To maintain awareness of the level of understanding of the students as each lecture was conducted, and, on an individual student basis, over the course of many lectures, we used a classroom response system ("clickers").

Lectures were prepared in advance of the class and posted on the website, as teaching this course in a previous offering had shown that students greatly appreciated being able to print the lectures for class, and take notes on them, as well as developing questions to be asked during class time.

Mainly to aid the lecturer, indications when clicker questions were to be asked were placed in the lecture notes. Thus students could predict when questions would be asked, but not know the questions, as these were kept in a separate file, published only after class. Students requested that these be published, with explanations for the correct answers.

Though we used clickers for classroom response, and we started with a peer-instruction style of question, discussion, question [9]–[11] students requested that we deemphasize their discussion and offer more questions, and that we explain after each poll, what the answers were and why. We found it valuable to note the votes as they arrived, and we saw a population that voted early and mostly correctly, followed by a population that was less sure. We adjusted the amount of time spent on topics in lecture according to the fraction of students less sure. Based upon a survey taken halfway through the course, the students were grateful that their understanding influenced the pacing of the lectures.

Students requested instruction on inverting logical statements including multiple quantifiers. This topic was addressed, not only with overheads, but, in two separate lectures, interactively, at the board. (Regular: $\exists$ at least one segmentation, $s = xy^iz, |y| > 0, |xy| \leq p$, s.t. $\forall$ values of $i \geq 0, xy^iz \in \mathcal{L}$, so, not regular: $\forall$ segmentations $s = xy^iz, |y| > 0, |xy| \leq p$, $\exists$ at least 1 value of $i \geq 0$, s.t., $xy^iz \notin \mathcal{L}$.)

5) Differences from Other Offerings: We examined three sets of overheads, those from the MIT course 6.045J [12], associated with Professors Lynch and Aronson, those from the peer instruction class at University of California, San Diego (UCSD), by Dr. Bailey-Lee, available at peerinstruction4cs.org, (where some of our overheads can also be seen), and our own. The MIT overheads delivered the material thoroughly and comprehensively, our class emphasized more how to see the language specification in what might be called feature space (as used in machine learning [13]), to provide guidance in the choice of string to pump out of a language, and the UCSD overheads showed a storyboard-like decomposition approach to the reasoning process during application of the pumping lemma.

6) Help Sessions: A modified version of Moore's method [3] of asking a student to volunteer to prove a theorem (in this case, that a given language was not regular) was used in help sessions: A student volunteer would try a proof, but would receive helpful hints when not progressing.

Some students were stuck at the notion that a pumping length was an attribute of a machine. When challenged to draw a (small) machine and then show how a machine could process a string whose length equalled or exceeded the number of states without revisiting a state, students made sense of this attribute. They learned the abstraction using the diagram. The distinction between comprehension and application, excerpted from Bloom by Anderson and Sosniak [14], was exhibited in this learning experience. Students attending the session could easily have answered "What is the pigeonhole principle?", and could probably have applied it to the diagrammatic representation of the DFA, had they been prompted to, but on their own, they did not observe that p, the string length that implied reuse of a state, was equal to the number of states. Thus we located the students' advancement on the pigeonhole principle as comprehending but not applying, on the Bloom's taxonomy. A distinction can be drawn between, on the one hand, abstracting the idea of machine states encountered while processing a string, to the notation, and manipulating the symbols, while remembering what they symbols denote, and on the other hand manipulating some statements composed of letters. The rules about which manipulations are valid, when the letters have no meaning, must be remembered; when the symbols have meaning the rules make sense and understanding can aid memory.

7) Tutoring: Tutoring sessions provided additional awareness of the students' thinking and their capabilities. They also furnished numerous occasions where it appeared that students grasped concepts benefiting from seeing and working with diagrams.

8) Assessments: The class had many formative assessments on which collaboration was encouraged, including weekly homework and discussion postings, and two summative assessments, namely the exams. We knew, from the research of Mazur and Fagan [15], that students can adopt a "plug and chug" approach to dealing with problems, without necessarily developing an understanding of the process.

One method of assessing whether students understood the ease of application of the pumping lemma to a language to be proved not regular was offering a choice between using the Myhill-Nerode theorem with a strong hint or using the pumping lemma. The pumping lemma problem, which could very easily have been solved by application of the Myhill-Nerode theorem, especially with the supplied hint, was designed, when tackled with the pumping lemma, to require, for each possible segmentation, a different value of i (the number of repetitions) that would create a string outside of the language. The intent was to separate students who understood the meaning of the equation's symbols, and the equation itself, from those students engaged in s manipulation with at most superficial understanding.

III. Methodology

A. Design of the Study

The study was carried out on the exam documents. The interpretation was informed by remembering events that occurred in the natural conduct of lectures, help sessions and tutoring.

B. Sample Selection

In a recent course offering to 42 students, of whom 34 were men and 8 women, 41 traditional aged, one former Marine somewhat older, one collegiate athlete (a woman), there were three students having Latin-heritage surnames, 1/4 of the students had Asian heritage, 2 had African heritage, and 8 were international students. Each student individually took the final exam. A choice among five questions was part of the final exam; one required applying the pumping lemma. Half the students (21/42) selected this problem. These were 17 men and 4 women. Three quarters of those (15/42) selecting the pumping lemma got it wrong. These students, who chose the pumping lemma problem and subsequently erred on it, form the population of our study.

C. Data Analysis

We used the final exam as our data source.

We looked at all of the solutions to the pumping lemma problem. We selected from these, the ones with errors.

We wrote a description for each error. The erroneous solutions were categorized, to discover what improvements could be made in teaching.

With the categories, we looked for support for inference.

We used homework, classroom responses, extra credit assignments, participation in office hours, help sessions, and tutoring, for insight into the development of the students' understanding.

TABLE I. Some example errors

Let x be empty
$\|xy\| \leq p$, so $xy = 0^p$
$\|xy\| \leq p$; let $x = 0^{p+r}, y = 0^{p-r}, 0 < r < p$
Let's choose $\|xy\| = p$
$0^{p+1}0^b1^p \neq 0^{p+1}1^p \therefore xy^2z \notin \mathcal{L}$ where $\mathcal{L} = \{0^i1^j, i \neq j\}$
we choose $s = 0^{p+1}1^p$ within $\|xy\|$
thus $\neq 0^p1^{p+1}$
Let $x = 0^a, y = 0^b1^a$
$x = 0^{p-h}, y = 0^h$
$x = 0^i, y = 0^i, z = 0^i1^j$

We carried out some inferences, which are our findings. Compliant with the guidance of our Institutional Review Board, we report only anonymous, aggregate data. We compared these with findings from the literature.

D. Validity and Reliability

Some support for the validity of the results comes from seeing several variations of each proposed error type. We found in our data multiple versions of unwarranted restrictions: choosing x to be empty or choosing the length of xy to be p, and others. We found in literature warnings against attempts to prove statements with universal qualifiers true by means of showing the existence of examples [2], [16]. These warnings suggest these errors have occurred before. In textbooks [17], [18] we find single counterexamples for showing such a statement false, and the method of exhaustion for showing a finite universal statement to be true. Proof by contradiction for the purpose of showing such a statement true, i.e., that any particular tentative counterexample contained an inherent contradiction, is not itself universally accepted, due to not necessarily being constructive [19] (page 2). We also found in our data, several versions of misunderstanding inequalities. We found support in literature for errors of misunderstanding how to work with inequalities, by students of this level [20].

E. Researcher Bias and Assumptions

The authors find diagrams useful; one (TMS) believes diagrams aid the abstraction process. The researchers tend to believe that students want to learn, and will try to comprehend and to become able to apply the material, and that the limitations temporarily present in the student can be overcome by explanation and practice.

IV. Results

The most common error was not understanding that the segment xy, the part of the automaton from the starting state and including the number of traversals of the cycle in the sample string, can be of length less than the pumping length, denoted p. Other errors suggested lack of understanding of the individual symbols, x, y, z, p, i.

An excerpt of the errors is shown in Table I.

One error was stating the rule that $|xy| \leq p$, and then immediately afterwards equating $|xy|$ to p. One error was stating the rule that $|xy| \leq p$, and then immediately afterwards

TABLE II. EXAMPLE ERROR DESCRIPTIONS

This assertion is not accompanied by other cases, so is an unwarranted restriction.
inequality or quantifier
superficial manipulation
string is not the whole language
symbolic formulation

TABLE III. CATEGORIES

understand inequality
formulate correctly
distinguish between particular and generic particular
correctly apply universal quantifier
recognize string as member of language set

giving a segmentation in which $|xy|$ was $2p$. One error was stating the rule that $|xy| \leq p$, and then immediately afterwards giving a string $0^{p+1}1^p$ which, it was claimed, was necessarily segmented with $|z| = 0$. One error was restricting to the case $|x| \neq 0$. One error was stating the rule that $|y| > 0$, and then immediately afterwards equating $|y|$ to 1. One error was stating that y^0 corresponded to one instance of the substring y occurring. One error was stating that pumping would change the content of the segment x. One error was exhibiting one segmentation that could not be pumped, without addressing all possible segmentations. One error was claiming the rule $|xy| \leq p$ could be violated by some specific content in z. One error was not being able to show that, for any given segmentation, pumping would produce a string, for some i, that was outside the language. One error was confusing a string as a member of a language with a description of a language.

V. ANALYSIS

We wrote descriptions for each error. Some example descriptions are in Table II.

A handful of students did exhibit their reasoning that for all segmentations there would exist at least one value of i that would generate a string outside the language.

We categorized the errors as misunderstandings of one or more of:

1) $|xy| \leq p$ permits $|xy| < p$
2) x is the part of the string prior to the cycle
3) y is the part of the string which returns the state of the automaton to a previously visited state
4) z is the part of the string after the (last) cycle up to acceptance
5) $p - 1$ characters is the maximum size of a string that need not contain a cycle, (strings of length p or greater must reuse a state)
6) i is the number of executions of y
7) There must be no segmentation for which pumping is possible, if pumping cannot occur.
8) A language is a set of strings.
9) A language class is a set of languages.

Categories are shown in Table III.

Some examples of inferences are shown in Table IV.

Some errors. e.g., $|xy| \leq p$, Let $x = 0^{p+r}, 0 < r < p$ illustrate students are not recognizing the symbolic formulation, entirely apart from the pumping lemma's segmentation of

TABLE IV. EXAMPLE INFERENCES

$x \leq p$ then $x = 2p$ is formulation
Inequality $x \leq a$ restricted to $x = a$ could be inequality or quantifier.
Inequality $x \leq a$ restricted to $x = a + 1$ is both inequality and quantifier.

strings, and apart from choosing a merely particular example when a generic particular is required. The presence of this, accompanied by others slightly less clear, show that some students need remediation at the level of formulating mathematical relations.

There are many examples of unwarranted restrictions, such as $|x| = 0$, $|x| \geq 1$, $|z| = 0$, and they occur in the context of inequalities. Concerning these errors involving inequalities we wish to see whether we can draw a distinction between two particular misconceptions.

One misconception is that restrictions can be chosen by the student without invalidating the work, and the other is that inequalities of the form $\leq$ and $\geq$ do not mean the disjunction of the equality relation and the less-than relation. One error begins with $|y| > 0$ and then restricts to $|y| = 1$. Because this is not a case of restricting $\leq$ or $\geq$ to being equality, we see that instead it is misconstruing that restriction (to a "mere" particular, rather than a generic particular) is valid.

Errors such as $|xy| \leq p$, so $xy = 0^p$ seem to be restrictions to merely particular cases, as opposed to generic particular cases, as are needed to prove a statement with a universal quantifier true.

This observation is of more general applicability than that of the pumping lemma. Perhaps more time could be beneficially spent observing what is required for a generic particular to be generic.

Errors suggesting a lack of understanding of the context of the pumping lemma, attaching meaning to the individual symbols, x, y, z, p, i include that pumping would change the content of the segment x, that a case of $i = 0$ corresponded to one copy of the segment y, and that the content of z could violate the rule $|xy| \leq p$.

Concerning the errors that inability to pump a single segmentation constitutes a sufficient argument that a string cannot be pumped, we observe these errors are, with the errors above, related to applying reasoning with quantifiers. We believe that these students could state the definition of for all ($\forall$), and of there exists ($\exists$), but we see empirically that when called upon to exercise these concepts as tools, they do not always succeed.

The pumping lemma is one example of a statement with multiple quantifiers, but such statements are used more generally [2], [18].

Some inferences specifically related to the pumping lemma are: Had the students understood that $|xy|$ denoted the part of the string that moved the state of the automaton from its initial state to the completion of one iteration of the cycle, and that any finite length could occur prior to the cycle, and that p was the number of states, they would not have restricted their considerations to $|xy| = p$, or, for that matter, $2p$. Had the students understood that x denoted the initial transitions prior to the state reused in the cycle, they would not have excluded the start state from being susceptible to reuse. Likewise, had the students understood that z denotes the part of the string occurring after the last cycle, they would not have restricted its length to 0, nor claimed that a setting for z would change the content of xy.

VI. Discussion

Students seemed to have trouble with applying reasoning involving quantifiers, understanding symbolic formulations and forming abstractions. These skills are relevant for proofs in general, not only those specific to pumping lemmas. While the pumping lemma for regular languages furnished a test case, other problems surely also serve to illuminate students' abilities to deal correctly with quantifiers and inequalities.

A. Quantifiers

Perhaps the most interesting result was that students applied unwarranted restrictions to their considerations, when they needed to show something held for all cases.

That is, students showed existence of one case (for example, one segmentation), when what was needed for a sufficient argument was to handle all cases.

We know these students have seen proofs using a generic particular, and we wonder whether they grasp what is needed for a particular case to be generic.

We had students who found statements with more than one quantifier difficult to comprehend. We found students who comprehended, but did not freely apply, the pigeonhole principle.

Devlin [2] reports logical statements containing more than one quantifier as a source of difficulty for beginning students. Velleman [21] observes that students find logical statements containing more than one quantifier confusing. He recommends an approach to understanding these [21].

So it appears that the topic of how many is enough, whether it be the quantity to satisfy a proof or quantities in the pigeonhole principle is one that permits Bloom's [6] level of comprehension without necessarily requiring the ability to perform Bloom's [6] level of application.

B. Symbolic Formulations

A second result was that students would carry out operations using symbols, exhibiting inconsistencies in the use of the symbols, such as the case where the very thing that was $\leq p$ was also $= 2p$, for $p > 0$.

The possibility of students attempting what Fagan [15] calls a plug-and-chug approach appears to be worthy of some effort to counteract it. We want to draw a distinction between performing then using a formulation (a kind of abstraction), and making use of a formulation, without having understood it. In the former case, efficiency is gained. Rules for manipulation make sense in terms of the original situation. In the latter case, the reasons for the rules are not appreciated, and the rules might be more easily forgotten. One example of a correct formulation, seen and learned, used a variable a to take on any of the values $0 \leq a \leq p$; the variable was not understood to represent the range, instead was thought to be as a single value, somewhere in the range $[0, p]$. This error might be related to the misunderstanding seen about merely particular vs. generic particular, because the generic particular, of course, represents the whole range. It seems an important kind of error for computer scientists, because variables play an important role in programs. The difference between "holding a single value" and "representing an ensemble of values" should be useful in situations were characterizations of accuracy apply, for example.

As Devlin [22] says "Our goal here is to develop mathematical thinking skills. The symbolic (expressions) are ...a way of achieving that ...strongly recommend ...approach every problem in terms of what it means, using its own language."(p. 44).

From the perspective of the mathematical symbol representation, we have seen evidence that inequality might be difficult to handle, as Mattuck has observed in Introduction to Analysis [20].

C. Abstraction

Representing the machine (which the students see as a graph of states and some memory) in a symbolic formulation is an act of abstraction. Looking at a symbolic formulation is not necessarily an act of abstraction.

We want the students to master the symbolic formulation so that they can use the power it brings, through abstraction, to the reasoning process. If the students are not reasoning about the underlying system that is represented symbolically, rather only hoping that the manipulation steps they perform are valid, they do not gain the benefit of the abstraction.

We agree with Weidmann [23] that students might need practice thinking abstractly. Papert and Harel [24] have shown that when students are tasked to write a program to teach an abstract concept, such as fractions, the programmers learn the abstraction well. Because Sipser's [1] diagrams aid understanding and Papert and Harel's [24] students, who were shown to learn abstraction successfully depicted fractions, and as Reid and Knipping [25] cite Martzloff [26] observing the use by Euclid of "$\delta\epsilon\iota\kappa\nu\upsilon\mu\iota$", which meant "to make visible", perhaps there is a role for pictures in enhancing the ability of student to learn abstraction.

D. General Significance

Students of computer science need the ability to comprehend and apply inequalities, symbolic formulations, quantifiers and abstraction. They need the ability to comprehend simple proofs involving these concepts. Do we wish students to think of program variables as profoundly different from defined constants, e.g., as able to take on a range of values, for an ensemble of program executions, perhaps even having probability density functions for those values? If the value taken by a program variable depends upon input data and the data are stochastic, it can be useful in sensitivity analysis to think of the variable as taking on a range of values, and focus on that range. The results of this study suggest that juniors in computer science might not be prepared for this.

Supplementary course resources could be provided, that help the students master these generally useful concepts. Incoming assessment addressing these specific needs, and provided materials and learning environments, we can guide and support the students in mastering this material. This is merely an application of a recommendation of Simon et al. [27] to the Theory of Computation course. Additional emphasis on the difference between the universal quantifier and the existential quantifier seems warranted, as well as practice with statements containing multiple quantifiers.

Because the underpinnings of these ideas for which we found misconceptions are treated in a course on Discrete Systems, discussion fora and tests for mastery of these concepts might be particularly useful in that subject.

VII. Related Work

Mattuck [20] states “analysis replaces the equalities of calculus with inequalities: certainty with uncertainty. This represents for students a step up in maturity.”[page xiii] and “these are things which I find that many of my students don’t seem to know, or don’t know explicitly. They subtract inequalities . . . ”

In 2010 Pillay [28] asserted that “there has been no research into the actual learning difficulties experienced by students with the different topics” in formal languages and automata theory. Of the pumping lemmas, Pillay states “A majority of the students made logical errors when proving that a language is regular and using the Pumping Lemma to show that a language is non-regular. These could be attributed to a lack of problem-solving skills and an understanding of the Pumping Lemma.” Devlin [2] observes that quantifiers can appear daunting to the uninitiated, and that statements containing multiple quantifiers can be difficult to understand. Hüttel and Nørmark [29] described a successful method for improving both student activity level in the course and final grades, which combines peer assessment with creation of notes that can be used during the exam. (“The incentive was that their answers to text questions would be available for them to use at the written exam. No other textual aids would be allowed at the exam.”[p. 4]) The better performance on the exam is welcome; whether it is due to having notes compared to closed book, or having performed the review might not be certain.

According to Arnoux and Finkel [30], it is not unusual for students to acquire mathematical knowledge without attaching meaning to it, and leaving them unable to solve some problems. They go on to report that Paivio proved that “double coding (verbal and visual)” facilitated remembering. They also report that different parts of the brain are used to process verbal and visual information, and therefore more of the brain is involved when both verbal and pictorial communication is used. They prefer multi-modal representations.

Xing [31] writes about aiding students comprehension of proofs being aided by graphs. She reports “students feel that Pumping Lemma(PL) is so abstract to grasp that using it to prove that a language is non-regular is a daunting task.” She shows a graphically laid out proof that a given language is not regular. This graph has the advantage over a traditional proof, i.e., a sequence of statements, that the dependencies of states on axioms or intermediate results are plainly shown by graph edges.

Simon et al. [27] ask “Is it possible that students plug and chug in computing, not really understanding the concepts as we would like them to?” and go on to say “We posit that the need exists for computing instructors to design assessments more directly targeting understanding, not just doing, computing. And, of course, to adopt teaching approaches that support student development of these skills.”

Mazur [9] developed peer instruction to address students’ propensity to practice a plug-and-chug approach to problems. This approach has been applied to computer science teaching, including theory of computation, by several researchers including Simon, Zingaro, Porter, Bailey-Lee and others [11], [32]–[35].

In 2003 Weidmann [23] wrote a dissertation on teaching Automata Theory to students at the college level. She found that past performance in prerequisite theory courses was a statistically significant indicator for success in their college level course. She described a theoretical framework called “pedagogical positivism” a stance between logical positivism and constructivism, allowing the notion of a teaching method best suited to a group of students to learn Automata Theory. She interviewed a teacher with “several” years of experience teaching this course (p. 5), who “admitted that she did not have a better way to teach abstract thinking other than repeated exposure” (p. 98).

In chapter 5, Discussion, Conclusions and Implications, of this dissertation [23], the suggestion “Instead of simply providing the solution to a problem in class, or stating the intuitive leap that makes the problem easy to solve, the students should be exposed to the iterative thought process that lead to the intuition that created the solution.”(p. 201) appears. One suggestion is “Learning objectives should be set to focus on familiarity with formalisms and rigorous mathematical notations” (p. 224) and another suggestion is “Include programming projects as part of the required coursework”(p. 224). The combination of these brings to mind the suggestion of Harel and Papert [24]: “constructing personally designed pieces of instructional software”, and the thought that the students might dwell more effectively on the notion of abstraction as they tried to teach someone else about it.

VIII. Conclusions

Students are not necessarily well enough prepared when they arrive at the Theory of Computation class, to understand the logic used in the pumping lemmas, which deters them from applying the pumping lemmas correctly. As the purposes of the class include practicing abstraction, and noticing the increase in power from stack memory and subsequently random access memory, and as this increase in power manifests itself in the increased complexity of the languages, if students’ preparedness is weak such that they cannot use the tools for discriminating among these languages, such as applying the pumping lemmas, then they are not equipped to be properly convinced of the differences in these complexities.

Incremental approaches to learning the logical components underpinning the pumping lemma, to exercising synthesis of these components, and to learning abstraction using constructionist techniques exist.

It remains to be seen whether application of these approaches can be carried out in a semester leaving enough time for the student to apply these improved capabilities to Turing machines, reductions and complexity classes beyond regular languages and languages with context-free grammars.

IX. Future Work

We plan to emphasize reasoning with inequalities, symbolic formulations, multiple quantifiers and abstraction in student discussion, such as in Piazza [36], and provide anonymous (to students) discussion fora. We would like to qualify each concept, on the list of concepts needed to understand the pumping lemmas, with the level of advancement along Bloom's taxonomy needed for that concept. For example, we found some students' state of advancement, according to Bloom's (cognitive) taxonomy [14], on the pigeonhole principle to be comprehension without application and we know we need application for understanding how to apply the pumping lemmas. We would like to assess the students' advancement according to Bloom's taxonomy, as they start and continue with Introduction to Theory of Computation, on these several concepts. The ability to invert logical statements containing multiple quantifiers is one such concept that we found the students not yet masters of comprehension, and we would like to study how to encourage the students, adapting pedagogy from mathematics to computer science. We would like to compare various discussion questions for their ability to clarify to students when it is a statement with the universal quantifier that they must prove, and how to distinguish a generic particular from a merely particular example. We would like to test the hypothesis that comprehension for inversion of logical statements containing multiple quantifiers is enough for the purpose of mastering the ability to apply the pumping lemmas. Alternatively, application might be needed. We would like to determine the scope of support, such as preliminary reading, but also formative assessment, for achieving the hypothesized necessary level of advancement. We might want to find out whether, having achieved these levels, students subsequently learned from lectures, to apply them successfully. We could use the pumping lemmas as test cases.

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Assessing Individual Performance in Agile Undergraduate Software Engineering Teams

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***Abstract*—The Agile Software Development (ASD) process is at the forefront of rapid product development driven by changing customer requirements and a trusted, self-organizing development team. Scrum has become a viable model of ASD focusing on determining immediate deliverables and structuring short timelines, called Sprints, for designing, implementing, and providing them for testing by the customer. While these practices are being adopted by organizations, there is significant difficulty in scaling them to the classroom. Once in place, it is a complex task to evaluate individual student performance based solely on the product outcome and Sprint grade. Thus, there is limited opportunity to catch performance problems that may lead to missing deliverable deadlines or decreasing team trust. In this paper, we impose ASD using Scrum on a senior software projects course in Computer Science. Using a collaborative environment that embeds a social network, project management modules, and event capture system, we perform broad data and event capture and analysis to investigate metrics that are relevant to assessing individual performance aspects related to functioning on an Agile team for software development. Our results suggest that predictive data is available after each Sprint to ascertain individual performance attributes and their relationship to product outcomes.**

Keywords—Agile Software Development; performance assessment; Scrum; undergraduate software engineering

I. Introduction

Many organizations have moved toward Agile Software Development (ASD) [1] for rapid deployment of software products, especially for web applications, web services, and cloud computing. A research survey conducted at Microsoft [2] found that around one-third of the respondents use ASD, with Scrum being the most used practice. Only recently has ASD and Scrum, specifically, been studied and reported on within a software engineering course setting. Many studies have analyzed the design of the curriculum covering the benefits and drawbacks of ASD and Scrum [3, 4]. For example, meeting frequency can be burdensome if it is required to be face-to-face every time. This observation parallels industry surveys where meeting frequency is viewed as a necessary drawback of Scrum [2]. Despite the drawbacks, the benefit of rapid delivery of product functionality from using ASD translates into student teams realizing non-trivial software products using three Scrum Sprints over a 16-week semester; something that is enormously advantageous to the graduating computer scientist.

When deploying Scrum in a course setting, product requirements and user stories are placed in an adaptive *Product Backlog*. Teams construct incremental, functional deliverables in the short timelines of the Sprints. A *Sprint Backlog* houses the tasks required to develop each deliverable designated for that Sprint. *Sprint Meetings* require team members to individually discuss their current progress on assigned tasks, their next task, and any problems they encountered or impediments they see in deliverable given their results and those of other team members.

While methods for integrating ASD into software engineering courses have solidified, assessing individual performance can be difficult because the Agile team's productivity and outcomes can mask individual contributions. Such assessment is needed to identify how an individual participated and to what extent. The assessment requires metrics that separate the individual's participation from the team results. Though research has been performed on individual assessment in a variety group projects, it often relies only on self-reporting by individuals on their efforts and their team members' efforts to produce a grading scheme. Virtual teams have been studied to determine if leadership or influence attributes can be assigned by studying social network interactions. Because we are studying ASD teams that are pre-formed in a pedagogical setting, we need specific metrics that track the Scrum process and its use by team members to deploy Sprint deliverables. The goal is to determine if predictive data exists after a Sprint that indicates individual performance so that individuals can be better trained to reach team goals. The study requires online tool support for capturing the discussion and logging product-related activities as they occur.

There is wide recognition in the tool support community [4-6] that specific tools must be made available, such as wikis or Google collaboration tools, forums or email, version control, and shared calendar applications to support project management, product development and interaction. However, substantial effort is needed to consolidate information captured from diverse tools into a single time series necessary for team or individual assessments.

In this paper, we define four performance metrics. These metrics are designed to characterize the depth and quality of individual performance as it relates to ASD team functions. *Contribution* measures the direct participation and quality of involvement of the student during Sprint Meetings. *Influence*

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measures if and how an individual directs the team's progress by being an engaged and active member of the team. *Impact* documents the causal relationships between what students say they will do, the actions the actually take, and the artifacts that result from their actions and, ideally, improve the Sprint deliverable's quality. Finally, *Impression* measures how well team members acknowledge the effort and performance that fellow team members make toward the successful completion of project deliverables.

We outline a methodology to assign values to each metric. The values form a numeric *assessment profile* of an individual student within an ASD team using Scrum in a university capstone software engineering course (see Table 1 for example). We rely on our open source courseware, called SEREBRO, to capture and consolidate team event data. Subject matter experts (SMEs) perform content inspection to calculate the metric values. We state research questions relevant to the study that direct how the assessment profile can be used to understand individual performance on an ASD team.

In the next section, we discuss various studies on ASD. Section III outlines the capabilities of SEREBRO and prior studies conducted with using its data capture functions. Section IV details the methods for measuring Contribution, Influence, Impact, and Impression, states the research questions, examines the data collected, and discusses the implications of the results. Section V concludes the paper.

II. Related Work

Pushing ASD into an undergraduate or graduate software engineering class requires careful set up and management so that the students are not overwhelmed by the pace and activity of the process, given what is involved in a Scrum Sprint. Researchers have drafted such courses and reported, often anecdotally, on the findings [7]. Studies conducted in undergraduate classes have examined the social interaction with respect to ASD for the purpose of determining if students have more effective learning opportunities. One study [8] points to pair programming in ASD as a potential learning opportunity for software development. A Social Interaction Model of Pair Programming resulted from data collected in two forms for assessment: interviews to gauge participation and satisfaction, and self-reported documentation by the students about their perspective on project outcomes. These results indicated not only a feeling of more productivity, but also an increased skillset confidence and interest in IT.

In contrast to focusing on process, studies examined human behavior based on automatically data collected by IBM's collaboration tool JAZZ [9]. A social network was constructed by finding indirect interactions through developer build commits and artifact versioning as entered in a time-stamped software repository. The resulting *socio-technical network* was used to predict software quality based on whether or not successful incremental builds showed a high degree of connectivity, and hence, collaboration among developers [10]. These results emphasize the importance of collaboration in software engineering teams, further substantiating the use of collaboration metrics as performance measures [11].

Other studies examine the perception of productivity and satisfaction of using ASD [2, 4, 12]. Assessment is generally performed via surveys and personal interviews. Many claim a positive response to the practice, including a perception of increased productivity and product quality [13]. Others found that the main values attributed to ASD relate to communication and collaboration [14]. Studies of using ASD in graduate software engineering courses concur; also citing increased student team productivity and product quality [7].

A review of literature on assessing individuals in group projects does not provide adequate, reusable metrics for ASD teams. Existing measures heavily rely on self-reporting activity, detailed project evaluation rubrics, surveys and grades based on individual submissions related to the project [15-17]. This lack of metrics is especially an issue for classroom settings where feedback and individual grades should be provided after each Sprint to improve student activity quality and accountability on the project, in general, and within the development process and on a team, more specifically.

III. SEREBRO

SEREBRO 3.0 is used as courseware for three classes at the University of Tulsa: Software Engineering Projects I and II and Introduction to Psychology. SEREBRO features an *idea network*, which combines aspects of issue management and social networking, a set of *project management modules*, and an *event capture system* that logs all activities within the idea network and modules.

Fig. 1 is a screen shot of a SEREBRO idea network as a graphical forum for asynchronous postings of brainstorms (blue circles), agree and disagree nodes (green and orange triangles), and comments (bubbles). Multiple brainstorms may be used within a single topic thread and may be started by any team member. SEREBRO provides optional directed email alerts for posting and project activities to ensure team visibility. The idea network is implemented in jQuery and displays post content when a user hovers over a node icon. Clicking an icon in the network marks it on the left and brings up the corresponding post to the right of the tree for user response.

SEREBRO's project management modules include a Gantt chart, calendar, wiki, document upload area, Subversion (SVN) software repository, activity feed, and a spreadsheet. The wiki is most often used to build and structure project documentation. SEREBRO *uploads* typically consist of images, presentations, and other non-textual files relating to the project. The *SVN module* provides source and version control repositories for each team as well as a WebSVN UI, which allows team members to make manual changes from a web browser, and a commit feed that displays commit messages and allows SVN commits to be tagged using the tagging system. The SEREBRO *spreadsheet system* provides Excel-like functionality in a web-browser to allow students to store and process numerical or textual data. The Gantt Chart is used to assign and track tasks throughout development milestones.

Previous studies have been performed using SEREBRO data captured in the CS and Psychology courses. These studies examined motivational techniques to increase creativity [18], including features to support teams [6],

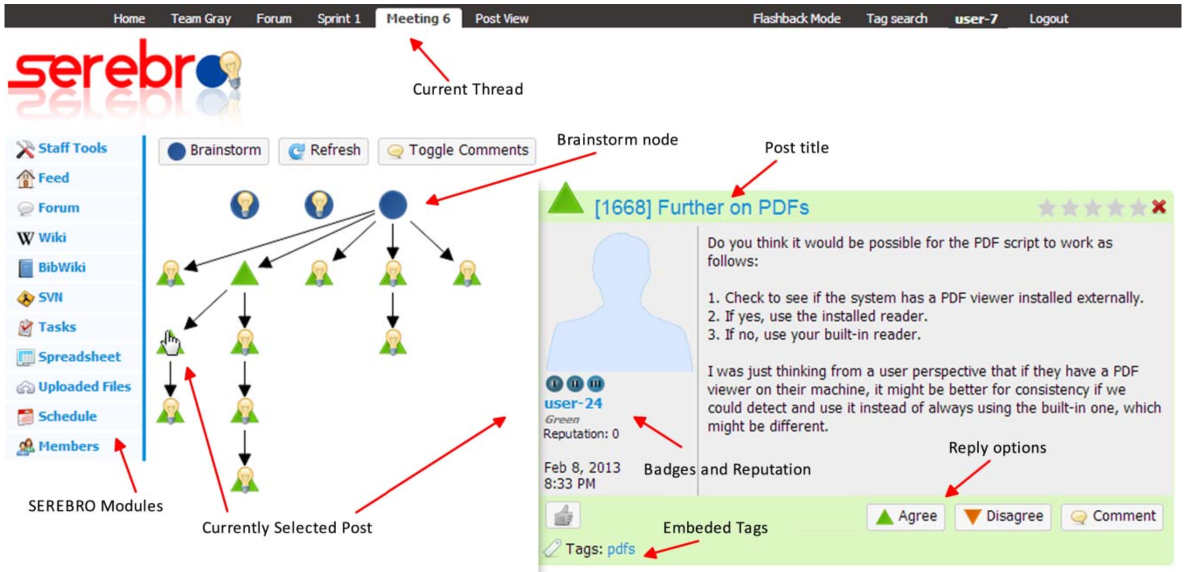

Fig 1. Sample SEREBRO Idea Network and Interface

developed event logging and automated scoring techniques for analyzing milestone performance within the Rational Unified Process [11], provided a tagging system for traceabilty across the artifacts [19], and proposed potential learning indicators evident in web-based collaboration [20]. Prior to Fall 2013, all Software Engineering Projects classes used a cross between the Waterfall development process and the Rational Unified Process to drive milestone formation and completion, which formed the basis for the prior studies. SEREBRO was tailored by class rubrics designed for each process milestone. Thus, posting in previous studies was very unstructured and conversational, informal, and sometimes completely off-topic. In addition, there was more freedom in how the various SEREBRO support modules were employed. The introduction of ASD, as discussed in this paper, required the teams to use the idea networks and project management modules in a much more structured way to facilitate Scrum practices such as attending Sprint Meetings, and maintaining the Product Backlog and the Sprint Backlog.

IV. Methodology and Assessment

In this study, we work within the ASD process using Scrum to the extent possible where there are frequent meetings with specified individual input requirements. The full set of SEREBRO modules is used to produce the various Scrum Sprint artifacts. The goal of the effort is twofold. First, we need to understand what is required to successfully scale Scrum to a class setting with one instructor and external customers, when students have additional classes and are preparing for graduation. Second, we want to get a clearer and more readily available picture of individual performance on an Agile team by obtaining predictive assessment metrics that identify how individuals perform during a Scrum Sprint.

Our study follows 16 students, across 4 teams in Software Engineering Projects II, working on non-trivial software products. The students were prepped on the use of SEREBRO, ASD, and Scrum as part of the previous fall semester software engineering immersion class (Software Engineering Projects I). During the fall course, students used SEREBRO for short project challenges to practice Sprints. For the Spring Sprints, the instructor serves as the Scrum Master and external customers serve as the product owners. Because pair programming in ASD has mixed reviews in both industry and academics [21], it was discussed as a potential strategy, but not required of the teams. We use the following artifacts generated within SEREBRO as part of a Scrum Sprint.

Meeting Check-ins: These are specific posts required in the idea network that are structured to simulate Sprint Meetings, though check-in times are generally 48-72 hours apart. In the studied Sprint, we analyze 10 meeting check ins that occurred over a 3 week period.

General Posts: These posts reside within the idea network and include face-to-face meeting minutes during customer meetings, general discussions on research, server configuration, technical problems, and conversations with the instructor. These posts have value as part of the general student engagement in the project.

Wiki: Generally, the wiki holds all documentation related work products. For the examined Sprint, the Wiki was required to hold an executive summary of the product, use cases, research on technology and competition, execution instructions, and a Sprint review or post mortem.

Subversion Repository (SVN): The shared repository contains code commits and associated commit messages for version control during product development.

Gantt chart: A project management and task assignment tool houses the Sprint Backlog that is updated as tasks are assigned and completed during the Sprint or issues and impediments identified by the team are added and assigned to responsible parties.

Spreadsheet: The spreadsheet module in SEREBRO contains the Product Backlog that includes the product requirements and user stories.

Uploaded documents: SEREBRO provides a shared space for storing non-textual documents such as images and presentation files that supplement other module content.

Team Evaluations: After each Sprint, team members submit a confidential evaluation sheet on perceptions of their performance and their team members' performances during the Sprint. The evaluation consists of two parts. The first part is a questionnaire with 10 general evaluation questions in which every person evaluates his or her personal performance and the performance of each team member using a range of 0-10, with 10 being the highest. The second part of the form denotes a variety of roles and responsibilities, such as general manager and organizer, leader and inspirer, programmer, designer, analyst, and tester. In this part, each person denotes a percentage weight for a role or responsibility for each team member and then scores that performance from 0-10 at that role or responsibility.

Team Rankings: Each student ranks the amount of perceived engagement in intellectual input (product vision, understanding, and interpreting customer requirements), creative input (elegance in design, coding, aesthetics), and results achieved (tangible evidence of work and experience) for each team member. These rankings supplement the more detailed Team Evaluations with direct comparison.

Sprint Deliverable Grade: The deliverable for the Sprint includes a stand-alone functional component within a web application or integrated components that meet one or more essential requirements and encompass at least one user story. The deliverable is accompanied by project management artifacts that include the Product Backlog of requirements and user stories, the Sprint Backlog of tasks, impediments, and issues related to the Sprint, wiki documentation associated with the deliverable, the SVN repository, and the Sprint presentation and demonstration. A project grade is given to the team according to the quality of the deliverable overall. The Sprint Deliverable was worth a total of 800 points for which a complete set of rubrics was provided to the class.

A. Contribution Scores

Contribution assesses the direct participation and quality of involvement of the student in required Sprint Meetings, in the form of Meeting Check-ins. There were four separate check-in requirements: (a) being on time, (b) stating what was done since the last meeting, even if it was little to no activity, (c) stating what will be done for the next meeting, and (d) discussing a project issue, impediment, or activity found by the individual or a team member. Each requirement was worth 3 points with the Subject Matter Expert (SME) scoring as follows: 0 = not met, 1 = almost met, 2 = met, and 3 = exceeded requirement. The Total Meeting Points is the sum of the requirement points from 0-12 per individual for each meeting across all 10 meetings. The data in Table 1 consists of the users (column 1), the Sprint Deliverable Grade (column 2), the Total Meeting Points (column 3), and the final Contribution score (column 4) which is defined as the Total Meeting Points divided by the 120 maximum possible points. Contribution scores ranged from 31% to 90%, with a 54% average. Values for Impact, Impression, and Influence (columns 5, 6, and 7, respectively) in Table 1 and discussed in subsequent sections, comprise the numeric *assessment profile* for each student.

The first research question accounts for ASD and Scrum expectations, that short, frequent meetings where individuals are self-directed, accountable, and trusted produce better product outcomes. It assesses whether the amount and quality of meeting participation leads to a better deliverable.

RQ1: Does a team with high overall Contribution have better product outcomes?

To answer this question, we examine the linear dependence between the Contribution score and Sprint Deliverable Grade in Table 1 using the Pearson correlation coefficient (Pearson's r) [22] to determine if higher individual Contribution scores correlate with higher Sprint Deliverable Grade. Correlation values for this and subsequent research questions are calculated using sum of squares, as part of linear regressions between series of data for two metrics. All r values are calculated with 14 degrees of freedom (df) corresponding to the 16 users present on the 4 examined teams, i.e. df = 16-2 for two-tailed test. In this and the following sections, we use the standard critical values for r as follows:

- $|r| > 0.426$ corresponds to a significance level, denoted by a p value, of $p = 0.10$ (shown in correlation tables as purple),
- $|r| > 0.497$ represents $p = 0.05$ (red),
- $|r| > 0.574$ represents a high significance of $p = 0.02$ (yellow), and
- $|r| > 0.623$ is indicative of a very strong significance $p = 0.01$ (green).
- Any r values such that $|r| < 0.426$ are considered to be not indicative of a correlation (white).

TABLE 1. GRADE AND ASSESSMENT PROFILE

Student	Sprint Deliverable Grade	Total Meeting Points	Contribution	Impact	Impression	Influence
user-6	0.88	49	0.41	0.76	8.81	0.19
user-9	0.88	59	0.49	1.35	8.60	0.18
user-11	0.88	53	0.44	1.47	9.27	0.23
user-23	0.88	64	0.53	3.12	9.25	0.39
user-13	0.86	69	0.58	2.47	9.54	0.29
user-18	0.86	64	0.53	1.53	9.27	0.21
user-19	0.86	74	0.62	2.47	9.19	0.21
user-22	0.86	70	0.58	1.18	9.21	0.23
user-2	0.98	49	0.41	1.41	8.82	0.06
user-17	0.98	95	0.79	4.71	9.56	0.29
user-21	0.98	108	0.9	5.00	9.28	0.49
user-24	0.98	61	0.51	0.53	7.74	0.14
user-7	0.82	37	0.31	0.24	7.46	0.09
user-8	0.82	71	0.59	1.59	9.43	0.37
user-10	0.82	64	0.53	0.35	9.24	0.23
user-16	0.82	44	0.37	0.35	8.48	0.15

The p value is formally described as the probability of obtaining the observed result given that the null hypothesis is true. Our work uses a null hypothesis which can be stated as *there is no relation between metric X and metric Y*. Thus, a p-value of 0.01 would mean there is a 1% probability that one could observe a correlation given there is actually no linear dependence between the two metrics. In other words, the lower the p-value, the higher the likelihood that the correlation result is significant of an actual dependency relationship between X and Y.

For RQ1, we found that higher Contribution scores correlated with higher Sprint Deliverable Grades (r=0.47, p=0.10). This suggests that, with 90% confidence, we can say that better individual contributions across the team lead to better final products. All correlations discussed henceforth will report the r and p values.

B. *Influence Scores*

Influence measures if and how an individual directs the team's progress by being an engaged and active member of the team. This activity may be in the form of intellectual and creative input or vision, results production, general project communication, and managing the team. We measure influence using the SEREBRO event system to obtain a raw count of the total number of posts, activities affecting artifacts, and the average events per day for an individual. Since each team has unique project requirements, energy, commitment, and skill sets, we weight the Influence score against the events of the team as a whole (see below). Given an individual's calculated Influence score, the second research question examines if an engaged and active team member, i.e. one with a high Influence score, drives the product progression. The third research question determines if an engaged and active team member is recognized as such by the team. The importance of these questions to the study is to understand how engagement and activity can and should be manifested so that an individual's participation is recognized as valuable.

$$\textbf{Influence score} = \frac{average(individual\ events\ per\ day)}{average(total\ team\ events\ per\ day)}$$

RQ2: Does an individual's Influence determine how much that person impacts the overall product?

For this question, we return to the students' numeric assessment profiles in Table 1. Influence and Impact (defined next) are highly correlated, (r=0.74, p=0.01) indicating there is a very strong relationship between the number of events an individual performs relative to the team and his/her impact on the final product.

RQ3: Does an individual's Influence score match the team's overall perception of the person's activities?

To answer RQ3, we use the Team Rankings to determine if a seemingly engaged and active person is ranked highly in intellectual input, creative input, and results achieved as perceived by their peers. Table 2 shows the results. Note that the negative numbers are inversely correlated because the higher the influence (i.e. the more events) the lower the rank should be, since students are ranked from best (1) to worst (4). For intellectual input, (Intellect with r=-0.58, p=0.02), the strength of the correlation indicates that highly influential people are recognized as providing vision and quality ideas to the development process and resulting product. This result implies that individuals who communicate more frequently in the idea network or create more artifacts (i.e, code, wiki documentation, spreadsheets, or uploads), are perceived to have provided intellect through that effort. Similarly, the results achieved (Results) strongly correlates to Influence (r= -0.65, p=0.02), indicating that the team acknowledges that engaged and active people produce actual work products. This correlation is expected because high result achievers will likely perform more artifact manipulation, increasing their Influence score. Creative input did not correlate with Influence. We infer from this result that either creativity is not well understood by the team members, or there is no perceived association between a person's creative input into a project and the activities performed. Though not shown, creative input also did not correlate with intellectual input (r = 0.42) indicating that individuals did not rank their teams using the same criteria for intellectual and creative rankings.

TABLE 2. INFLUENCE CORRELATED WITH INTELLECTUAL, CREATIVE, AND RESULT RANKINGS

	Intellect	Creative	Results
Influence	-0.58	-0.01	-0.65

C. *Impact Scores*

Impact documents the causal relationships between posts and activities that subsequently alter artifacts. Impact scores are based on three forms of self-regulated learning strategies [23]. An individual posting that he or she will perform a task is a form of planning. Following that statement with an action constitutes a preplanned activity. If a user performs an action and then posts, any request for evaluation is a third form of self-regulated learning.

To measure an individual's project Impact, we link communication posts with artifact creation activities. We automatically filter posts according to phrases and words indicative of the self-regulated learning strategies, such as "will," "done," "I'll," "I can," "I have," "doing," "I did," and "I've." A manual review of the filtered posts is performed to remove any spurious posts. The remaining posts contain one or more *goal statements* that relate to the creation or advancement of the Sprint Deliverable. The SME compares the posts against the set of product deliverables to determine if the goal statements relate to actionable events in SEREBRO. An actionable event is defined as the creation or modification of an artifact within a SEREBRO module. Actionable events include SVN code commits, file uploads, updating the Product or Sprint Backlogs, and documentation wiki edits. The SME records the number of *links* that a goal statement post has to an actionable event and assigns a quality value to the event's effect on the deliverable. These values are

- 0 = Poor quality work – event had minimal effect on deliverable completion.
- 1 = Low quality work – event had little effect on deliverable completion.
- 2 = Good quality work – event had direct effect on deliverable completion.
- 3 = High quality work – event had significant effect on deliverable completion.

Some example quality assessments include:

- poor quality code commit (uncommented, no commit messages, few lines or single characters)

- high quality code commit (well commented, commit messages, significant number of lines added or changed)
- poor quality use case diagram uploaded file (lots of errors, carelessness is evident)
- high quality use case diagram (no or low errors, thoughtful, complete)
- poor quality wiki change (spelling errors, broken links, incomplete, and non-descriptive, with no change messages provided)
- high quality wiki change (no errors, no broken links, complete and descriptive, change messages provided)

We calculate a single Impact score using the formula:

Impact score =

$$\frac{\text{Scored Posts}}{\text{Total Scored Posts for Team}} * \text{Average\#Links} * \text{Average Quality Assigned}$$

where Average#Links is the average number of links the individual has across all filtered and scored posts, Average Quality Assigned is the average assessment value of all of the links found, and (Scored Posts / Total Scored Posts for Team) normalizes the Impact score given a particular team.

RQ2 shows that an individual's Impact is related to his or her engagement and activity (i.e., Influence). We introduce a fourth research question to determine if an individual's Impact is indicative of overall product outcome. This question studies whether an individual's planning of an activity, followed by its performance leads to a better overall deliverable.

RQ4: Do individuals with high Impact Scores have better product outcomes?

We answer this by determining if Impact scores correlate with higher grades given the student assessment profile in Table 1, which shows a strong relationship ($r=0.54$, $p=0.05$).

D. Impression Scores

Impression examines how a team member acknowledges the effort and performance that another team member has made toward completing a successful Sprint Deliverable. A poor evaluation by the whole team can cost a member a letter grade for the Sprint Deliverable, so they are taken very seriously. How individuals view and value their team members should qualify the extent of the high trust environment on an ASD team. If an individual is a 'social loafer', then the team may continue the project without input from him or her, and provide low evaluation scores. In contrast, if everyone's impression of a person's role and responsibilities and the effort put into them is similar, then it can be assumed that the person can be trusted at some level of proficiency, competency, and work ethic. Thus, individuals that are actively involved with the team with tangible effort toward a successful Sprint Deliverable, as measured by Contribution, Impact, and Influence scores, should be highly valued.

Using the Team Evaluations, we form Impression score as:

Impression score =

$$\frac{\text{Avg(G.Q1...G.Q10)} + \text{Avg(R.Q1...R.Q10)}}{20} = \frac{\text{G.Avg} + \text{R.Avg}}{2}$$

where G.Q1…G.Q10 are the 10 general survey questions taken from the Team Evaluations and R.Q1…R.Q10 are the 10 weighted role-based survey questions. The metric G.Avg is the average across the 10 general questions, while R.Avg is the average across the 10 role-based questions. The next research question (RQ5) asks if team member impressions are indicative of overall performance.

RQ5: Do group impressions of team members accurately reflect the team member's performance towards completion of a Sprint Deliverable?

To answer this question, we examined group impressions at the aggregate level using G.Avg, R.Avg, and the combined Impression score, and also at a finer granularity by examining individual question responses of the Team Evaluations. These values are correlated against Impact, Contribution, and Influence. We correlated these values with measures of specific activities. We compare the Team Rankings on intellectual input, creative input, and results achieved and Impression against the other metrics to determine if ranking mirrors the Impression score.

TABLE 3. CORRELATIONS BETWEEN IMPRESSION METRICS AND IMPACT, CONTRIBUTION, INFLUENCE, AND PERFORMANCE METRICS

	Impact	Contrib.	Influence	Wiki	Upload	SB	Commit	Artifacts	Thread	Ideas
G.Q5	0.16	0.25	0.54	0.67	0.72	0.62	0.10	0.59	0.32	0.44
G.Q9	0.48	0.35	0.23	-0.13	0.06	-0.12	0.28	0.29	0.03	0.16
G.Avg	0.54	0.60	0.67	0.14	0.29	0.17	0.57	0.63	0.61	0.57
R.Q1	-0.14	0.04	0.31	0.57	0.66	0.70	-0.31	0.29	0.17	0.27
R.Q7	-0.25	-0.17	0.01	-0.09	-0.04	-0.02	0.03	0.14	-0.16	-0.10
R.Q8	0.54	0.46	0.45	-0.20	-0.09	-0.28	0.69	0.32	0.49	0.50
R.Avg	0.59	0.54	0.51	0.20	0.33	0.22	0.40	0.60	0.27	0.36
Impress.	0.59	0.60	0.64	0.17	0.32	0.19	0.53	0.65	0.50	0.51
Intellect	-0.50	-0.46	-0.58	0.17	-0.07	0.13	-0.67	-0.48	-0.60	-0.55
Creative	-0.10	0.01	-0.01	0.34	0.14	0.05	-0.08	-0.08	0.02	0.06
Results	-0.52	-0.61	-0.65	0.05	-0.08	0.00	-0.70	-0.61	-0.56	-0.57

Table 3 shows these correlations along with a sampling of five individual questions (G.Q5, G.Q9, R.Q1, R.Q7, and R.Q8) taken from the Team Evaluations. In G.Q5, individuals are asked to score how well a team member "Contributed to document artifact creation and/or review." We found that individuals with high G.Q5 evaluation scores had higher percentages of Wiki changes, Uploads, and Sprint Backlog (SB) updates relative to their peers as well as higher overall numbers of ideas, artifacts and thus higher Influence scores. R.Q1 asks team members to weight the specific responsibility of "Organizing the requirements, user stories, and Sprint Backlog" and score that effort. In SEREBRO, these activities are recorded in the wiki, the Sprint Backlog, and uploaded document files, so it is not surprising that there are correlations to each fine-grained activity. Another question R.Q8 grades team members responsible for "Demonstrating exceptional programming ability." Table 3 shows that highly rated R.Q8 individuals also had higher Impact, Contribution, Influence and Code Commits relative to lower rated peers. On the other hand G.Q9 asked if, in general, a user "Completed all tasks assigned at agreed upon timeline" and R.Q7 which grades those users responsible for "Delegating tasks appropriately" both correlated very weakly across the board suggesting that either the team members did not have significant information to form accurate impressions about these topics or that the performance metrics in the table were not representative of the team evaluation questions.

Overall, the correlations shown in Table 3 suggest that team member impressions reflect performance reality during the use of ASD and Scrum within a class setting. The communication structure and notification system provided by SEREBRO appears to aid the ability of team members to accurately assess their teammates by providing better visibility and transparency across the board. That is to say, such a tool makes it easier for team members to detect the extent to which their teammates are performing their assigned tasks.

V. Discussion and Conclusion

In this paper, we define and study four metrics to quantify and qualify various individual attributes with an ASD team. The metrics, Contribution, Influence, Impact, and Impression, provide broad characteristics of the level of engagement, activity, and product related results of an individual on a team. We find that teams with higher individual levels of contribution and impact had better final product outcomes. In addition, team members are able to form accurate appraisals of each other's contributions, influence, and impact on the project given high visibility of the development process. The study provides a foundation for direct and objective feedback to individuals regarding more detailed qualities regarding performance after each Sprint.

Our results suggest that using collaborative environments to obtain performance and collaboration metrics allows for extensive individual evaluation and assessment. They also suggest that that high levels of transparency, as expected within the ASD process, contributes to a high trust environment, since individual efforts are visible to the team in tangible ways. This visibility relates directly to project outcome. The challenge is to craft a supportive environment for ASD process facilitation and collaboration for a class. While these environments are becoming more readily available, such as IBM's Jazz, automated methods for detecting impact links, analyzing conversations and code commits, and assessing collaborative activity are lacking. Without environmental support, it is difficult to attach an objective value to an individual's detailed project performance. This dilemma is more notable at the university level when training in software engineering should result in a grade that shows where improvements can be made. Unless event and activity tracking can be translated into the performance metrics discussed, Impression must be heavily relied on for performance evaluation.

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Exploring Student Representational Approaches in Solving Rechargable Battery Design Problems

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Abstract—**The focus of this study is to characterize the representational practices of engineering graduate students who were involved in using computational and analytical mathematical models to solve a complex battery system design problem. The research question of this study is: How do students develop and use representational artifacts, while using mathematical or computer simulation models, for articulating their solutions to a complex battery system design problem? Results of this study provide descriptions of students representational artifacts produced in each of the stages of the problem solving process. The outcome of the study provides a framework for future studies using a larger sample size for investigating the role of mathematical and computational models in supporting students' problem solving processes in engineering education.** ***Keywords— representational media, computational tools, modeling and simulation.***

I. Introduction

Engineering disciplines have historically relied on computer simulations as a tool for solving problems and describing physical phenomena using mathematical models [1]. In particular, mathematical and computational models assist engineers and scientist in making central features of a phenomenon explicit and in generating representational artifacts required to inform scientific predictions and explanations within a particular domain [2, 3].

Educational researchers have maintained that the use of representational tools and artifacts can have a significant role in guiding students' conceptual understanding and problem solving processes [4, 5]. In particular, literature in math education suggests that the ability to implement and translate meaning among different representational forms results in higher forms of conceptual understanding and learning transfer [4, 6]. Although researchers have observed a positive correlation in students' cognitive development and their use of modeling and simulations tools, there is evidence that students face challenges when learning using modeling tools [7]. For example, computer simulations tools used in engineering educational settings are often developed by domain experts [8], have steep learning curves [9], and require some programming and computational thinking skills [9].

Current literature highlights a critical gap in understanding how to best integrate computer simulations tools in a way that constructively develop novices' conceptual understanding and problem solving skills. The purpose of this study is to address the current gap by investigating the role of mathematical and computational models in supporting students' problem solving process in engineering education. Specifically this study explores the representational practices of engineering graduate students who were involved in using computational and analytical mathematical models to solve a complex design problem in the Material Science Engineering domain. The research question of this study is: *How do students develop and use representational artifacts, while using mathematical or computer simulation models, for articulating their solutions to a complex battery system design problem?*

II. Theoretical Framework

Engineers use computational models as tools to critically analyze current real-world systems in order to construct predictions, formulate new ideas, and design new materials and devices [10]. Hamilton et al. [5], described models as conceptual structures that an individual employs to solve real-world problems. Having students involved in the process of construction of models helps them to articulate and build their own understanding of a system or physical phenomenon. Computational tools are becoming more useful pedagogical tools because of their ability to create and display representational models, often interactively and as a function of time [9]. Specifically, representational artifacts such as graphs, visual models, and simulations of physical or non-physical phenomena can serve as mediation tools to construct solutions in engineering design [2].

III. Conceptual Framework

The conceptual framework for this study integrates a conceptual system model from Lesh and Doerr [2] and Polya's model of the problem solving process [11]. The Lesh and Doerr representation media model, adapted for this study, is depicted in Figure 1. Lesh and Doerr's model defines conceptual understanding as a function of representational fluency, i.e., the ability to represent ideas in multiple forms and make connections among different representational media [2].

In addition, Polya's work describes the process of problem solving as a four step model that includes: (1) Representation of the problem, (2) Goal setting and planning, (3) Execution of the plan and (4) Evaluation of the solution. These two models can be applied in conjunction to provide insight of the interplay between the students' representational artifacts and the students' solution processes in solving problems using computation tools and written analytical solutions. Specifically, we implemented these two frameworks to examine and explore the participants' use of conceptual systems and artifacts to solve problems related to the design of rechargeable batteries.

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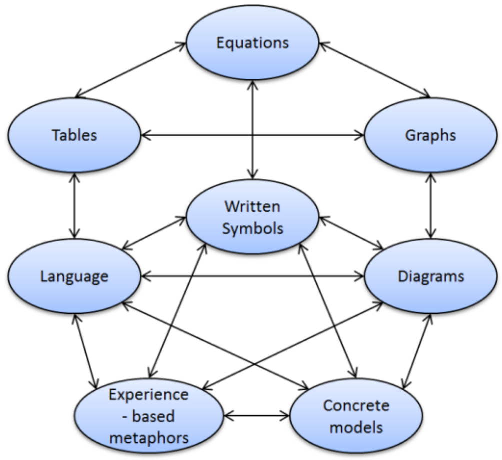

Fig. 1. Diagram of conceptual systems implemented to support and communicate understanding [2].

IV. Methods

Participants of this study were drawn from a population of twenty-four graduate students from a materials engineering course titled Introduction to Rechargeable Batteries. Using the homework assignments outlined in Table 1, the selected population included a total of six students, three in each group (Group 1: analytical tools; Group 2: computational tools). Students self-selected the assignment they wanted solve (i.e., analytical or computational), which determined the analysis group they were assigned to. The general population under study consisted of students in their first two years of graduate study with majors in engineering. Information on gender and ethnicity was not provided for this investigation. The sample population include students that scored 80% or higher for their particular homework assignment.

The assignments for Group 1 focused on mathematical analytical modeling and students' were asked to develop an expression for the reaction zone. Secondly, Group 2 students utilized the Virtual Kinetics of Materials Laboratory (VKML) [12], simulation tool and were asked to develop a computer model to design a graded porous electrode. The VKML tool was designed to be an open source online computing tool that (a) performs mulitiphysical equilibrium and kinetic calculations of material properties and (b) enables the novice user to focus on rapid model development and results visualization, not programming [13]. Both groups were then asked to respond to questions related to battery performance, such as discharge time, total charge, power density, porosity gradients, electrical conductivity, and additional parameters related to the design of a $LiMn_2O_4$ based battery system. Qualitative analysis was conducted using Lesh and Doerr's model [2] in order to describe the elements of the conceptual systems students employed for each stage of the problem solving process. The frequencies were summarized and compared between groups.

TABLE I. Mapping of Polya's problem solving process for each groups' design problem

Polya's model	Group One HW Questions	Group Two HW Questions
Represent the problem	Develop a model to design a graded porous electrode. 1. For the porous graded electrode with given gradient develop a an expression for the reaction zone. 3 & 4. Find an expression for the discharge time given the conditions of the porosity gradient, a. where Q3 α > 0, positive and Q4 α<0, negative.	Develop a computational model to design a graded porous electrode. 1. Extend the proved script to describe the porous graded electrode with given gradient. Make the appropriate substitutions for the reaction zone and baseline porosity.
Goal setting and Planning	2. Find conditions for which the reaction zone will be positive and real. How will this result impose a constraint on the porosity gradient? 5. For both types of porosity gradient electrodes, α is positive or negative, will allow for longer discharge time on the electrode?	3 &4. Using the developed model find the porosity gradient the minimizes/ maximizes the discharge time given the conditions of the porosity gradient, a. where Q3 α > 0, positive/Q4 α<0, negative.
Execute the Plan	6. For the $LiMn_2O_4$-based system propose: a porosity gradient (α), baseline porosity (ε_o), and electrode thickness (h_c) that optimizes the battery microstructure for a $LinMn_2O_4$ based system.	2. Given your developed model propose a battery microstructure: porosity gradient (α), baseline porosity (ε_o), electrode thickness (h_c) that optimizes the battery microstructure for a $LinMn_2O_4$ based system.
Evaluate the solution	7. How would your results change if you instead use a battery with constant porosity, ε_o? 8. Considering the results obtained in questions 6 & 7, comment on the advantages and disadvantages of a graded porous electrode battery.	5. For both types of porosity gradient electrodes, a positive or negative, will allow for longer discharge time on the electrode? 6. How would your results change if you instead use a battery with constant porosity, ε_o? 7. Considering the results obtained in questions 2 & 6, comment on the advantages and disadvantages of a graded porous electrode battery.

V. Results and Summary

Table 2 presents a summary of the conceptual systems students used to approach the solution to the design problem. Preliminary results describe students' use of representational media and how it is related to conceptual models they used to guide the problem process. These findings also suggest that students conceptual understanding are distributed across a variety of representations [2].

TABLE II. Summary of Represnational Media Usage

Polya's model	Representational media	Group 1			Group 2		
		S1	S2	S3	S1	S2	S3

1. Represent the problem	Written	6	0	2	0	0	0
	Pictures	0	1	0	0	0	0
	Equation	15	18	17	14	15	14
	Graphic	0	0	0	0	0	0
	Written with Symbols/Equations	9	4	4	0	0	0
	Computational	0	1	0	1	1	1
2. Goal setting and Planning	Written	1	1	2	0	1	1
	Pictures	0	0	0	0	1	5
	Equation	14	11	9	0	0	0
	Graphic	6	0	0	0	1	5
	Written with Symbols/Equations	7	6	11	2	1	2
	Computational	2	0	0	0	0	0
3. Execute and Plan	Written	4	1	1	0	1	1
	Pictures	0	0	0	0	1	1
	Equation	12	12	9	0	0	0
	Graphic	1	0	2	0	1	1
	Written with Symbols/Equations	3	7	5	1	1	0
	Computational	0	0	0	0	0	0
4. Evaluate the solution	Written	6	2	2	1	3	0
	Pictures	0	0	0	0	0	1
	Equation	3	3	3	2	0	0
	Graphic	0	0	0	0	0	1
	Written with Symbols/Equations	4	0	2	2	0	2
	Computational	0	0	0	0	0	0

The results of this study are supported by Lesh's and Doerr's theory for conceptual systems in problem solving, in that students conceptual understandings are distributed across a variety of representational media [2]. The participants' performance in the first group varied from the second group in terms of their use of representational media. The data suggests, students not using computer simulations relied more on analytical equations and related symbols to help investigate and infer the behavior of variables related to the physical battery system they were designing. These results highlight the relationship between the problem representation and the cognitive process students used to approach problem solving. In addition, results highlight the nature of computing tools in supporting students conceptual system to reason with more graphical and pictorial artifacts.

Table 2 does provide a means to identify the differences for the individual mappings among conceptual structures students followed throughout the problem solving process. Potential explanations for these differences can be hypothesized, from the data summarized in Table 2. In particular, students using a computer system, relay on more on the process of abstraction when using the computer program to generate additional representations of the design problem and the instructions to complete the computer program [1]. Furthermore, student's inquiry process can be supported using computer tools, without the need to explicitly reproduce the computational abstractions in written or graphical form. In contrast, the traditional methods of using mathematical analytical models, directs students to rely more on the use of explicit representations such as equation and symbolic forms.

This exploratory case study provides a framework for future studies using a larger sample size for investigating the role of mathematical and computational models in supporting students' problem solving processes in engineering education. Results also help to gain meaningful insight for future exploration in the way representations are used in each of the stages of the problem solving process using a verbal protocol analysis or interviews with student participants in engineering education.

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Health Clinic Infrastructure Design across Cultures in a High School Biology Course

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***Abstract*—A design project is a great way to engage and interest students about engineering subjects. This paper describes an engineering design project intended for use within the high school classroom that transcends global boundaries. The main goal of the project is to give students a better understanding of engineering, and introduce students to the concept of engineering design. Students assume the roles of engineers, first designing, and then building a small model of a health center. This paper describes the design project, as conducted in East Africa, which has a similar component implemented within the United States. Project implementation in East Africa occurred over a two-week period, while the project is designed to last for a longer period in the United States. Survey results and classroom observation from the East African component reveal project efficacy in the areas of student engineering awareness, engineering interest, engineering efficacy, and cross-cultural sharing.**

Keywords— engineering design; international collaboration; high school design project

I. Introduction

Engineers are essential in society and economy. The technological innovations that engineers create can range from processes and systems, to medicines and devices, which are all designed to make improvements in how people live everyday [1]. These achievements have helped to shape our way of living, allowing for safe drinking water, access to large databases of information, power and electricity in areas and medical innovations that cure and treat the most deadly of diseases. These achievements represent what engineers have been able to accomplish in the past, but as the future approaches, engineers have increasingly more challenges to face. The National Academy of Engineering's (NAE) 14 Grand Challenges for Engineering seek to describe those future challenges that engineers will continue to work on. They include the need for advancing healthcare informatics, making solar energy economical, and managing the nitrogen cycle [2]. Most K-12 students understand that engineers are proficient in math and science [3]. However many still fail to realize the impact that engineers have on the community and their contribution to everyday life.

To increase student interest in engineering fields, a project was created using the NAE grand challenge "Restoring and improving urban infrastructure" as a point of motivation. Infrastructure refers to the systems (both physical and organizational) that make up society and engineers help design and maintain the systems that govern infrastructure, playing roles in water management, facility development and energy resource design. To implement an infrastructure project within a high school biology course, healthcare was selected as a topic of interest. Health centers are a major point of service for the prevention and treatment of disease within a particular community. It is normally the first place, residents turn for preventative and long term care [4]. The combination of these topics into a fun and entertaining design project allow students to get a better understanding of engineering principles, while allowing students to refine skills necessary for success in their science classes. By allowing students to work on this as a design project, it will inspire a greater number of students to begin thinking about engineering careers.

The use of project based learning with hands-on activities provides a great way to introduce students to introductory concepts and increase awareness in a particular area [5]. This has been shown to be an important approach when teaching engineering concepts to students at many educational levels [3, 6, 7]. In this project, students learn about the engineering design process. The engineering design process is used by engineering teams to come up with a solution to a design challenge [7]. The project takes students through a modified version of this process, in which students take on the role of an engineer and design a health facility for a community within either Philadelphia or Kenya. By allowing students to take on these roles and go through the process for themselves, they can learn how engineers create technological designs, and get a better understanding of what engineers do [5]. This project was presented by an NSF GK12 Fellow in Biomedical Engineering who spent instructional time both in East Africa and in Philadelphia. The clinic design project was implemented over a two-week period in East Africa and is currently being introduced to students in Philadelphia.

In this work, two classrooms in rural East Africa and two classrooms in a large urban school district in the United States (a total of 93 students) participate in a health clinic engineering design project. Students work in groups with classes divided into teams of 3-7 students. Students first conduct research about the design and construction of health centers, then use that information to help in designing a three dimensional model of the clinic. After initial research on the design and

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construction of health centers, students were tasked with first designing the blueprints and schematic for a health center. They were asked to create the drawings to a set scale in order to be able to translate those designs into a three dimensional representation. The primary desired outcomes of the project are to:

- Introduce students to the National Academy of Engineering's Grand Challenges
- Demonstrate how the engineering design process works and how engineers are fundamental in society and the economy
- Encourage students towards careers in engineering
- Foster an international collaboration between two schools

In this paper, the project as presented in East Africa and designed for the United States is described. While carried out as part of an NSF GK12 program, this work can be a sustainable model for teachers to use in any cross-cultural collaboration or individual classroom design project. Student work is shown and survey results that measured student interest and opinions are presented.

II. Project Implementation in East Africa

The design project was implemented over a two week period for the students in Kenya. Over the course of that time, the students were introduced to engineering through a series of lectures and activities. Students were presented introductory modules on engineering through lectures and activities; while project work consisted of the research on the construction of health clinics, the design blueprint and schematic, and a presentation of the model to their peers. In the first week, students were given lectures and activities that would introduce students to engineering careers such as biomedical, electrical, and chemical and computer as well as to engineering challenges such as information transfer, medical research, and energy storage. During the second week, students became junior engineers to design and construct a physical model of an ideal health clinic.

A. Engineering Introduction

"What is engineering?" "What do engineers do?" These were the questions initially posed to the students. To introduce them to engineering careers, challenges and achievements, students were presented lessons about engineering technology in medicine, energy storage, and infrastructure management. These technologies were shown to address NAE grand challenges such as Advancing healthcare informatics, and restoring and improving urban infrastructure. Additionally, small activities were incorporated to help students in understanding these engineering challenges.

B. Identify the problem and do background research

Student research on the design and construction of clinics within Kenya was conducted prior to fellow arrival. Students were presented with the challenge to design a health clinic for the opposite location. In order to better prepare students for the design project, several students visited a health clinic and came up with the materials used in the construction, departments located within, and how illnesses were being treated in a health clinic. The students used this background information in the schematic design of their ideal clinic and also translated this information into the development of the physical model of their schematic design.

C. Specify the requirements: The internal and external layout of a health clinic

Students were shown pictures and given information about health clinics located within Philadelphia. This information coupled with their own pre-existing knowledge about the structure and layout of health clinics (from clinic visit and research), served as the background research for students to come up with a list of specifications for their clinic design. This list helped to guide students in the schematic design and subsequent physical model building activity that followed. Students completed the design and build phase of the clinic project over the course of the second week.

D. Create solution: Schematic design and model building

After a lecture and activity on schematic design and model creation, students were asked to create the schematic design and blueprints necessary to create their model clinic. In order to demonstrate the necessary components of the drawing, students were asked what information was needed and how they would recreate a desk located at the front of the room. Using this information, students came with their own specifications for their schematic drawing and used those dimensions when creating the scale model of their clinic design. After building the model, students presented to their peers. In the presentation, they were asked to not only present the design, but also to present any challenges they faced during building and also how they managed to overcome those challenges.

III. Pre-project Preparation-United States

Project implementation within East Africa and the United States were meant to be similar (the task, and deliverables), however the project was run separately in both countries. The main difference between project implementation within the United States versus East Africa is the time the fellow spent with each group of students. While the East African component was meant to be a short term experience, the fellow had an entire school year (~ 9 month period) to work with students within the United States. Therefore, project work was prolonged over the course of the year, and small sections about engineering and other aspects were introduced on a weekly basis.

Before beginning the design project, students were introduced to engineering ideas, achievements and concepts in a few short presentations and activities by the NSF GK12 Fellow. Each of these short presentations and activities were meant to introduce the students to engineering ideas, by relating the presentation or activity to one of the National Academy of Engineering's Grand Challenges for Engineering [2]. This set of 12 challenges served as a guide to create introductory material that related to the areas the students were already studying as a part of the state prescribed curriculum.

A. Introduction to Engineering Jeopardy Game

As an introductory module to engineering, students were divided into teams to play in a competitive Jeopardy style game. Students were positioned in groups of 4 and took turns selecting a category for questioning. The categories held questions that related to topics that were meant to introduce students engineering achievements in the past and present, the National Academy of Engineering's Grand Challenges, and what type of jobs engineers hold.

B. Engineering News Report

During the course of the school year, bi-weekly presentations were prepared to introduce the students to many current engineering achievements, as well as discuss the jobs of the engineers who created those achievements. After the presentation, students were invited to ask any questions and discuss the significance that achievement may have. The topic for presentation was chosen based on the relation of the National Academy of Engineering Grand Challenges to the current topic students were covering in class. Using this format, the students were able to cover challenges such as providing access to clean water and engineering the tools of scientific discovery, while learning about achievements that were related to each challenge, such as advancements in water filtration technology, and molecular imaging modalities.

C. Design Process Module

Students are first introduced to engineering design by presenting the engineering design process in an analogous manner to the scientific method. To reinforce the concepts presented, students were given the challenge to design and create a tall tower using very limited resources. Groups were asked to use the design process to address that challenge. The primary restriction was that the tower had to be comprised of a single A4 sheet of paper. The goal was to redesign the paper to make the tower as tall as possible. Following activity completion, to assess student understanding, students are asked to describe the steps of obtaining their solution, using the process as a guide, as well as outlining the main issues involved with addressing that challenge.

IV. Project Implementation in the United States

The design project was implemented over a four month period for the students in Philadelphia. This work was completed after the fellow spent time in East Africa. Over the course of that time, they were given four main tasks to complete. These tasks were meant to mirror different steps of the engineering design process to allow students to get a better idea of how engineers perform their jobs.

A. Identify the Problem and do background Research

The first project deliverable will be a research summary that will describe the basic elements of a clinic and also a disease that affects the population of Kenya/Philadelphia. The students are asked to design a clinic that will be able to treat that particular disease. In the summary, students are asked to describe the disease in detail (based on a list of questions), as well as summarize the difference between a hospital and clinic, and what services are offered. The main purpose of this segment of the project is to introduce students to the needs of the population and for students to identify the services within a clinic that are needed to treat that particular disease. Students were able to use web, text or any other resources available to find the information needed to complete the summary.

B. Specify the Requirements

The students are asked to design a clinic that will be able to treat the disease chosen during their research summary segment. As a second deliverable, students were asked to create a report describing the clinic design. A list of the requirements for the report is included in Table I.

TABLE I. Tasks for Design Report

Blueprint	*Research Summary*
Schematic	*Material Choice*

C. Create solution: Schematic Design and Model Building

Students were also asked to create a small scale model of their clinic, based on the design report given. The students are given several different material choices and then time building that model. They can create the model using foam, cardboard, wood, plastic, or any other type of material available. The main purpose of this portion is to illustrate how engineers translate drawings into models that can be used to test the performance of that object. Students then present their designs to their peers.

V. Assessment

A survey comprised of Likert-based and free response questions was developed in partnership with a third party evaluator to assess the outcome of the project. The students were given a pre-project survey before any of the introductory modules or project classes. A similar survey was then administered after completion of the project. In addition to the surveys, classroom observations and interviews with participating students were also used. The purpose of the assessment tools was to address program efficacy in achieving the primary desired outcomes:

- To introduce students to the National Academy of Engineering’s Grand Challenges
- To demonstrate how the engineering design process works and how engineers are fundamental in society and the economy
- To encourage students towards careers in engineering
- To foster an international collaboration between two schools

VI. RESULTS

Reception to the two-week program in East Africa was overwhelmingly positive. In examining the efficacy of lecture-based classes versus hands-on problem based lessons, the classroom observations revealed that the classes which contained hands on instruction were more enjoyable. In-class informal examinations also revealed better retention of content beyond the duration of the program. The observations also revealed increased student engagement in the project during hands-on lessons. These observations are also in agreement with the results from the survey question: "What was your favorite part of the NSF visiting Scholar programme?" In response to this question a majority of the students (66.7%) explicitly mentioned that the hands-on project experience was their favorite part of the program. An example of the hands-on experience is demonstrated in Figures 1, 2 and 3. These figures show the progression of students' participation in an introductory module (Figure 1), then building the clinic (Figure 2) and finally the completed clinics (Figure 3).

Figure 1 shows students working during one of the hands-on modules about Engineering. The theme for the day was Energy. After a brief discussion about various energy sources, students were given the task to create a battery using pennies and nickels. Students were engaged in the task and were able to make conclusions in their work. Students were initially more fascinated by the American currency, but after realizing that the batteries were in fact creating voltage, they became more engaged in the activity at hand. When asked the following week what they learned from the previous week about engineering, several of the students began discussing the principles and energy resources learned in this lesson.

When examining the overall goals of the project, the survey results are in agreement with the notion that the project was successful in its intended outcomes. The answers to both the free responses and Likert survey questions (Figures 4 and 5) show an overall increase in student understanding of engineering and the job that engineers do. They also show an increase in the percent of students that were considering pursuing engineering academically and professionally.

A. *Introduce students to the National Academy of Engineering's Grand Challenges*

Classroom observation revealed a dramatic increase in student ability to recount the various NAE Grand Challenges, which is in agreement with the results shown in Figure 4, demonstrating that nearly all students experience an increased knowledge of global engineering challenges.

To further assess this matter, a look at the students' understanding of engineering is helpful. This was assessed in the survey questions: "In your own words, what is engineering?" and "What does an engineer do?". The student responses to this question are presented in Table II. Prior to administering the project, 50.0% of the students had some understanding of what was engineering was. It can also be seen that few students (16.7%) had a solid grasp of engineering, while there was a number of students (33.3%) who had little to no understanding as well. After project implementation, there is a substantial increase in student engineering awareness. This increase can be seen by looking at the dramatic increase in students with some understanding or a solid grasp of engineering.

Fig. 1. Students working during introductory Module.

TABLE II. STUDENT UNDERSTANDING OF ENGINEERING

In your own words, what is engineering? What does an engineer do?		
Level of Engineering Comprehension	***Before Project***	***After Project***
Solid Grasp	16.7%	40.7%
Some Understanding	50.0%	44.4%
Little or No Understanding	33.3%	14.8%

B. *Demonstrating the engineering design process and how engineers are fundamental in society and economy*

During the second week of the scholar program, students designed and built a model clinic. This portion of the project served to demonstrate how engineers create designs that can be constructed. Figure 2 shows students building their clinic design model. The students were engaged and participating throughout the entire activity. They required little encouragement to remain on task during the building activities. Students took the initiative to organize themselves during the activity, with each group defining its own specific roles in the building process. Students were enthusiastic when translating their designs into three-dimensional structures, and even spent hours outside of the scheduled classroom time working to complete the models. A completed design is shown in Figure 3.

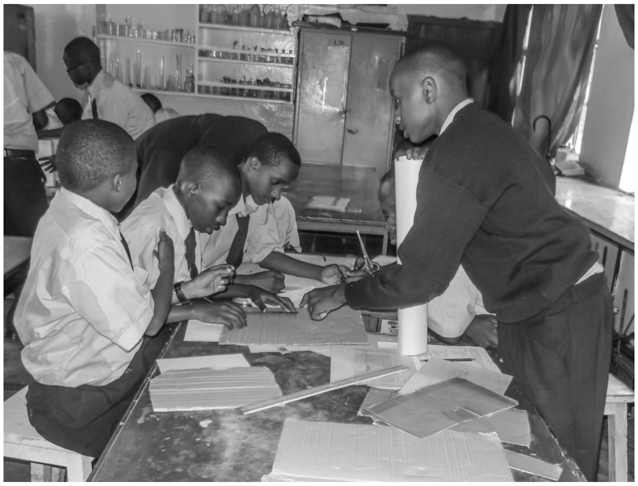

Fig. 2. Student collaboration during desing project building

Fig. 3. Completed student clinic models

Responses to the Likert-based survey shown in Figure 5 reveal that students demonstrated marked growth in awareness of the engineering design process and in their confidence to perform independent research. The free responses to the questions: What did you learn about engineering in the visiting scholar programme?" and "how has the health clinic design project helped you to see engineering differently?" also indicate that students felt as though the project allowed them to think positively about their own skills, to enhance creativity, and to think critically about executing tasks. Of particular importance to students was the introduction of the creative design process in solving problems. Despite increased awareness of the engineering design process, students showed insignificant increase in understanding the fundamental role that engineers play in society.

C. Encourage students towards careers in engineering

To assess whether the project was successful in encouraging student interest in engineering fields, the results to the survey question: "Select two career fields you are most interested in pursuing academically and professionally" are examined (shown in Table 3). In this question, students were asked to choose the two career fields they were most interested in pursuing academically and professionally. The pre-survey responses reveal that students indicated having some interest in engineering prior to introduction to the project. Despite having a large percentage (43%) of students who were interested in pursuing engineering, the post –survey showed a large increase in the number of students who self-selected engineering (63%). These results were also supported by the likert based survey questions shown in Figures 4 and 5. A majority of students agree or strongly agree that the clinic design project increased their interest in engineering (Figure 4). Additionally, the longitudinal results in Figure 5 demonstrate increases in selecting engineering careers. The results to the free response question "How has the health clinic design project helped you to see engineering differently?" show positive ideas about engineering and pursuing engineering after high school. Several students noted that they are very proud of the work they have completed, and that the project had given them hope of becoming an engineer one day. In the words of one student, "The design has made me feel like a real engineer and the design has made me see the difference between construction and the design of different things." Another student stated, "the health clinic design project has increased my interest in engineering and the health clinic design project gave me an idea of an engineer's role and responsibilities."

TABLE III. STUDENT CAREER FIELD INTEREST

Select two career fields you are most interested in pursuing academically & professionally		
	Before Project (%)	***After Project (%)***
Engineering	43	63
Law	5	15
Finance	5	0
Information Technology	14	7
Architecture	0	15
Healthcare	19	11
Art or Music	19	15
Public Safety	10	11
Business	10	7
Scientific Research	10	19
Other	19	11

VII. CONCLUSIONS AND FUTURE CONSIDERATIONS

In this paper, the implementation of a clinic design project in Africa and the proposed plan of execution for the same project within the United States were described. The results showed several trends. Students demonstrated an overall increase in engineering understanding and desire to pursue

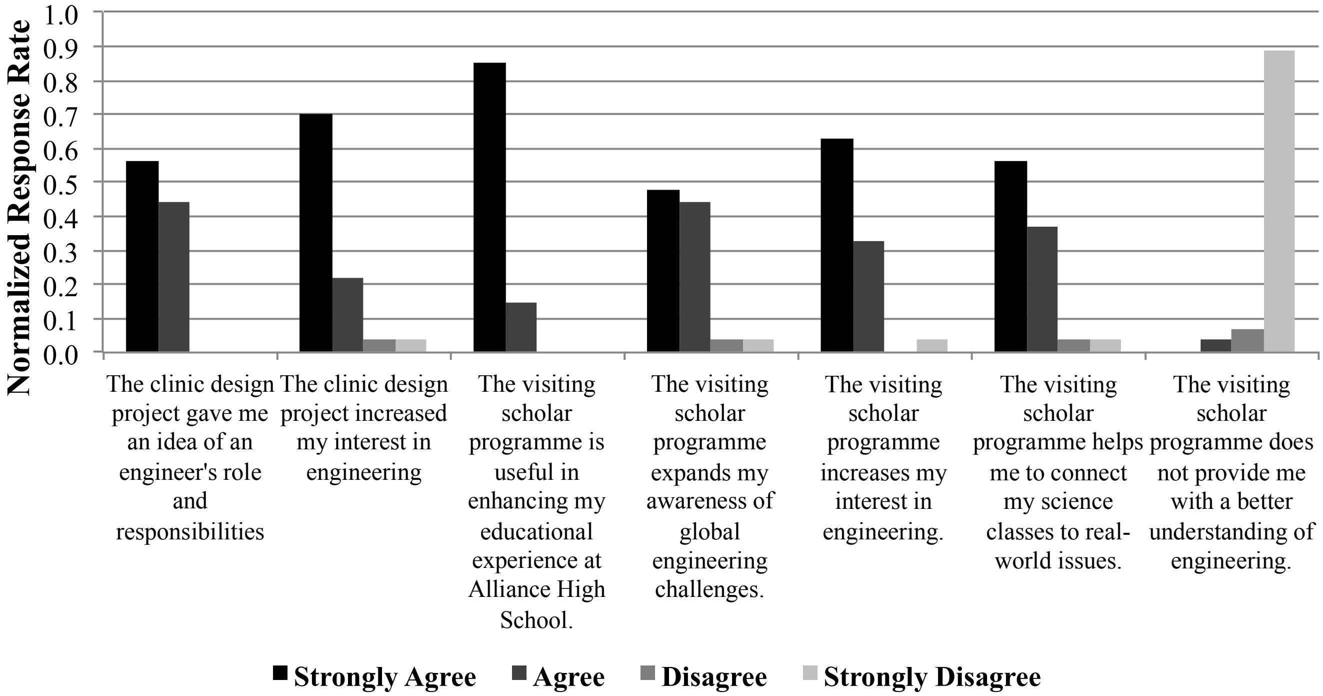

Fig. 4. Student responses to Likert-based questions after participating in the health clinic design project.

engineering career paths. In addition to giving students a better understanding of engineering concepts, students also came away with new ideas about engineers and working within the engineering field. The project was therefore successful in its engineering-related outcomes. Due to technological limitations, however, the ability to support cross-cultural interaction was limited. This was the primary idea for improvement that both evaluators and participantes mentioned. Methods for enhancing cross-culural sharing are currently being implemented, as the project is a part of a long-term commitment by all participating schools. The most important element is the ability to find low-bandwidth, engaging and secure ways to facilitate direct

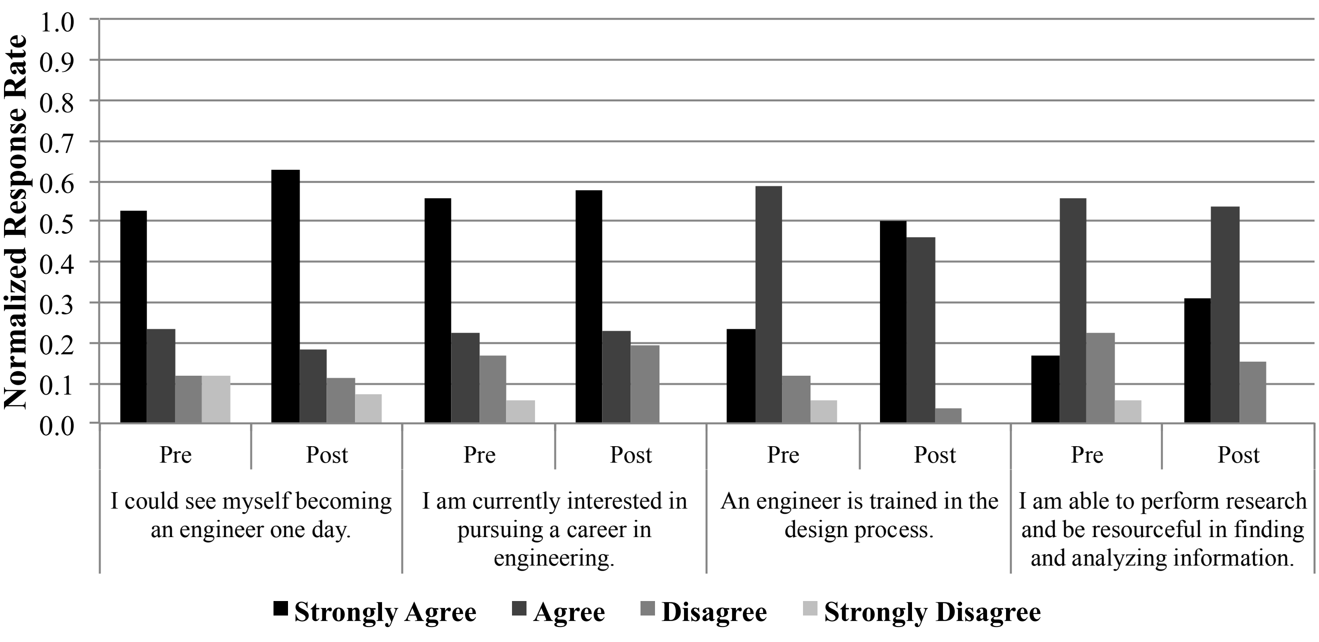

Fig. 5. Longitudinal student responses demonstrating the progress of student interest and awareness of engineering, engineering design and research skills

student interaction. Differing outcomes between the United States and Africa, including both cultural elements and the effects short-term versus long-term implementation of the design project are also under way.

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Establishing a Global Software Development Course: A Cultural Perspective

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***Abstract*— Global software development (GSD) is one of the main practices in software industry. The ability to outsource and manage software development at remote sites allows organizations to benefit from GSD since they get access to a wider and more economically feasible pool of developers. Recently, global software engineering courses are being introduced at academic institutes as part of computer science and software engineering degree requirements. There are many challenges associated with managing and executing globally distributed software projects in academic settings. In this paper, we will attempt to analyze the framework and components of a collaborative global software engineering course from a cultural perspective. We examine the different challenges related to team-setting, grading, communication tools, gender issues and associated risks. A discussion of how cultural differences may affect setting up the course is included. The uniqueness of the proposed research lies in two main areas: it examines collaboration between Kuwait, USA and Poland; and it investigates the proposed topics from a cultural perspective.**

Keywords—Global software engineering, computer education.

I. Introduction

Kuwait is a small country situated in the Persian Gulf region (GCC). With a 40% expat population, the government of Kuwait is working hard to encourage local employment and to generate qualified local caliber. Within this context, the Kuwaiti government is reinforcing educational reform at all levels [1].

Software and IT industries are truly global today - and so is software engineering. Global software development is increasingly becoming a common practice in the software industry. The ability to develop software at remote sites in projects allows organizations to overcome the geographic distances and benefit from access to a rich resource pool and reduced development costs. The rapid globalization of the software industry creates software engineering challenges due to the impact of temporal, geographical, and cultural differences [2].

In this paper, we will investigate the cultural factors that may affect initiating a global software development (GSD) course at the American University of Kuwait (AUK). Cultural dimensions suggested by Hofstede [3] will be considered as guidelines for recommendations. The following sections will be structured as follows:

- Section 2 outlines relevant background.
- Section 3 discusses similar projects.
- Section 4 summarizes the methodology and the research plan.
- Section 5 investigates relevant cultural dimensions.
- Section 6 includes a discussion of the relation between cultural dimensions and suggested course activities.
- Finally, directions for next steps are discussed.

II. Background

The American University of Kuwait (AUK) is an independent, private, equal opportunity, and co-educational liberal arts institution of higher education. The educational, cultural, and administrative structure, methods and standards of AUK are based on the American model of higher learning. The language of instruction is English. AUK was established as a Kuwaiti University but with an American name. This necessarily makes it bi-cultural. So while the educational system is American, it exists in a very different cultural environment which offers both challenges and opportunities.

The main aim of this paper is to investigate the challenges in setting up a new global software development course. The course is part of a project to establish a global software development lab in Kuwait. The goal of the project is to create an innovative, highly challenging learning environment for educating the next generations of software engineers. The environment allows students to envision new systems, understand user needs, and develop new concepts. It offers students opportunities to conduct their experiments and projects, and simulate operations of real systems in a scientific setting.

The main idea of this research is to have at least three teams in different sites (one at AUK, one in USA and one in Poland) collaborate in developing software projects. The three sites belong to different cultures which may result in challenges. The model simulates outsourcing in software development context. Many issues will be studied while the project is progressing. Typically, the teams are enrolled in a special topics course. Courses that involve such activity are 300-400 level courses with software engineering as prerequisite. The associated tools, risks and best practices will be investigated.

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III. Literature Review

A. Cultural Dimensions

Geert Hofstede conducted one of the well-known and most widely used studies about defining cultural dimensions. According to Hofstede, culture can be measured by six dimensions [3]. The following three dimensions are the most relevant measures to global software engineering [11]:

- Power Distance (PDI): This dimension expresses the degree to which people and society accept that power is not equally distributed. In societies with low power distance, people strive to equalize the distribution of power and demand justification for inequalities of power [3].
- Individualism versus collectivism (IDV): the degree to which people are attached to the group/tribe/family [3]. A society's position on this dimension is reflected in whether people's self-image is defined in terms of "I" or "we."
- Uncertainty avoidance (UAI): The degree to which people accept ambiguous and unknown future [3]. The fundamental issue here is how a society deals with the fact that the future can never be known: should we try to control the future or just let it happen? Weak UAI societies maintain a more relaxed attitude in which practice counts more than principles.

There are other cultural dimensions that will not be considered in our initial study. The remaining dimensions are[3]:

- Masculinity versus femininity (MAS): The masculinity side of this dimension represents a preference in society for achievement, heroism, assertiveness and material reward for success.
- Long-term versus short-term orientation (LTO): The long-term orientation dimension can be interpreted as dealing with society's search for virtue.
- Indulgence versus Restraint (IVR): Indulgence stands for a society that allows relatively free gratification of basic and natural human drives related to enjoying life and having fun.

Other efforts to define culture were reported. Examples include: Trompenaar's dimensions and Hall's dimensions [4]. The decision to base this discussion on Hofstede's dimensions is due to the fact that it is the most widely used cultural benchmark in the context of software industry since it was originally conducted at IBM. In next phases of research, other models and dimensions will be considered.

B. Global Software Engineering

Collaborative GSD is mainly concerned with studying methodologies, tools, infrastructures, and other factors that influence distributed software development by culturally diverse teams. The main classifications of collaborative software development are: context, support, tasks interaction, teams, individuals and overreaching factors [5]. Many empirical studies and literature reviews focus on the identification of challenges in collaborative work [6]. In the context of GSD in academia, there were similar projects that investigated possible challenges through experiments. The first project had two sites of software development (in multiple countries): one in Turkey and one in USA, while another experiment was done between USA and Sweden [7]. The clients in both experiments were from industry. During the first study, students from the US visited Turkey twice during the semester, once at the beginning of the project and once at the end. It was reported that time difference and language were among the major obstacles in performing the experiments [7]. The research group of Global Software Engineering at University of Victoria, Canada carried out several related research projects. One of the projects investigated whether geographical distance continues to affect developers' collaboration in large teams that use development environments specifically designed to support collaborative distributed teams. Communication and response time were analyzed [8]. Another project at the same university developed an improvement to the original socio-technical congruence calculation in the literature. A metric that measures the strength of relationships between people and tasks, interdependent tasks and between project members was used [9].

A model GSD academic center should have the following components [10]:

- Research and Development activities
- Educational activities: courses, seminars, lectures
- Members: faculty and students
- Credible affiliates/sponsors : academic, industry, and government

Many efforts aimed at applying Hofstede cultural dimensions on global software engineering. The same approach of Borchers[11] was followed in this research. Other research efforts argue that applying Hofstede's dimensions is not sufficient to study cultural factors in GSD [4]. Shah et all proposed using different cultural models instead of the dimensions of Hofstede [4].

IV. Methodology and Plan

The main plan for the research includes three main phases: initiation, implementation and analysis.

A. Phase I Initiation Phase (Initiation visits and meetings)

In this phase, the framework of the project will be established. The framework will include overall planning and time alignment. In addition, the type of courses to be integrated will be determined. Learning outcomes of the courses must be coordinated (there should be some sort of overlap of learning outcomes at least). Time alignment is a crucial factor because some universities adopt semesters while others adopt quarters, so university calendars have to be taken in consideration.

In this phase, professors and supervisors from the participating institutes should meet to decide on type of projects, possible communication models and tools. Possible tools include Skype and videoconferencing.

B. *Phase II Implementation*

In this phase, the experiments will commence at different sites. Data collection in this study will be based on the results of assignments and surveys. The following activities will be carried out:

- Courses will be offered in different locations.
- Meeting of participating students and mentors at to launch the experiment.
- Development projects will start.
- Surveys will be conducted at the end of the experiment.

C. *Phase III Analysis*

In this phase, analysis of the outcomes and documenting the findings will be carried out. The findings will be compiled in the form of a two dimensional matrix:

- Cultural dimensions proposed by Hofstede[3] will represent the vertical dimension
- Collaboration dimensions will represent the horizontal dimension. Collaboration dimensions include: Communication, Leadership, Coordination and Dependency.

V. Relevant Cultural Measures and Activities

Figure-1 illustrates the three chosen dimensions (PDI, IDV UAI) for the three proposed sites. The dimensions were extracted from the Hofstede center web-site based on Hofstede's surveys [12].

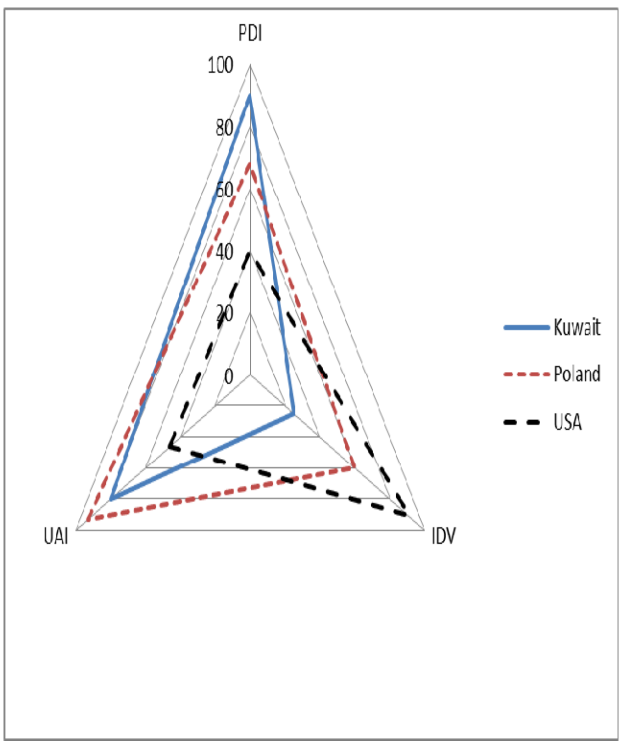

Figure-1 Cultural dimensions in Kuwait, Poland and USA

TABLE-1 CULTURAL DIMENSIONS IN KUWAIT, POLAND AND USA

	PDI	IDV	UAI
Kuwait	90	25	80
Poland	68	60	93
USA	40	91	46

It can be noticed from Table-1 that:

- Kuwait has the highest PDI, followed by Poland then USA.
- Poland has the highest UAI, followed by Kuwait then USA.
- USA had the highest IDV, followed by Poland then Kuwait.

A. *PDI*

- Kuwait has the highest PDI (90) which means that people accept an extreme hierarchical order which needs no further justification. Hierarchy in an organization is seen as reflecting inherent inequalities, centralization is popular, subordinates expect to be told what to do and the ideal boss is a generous autocrat.
- Poland (PDI 68) is a hierarchical society. This means that people accept a hierarchical order which needs minor justification.
- The United States score low on PDI (40) which is evidenced by the focus on equal rights in all aspects of American society and government. Within American organizations, hierarchy is established for convenience, superiors are always accessible and managers rely on individual employees and teams for their expertise [12].

B. *IDV*

- USA has the highest IDV which means that it is a very highly individualistic culture. This translates into a loosely-knit society in which the expectation is that people look after themselves and their immediate families. There is also a high degree of geographical mobility in the United States and most Americans are accustomed to doing business with, or interacting, with strangers. Consequently, Americans are not shy about approaching their prospective counterparts in order to obtain or seek information. In the business world, employees are expected to be self-reliant and display initiative. Also, within the exchange-based world of work, hiring and promotion decisions are based on merit or evidence of what one has done or can do.
- Poland, with a score of IDV 60 is an Individualistic society. This means there is a high preference for a loosely-knit social framework in which individuals are expected to take care of themselves and their immediate families only.
- Kuwait, with a score of 25 in IDV is considered a collectivistic society. This results in a close long-term commitment to the 'group', be that a family, extended

family, or extended relationships. Loyalty to the group in a collectivist culture is essential [12].

C. UAI

- Poland and Kuwait have high UAI thus they have a very high preference for avoiding uncertainty. Countries exhibiting high uncertainty avoidance maintain rigid codes of belief and behavior and are intolerant of unorthodox behavior and ideas. In these cultures, there is an emotional need for rules (even if the rules never seem to work). Time is money, people have an inner urge to be busy and work hard. Precision and punctuality are the norm, innovation may be resisted. Security is an important element in individual motivation.
- USA scores 46 on this dimension and therefore, the American society is what one would describe as "uncertainty accepting." Consequently, there is a larger degree of acceptance for new ideas, innovative products and a willingness to try something new or different, whether it pertains to technology or business practices [12].

VI. Discussion and Recommendations

In this section, a discussion about some of the major issues in establishing a global software development course is included. The issues are related to the cultural dimensions previously discussed in section V.

A. Team Structure

Research question: What is the optimum team formation to minimize risks and optimize the quality of the outcome? To be able to answer this research question, three different settings for the teams will be investigated and the outcomes will be compared. Figure-2 depicts a typical team structure with team leader in each participating academic site. Each team has three different types of roles: analyst, designer and developer. In this setup, each team will implement a subsystem of the project then integration will take place.

Discussion: Sites with low IDV (Kuwait) are more likely to collaborate locally due to their collectivist nature. Sites with high PDI (Kuwait) is expected to assume that the team leader has upper hand in decision making, while the case may be different in sites with low PDI like USA. Integration is expected to be challenging [11].

Figure-3 depicts an alternative approach. In this approach, each site is specialized in a certain activity (requirements, design and development) that better suits the culture and nature of participants in that site. Culture dimensions can be used as guidelines to assign roles.

Discussion: In this setting, courses at different locations may have different nature. One site can have systems analysis course to work with the requirements, another site can have an object-oriented design course to handle the design, while the third site can have a pure software development course. So the main advantage of this approach is that it minimizes the need to initiate new courses as most of these courses already exist in computer science curricula. However, timing and coordination will be a challenge.

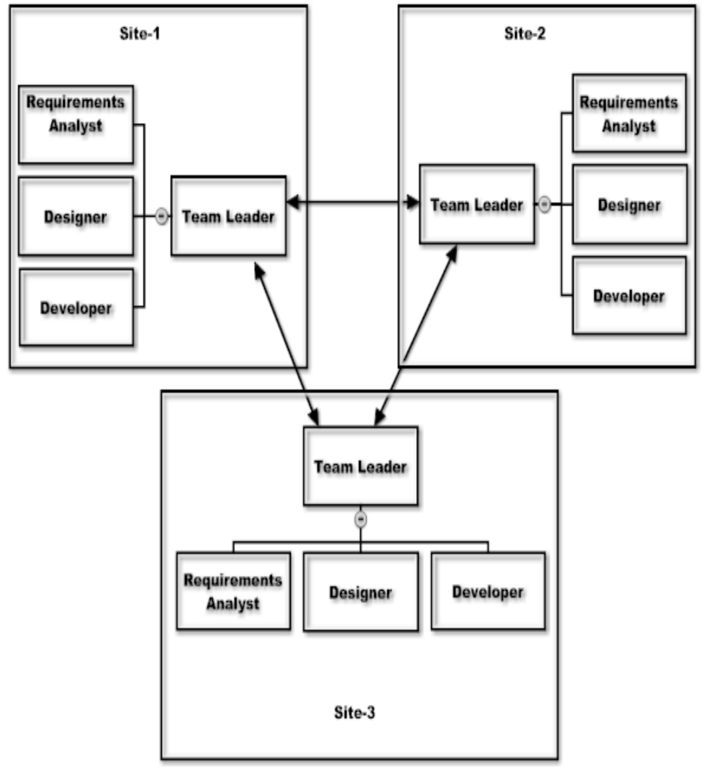

Figure-2 Setting-1 for team formation

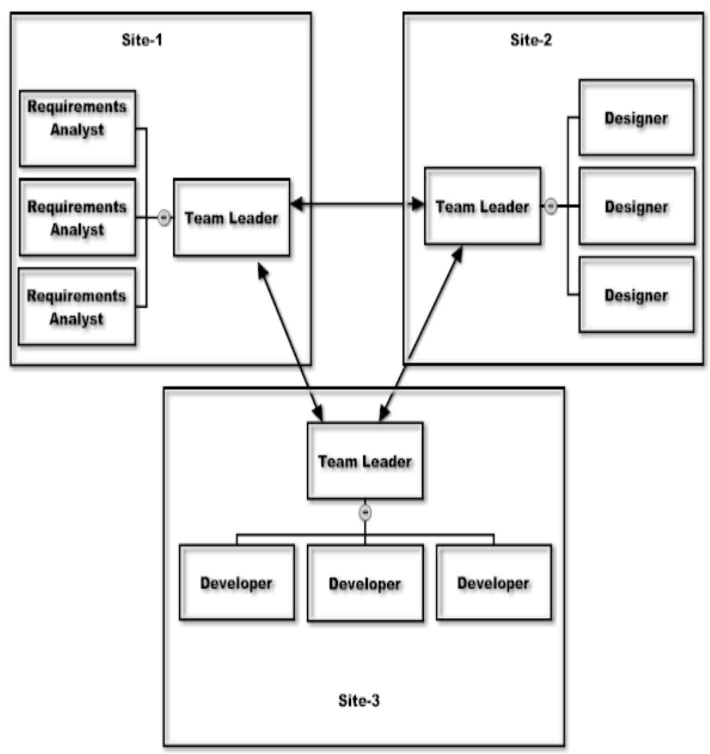

Figure-3 Setting-2 for team formation

Figure-4 depicts a more complex model. In this model, each team leader leads a team of a mix of cultures. In this setting, the members of each team are distributed. The role of each member is based on his/her qualifications.

Discussion: Leaders have to be aware of different cultures, otherwise delays and misunderstandings are probable. In addition, there is an overhead of communication among team members since they are in different sites and from different cultures and time-zones. The question to investigate is whether the qualifications of each member will make up for the overhead of communication or not. Problems may happen due to high expectations from the leader in groups where team members are from high PDI culture.

B. Communication Methods

Research question: What are the best communication methods? Difference in time zones is a factor that will affect comunication methods. Kuwait is UTC+3:00, Poland is UTC+01:00 (one hour behind Kuwait during daylight saving, two hours otherwise) while the American site follows EST (7 hours behind Kuwait during dalight saving, 8 hours otherwise). It is also worth mentioning that both Poland and USA follow daylight saving while Kuwait does not. Due to the time-zone factor, the following two methods of communications can be considered: synchronous and asynchronous methods. Synchonous methods include video conferencing and chatting, while assynchronous methods include email and document sharing.

Discussion: A combination of both methods will be investigated. Clear meeting agendas and minutes have to be written and disseminated early enough to give people with high UAI chance to read and prepare for meetings. Local meetings will provide an opportunity for low IDV teams to prepare and discuss in a more relaxed way before the actual formal meetings. A superior moderator for the meetings will be needed to accommodate teams with high PDI (Kuwait), while the moderator role could rotate in groups with low PDI (USA).

C. Collaboration Model

Research question: What is the best collaboration model? To be able to answer this research question, two different collaboration models will be considered and investigated. Possible models include client/developer model and development together model. In Client/developer model, one team will act as a client while the other will act as a software developer. Each team will be located in a different site (country). In development together model, both teams (in two different sites) will develop the same software together (using the same client).Yu proposed different models for collaboration to minimize risks [13].

Discussion: Choosing an industry client may lead to some cultural problems [7]. The availability of such client to the co-located team/members can be beneficial in settings 2 and 3 where all the requirements team/members are co-located. The language of the client can be a factor in proper understanding of the requirements [7].

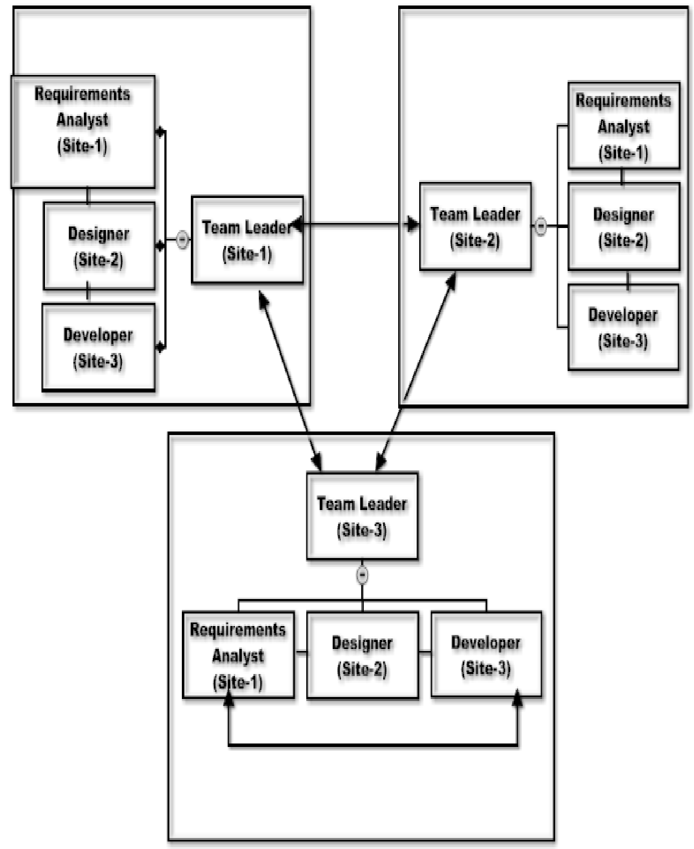

Figure-4 Setting-3 for team formation

D. Learning New Technologies

Research question: Can teams learn and apply new technologies in such setting? Which teams may have more flexibility to adopt and investigate new technologies?

Discussion: From the cultural interpretation in section 5, cultures with low UAI have larger degree of acceptance for new ideas, innovations and willingness to try something different. Depending on the team structure and culture mix, we will investigate which teams are faster in grasping and learning new technologies in such setting. This can be done by introducing a new programming environment and assigning the same assignment to all groups, then comparing the quality of the outcomes.

E. Documentation and Risk Management

Research questions: What are the best techniques to manage and avoid risks? Various risks related to GSD were reported in literature. Lack of understanding of requirements, selecting a wrong project, product quality and poor documentation are among the anticipated risks [13][14]. Risks in academic environment may vary from the ones related to industry.

Discussion: Using UAI as a guiding measure, it can be predicted that teams/members with high UAI can be more suitable for carrying out risk analysis and taking care of documentation along the way. The produced risk analysis documents will be compared and analyzed to verify this hypothesis.

F. Grading and learning outcomes

How to grade team members? Will the course be pass-fail or will it have scale with rubrics? Individual grading is expected to be more challenging where IDV is low. Low IDV indicates more loyalty to the collectivist culture. Cultures were IDV is high will have a more straightforward individual grading. The other anticipated problem is the difference in university calendars, national holidays and grading scheme. Due to difference in educational systems, courses may be offered as (pass-fail) in one site, while the matching course is graded (A to F) on the other sites. It was reported that difference in grading scheme may lead to lack of trust among different teams [7].

Discussion and Recommendations: It is better to have the courses following with the same grading scheme (if possible) to avoid such problems. The assessment criteria should be based on the experience gained out of the experiment rather than the completion of the software project itself. This will provide a way to evaluate each team member individually. The assignments can focus on student perceptions of cultural differences within the group [7]. Learning outcomes of the courses must be aligned properly before the courses are offered.

G. Gender-Issues

Percentage of females studying computer science and engineering in Kuwait is high compared to USA and most of Europe [15]. Teams will definitely have unbalanced gender distribution. While gender-segregation is a dimension of culture in Kuwait [15], it is not applicable in the other two sites. In previous research in Kuwait, it was found that gender-segregated students perform better than mixed-gender students [15]. It will be an interesting issue to research and investigate in setting up the teams.

Discussion: It is worth investigating with teams with high PDI, if gender will be an issue in choosing the team leader. This will be investigated by the survey that will be conducted at the end of the experiment.

VII. Conclusion and Future Work

In this paper, we presented the initiation phase of developing a GSD course at AUK. Hofstede's cultural dimensions were used to analyze and provide a framework for initiating the course. In the coming phases, other models will be investigated and integrated. In the next phase, more hypotheses of the research will be formulated and finalized. One of the possible outcomes in the next phases is to develop cultural-aware software development tools with features that support collaboration. Trust issues among distributed team members can be investigated. It is also worth investigating different process models to identify which ones can be properly used in such courses.

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A Comparative Study of Motivation and Learning Strategies Between American and Chinese Undergraduate Engineering Students

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***Abstract*—This paper presents the results of a comparative study of motivation and learning strategies between American and Chinese undergraduate engineering students. A total of 109 sophomore engineering students from two American and Chinese universities responded to a Motivated Strategies for Learning Questionnaire (MSLQ) survey. The survey includes six motivation scales (totaling 31 items) and nine learning strategy scales (totaling 50 items). Descriptive statistics and independent sample t-tests are performed to analyze students' responses to each MSLQ scale. The results show that statistically significant differences exist in three motivation scales and six learning strategy scales between American and Chinese students surveyed. Overall, American students exceed Chinese students in motivation, but fall behind in learning strategies.**

Keywords: Comparative study; motivation; learning strategies; American undergraduate engineering students; Chinese undergraduate engineering students

I. INTRODUCTION

Extensive research evidence has shown that motivation and learning strategies significantly affect student learning outcomes [1, 2]. A comparative study of motivation and learning strategies among different countries helps develop a better understanding of how diverse cultural backgrounds and experiences shape student learning, and thus helps develop appropriate pedagogy and course curriculum to maximize student learning outcomes [2]. Such a comparative study is important now as online and distance education expands rapidly across national borders to reach a global audience.

This work-in-progress study is the first comparative study of motivation and learning strategies between American and Chinese undergraduate engineering students. The research question is: Are there statistically significant differences in motivation and learning strategies between American and Chinese undergraduate engineering students?

A total of 109 sophomore (second-year) engineering students from Utah State University (USU) in the United States and from Beijing Forestry University (BFU) in China participated in this study. The two institutions share many common features: Both are comprehensive, public, research-intensive, and PhD-granting institutions. At the end of a recent semester, all student participants from the two countries responded to a well-adopted Motivated Strategies for Learning Questionnaire (MSLQ) survey [3]. This survey is an 81-item self-reporting instrument for students to assess their motivational orientations and their use of different learning strategies in a college course. The 81-item MSLQ survey includes six motivation scales (totaling 31 items) and nine learning strategy scales (totaling 50 items). Pintrich et al. [3] have provided a detailed description of each scale and each item. Each item can be rated from 1 to 7.

In this work-in-progress study, descriptive statistics and independent sample t-tests are performed to analyze students' responses to each MSLQ scale. The motivation and learning strategy scales in which statistically significant differences exist between American and Chinese undergraduate engineering students are identified. Beyond this WIP study, future research will be focused on studying how students' motivation and learning strategies affect their academic performances in the United States and China. The future research will also help understand diverse cultural backgrounds and experiences of engineering students in both countries.

II. STUDENT PARTICIPANTS

A total of 109 sophomore engineering students participated in this study: 71 from Utah State University (USU) in the United States and 38 from Beijing Forestry University (BFU) in China. USU students were primarily from mechanical and aerospace engineering majors (52.1%) as well as from civil and environmental engineering majors (26.8%). BFU student participants were all from civil engineering majors.

III. STATISTICAL ANALYSIS

Tables I and II show the results of descriptive statistics and independent sample t-tests for each MSLQ scale. The scales in which statistically significant differences ($p < 0.05$) exist between American and Chinese undergraduate engineering students are highlighted in Table II. Effect size (ES) is also listed in the last column in Table II. ES is calculated as:

$$\text{Effec size} = \sqrt{t^2/(t^2 + df)} \quad (1)$$

Based on the probability (p) values listed in Table II, statistically significant differences exist between American and

TABLE I. DESCRIPTIVE STATISTICS

MSLQ scales	American students (n=71)		Chinese students (n=38)	
	Mean	SD	Mean	SD
Intrinsic goal orientation	4.59	1.06	4.83	1.10
Extrinsic goal orientation	5.22	1.21	4.61	1.25
Task value	5.52	1.28	4.75	0.91
Control of learning beliefs	5.77	1.13	4.60	0.98
Self-efficacy for learning & performance	5.17	1.24	4.95	0.96
Test anxiety	3.77	1.66	3.96	1.42
Rehearsal	3.81	1.13	4.38	1.14
Elaboration	4.35	1.04	4.43	0.91
Organization	3.87	1.39	4.81	1.23
Critical thinking	3.54	1.33	4.59	1.50
Metacognitive self-regulation	4.14	0.73	4.50	0.83
Time/study environmental management	4.78	0.93	4.32	0.51
Effort regulation	4.73	0.65	4.61	0.67
Peer learning	3.23	1.68	4.25	1.21

TABLE II. INDEPENDENT SAMPLE T-TESTS

MSLQ scales	t	df	p	ES
Intrinsic goal orientation	-1.10	107	0.275	0.11
Extrinsic goal orientation	2.51	107	**0.014**	0.24
Task value	3.67	98.8	**0.000**	0.35
Control of learning beliefs	5.38	107	**0.000**	0.46
Self-efficacy for learning & performance	0.97	107	0.333	0.09
Test anxiety	-0.58	107	0.564	0.06
Rehearsal	-2.52	107	**0.013**	0.24
Elaboration	-0.40	107	0.691	0.04
Organization	-3.52	107	**0.001**	0.32
Critical thinking	-4.21	107	**0.000**	0.38
Metacognitive self-regulation	-2.35	107	**0.021**	0.22
Time/study environmental management	3.29	106.9	**0.001**	0.30
Effort regulation	0.93	73.7	0.354	0.11
Peer learning	-3.68	97.9	**0.000**	0.35

Chinese students in the following three motivation scales and six learning strategy scales:

Motivation scales:

- Extrinsic goal orientation (t = 2.51, p = 0.014)
- Task value (t = 3.67, p = 0.000)
- Control of learning beliefs (t = 5.38, p = 0.000)

Learning strategy scales:

- Rehearsal (t =-2.518 , p = 0.013)
- Organization (t = -3.52, p = 0.001)
- Critical thinking (t = -4.21, p = 0.000)
- Metacognitive self-regulation (t = -2.345, p = 0.021)
- Time/study environmental management (t = 3.292, p = 0.001)
- Peer learning (t = -3.68, p = 0.000).

Positive t-scores mean that the mean score of American students is higher than that of Chinese students (refer to Table I). Negative t-scores mean that the mean score of American students is lower than that of Chinese students. The differences of American and Chinese students in these nine MSLQ scales represent medium-sized effects varying between 0.22 and 0.46. Overall, American students exceed Chinese students in motivation, but fall behind in learning strategies.

As a representative example, Figure 1 shows the comparison of histograms for critical thinking between American and Chinese students. As seen clearly from Figure 1, a higher percentage of American students provided lower ratings (less than 4) for their critical thinking skills than did Chinese students.

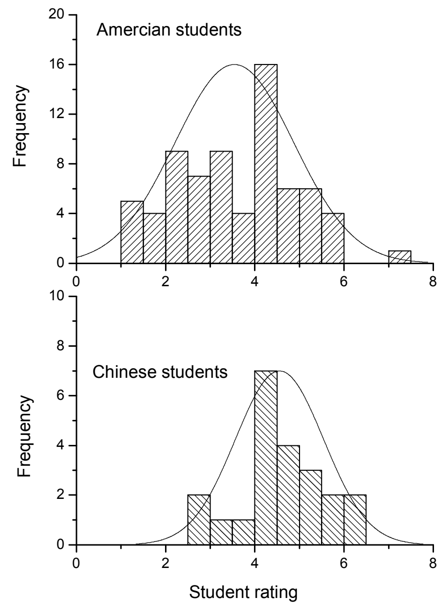

Figure 1. Comparison of histograms for critical thinking.

IV. CONCLUSIONS

Based on data collected from 109 engineering undergraduates from two comparable American and Chinese universities, the answer to the research question is: Statistically significant differences between American and Chinese students exist in three motivation scales (extrinsic goal orientation, task value, and control of learning beliefs) and six learning strategy scales (rehearsal, organization, critical thinking, metacognitive self-regulation, time/study environmental management, and peer learning). Overall, American students exceed Chinese students in motivation, but fall behind in learning strategies.

ACKNOWLEDGEMENT

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A Comparative Study of Learning Style Preferences Between American and Chinese Undergraduate Engineering Students

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***Abstract*—This paper presents the results of a comparative study of learning style preferences between American and Chinese undergraduate engineering students. A total of 132 sophomore engineering students from two American and Chinese universities responded to an Index of Learning Styles (ILS) survey. The survey is a 44-item, self-scoring questionnaire that assesses learning style preferences on four pairs of dimensions of the Felder-Silverman model: active/reflective, sensing/intuitive, visual/verbal, and sequential/global. Descriptive statistics and independent sample t-tests are performed to analyze students' responses to the survey. The results show that statistically significant differences exist in four dimensions (reflective, sensing, visual, and verbal) between American and Chinese students. Overall, American students show higher preferences in all four of these dimensions than do Chinese students.**

Keywords: Comparative study; learning styles; American undergraduate engineering students; Chinese undergraduate engineering students

I. INTRODUCTION

Students' learning style preferences are an important factor to consider in designing appropriate pedagogy and course curriculum [1, 2]. A comparative study of learning style preferences among different countries helps provide insights into how diverse cultural backgrounds and experiences affect student learning styles [3]. As online and distance education expands rapidly across national borders to reach a global audience, such a comparative study is particularly meaningful and important [4].

This work-in-progress study is a comparative study of learning style preferences between American and Chinese undergraduate engineering students. The research question is: Are there statistically significant differences in learning style preferences between American and Chinese undergraduate engineering students?

A total of 132 sophomore (second-year) engineering students from two universities in the United States and China participated in this comparative study. The two universities are: Utah State University (USU) in the United States and Beijing Forestry University (BFU) in China. The two institutions share many common features: Both are comprehensive, public, research-intensive, and PhD-granting institutions.

All student participants from the two countries responded to an online, well-adopted Index of Learning Styles (ILS) survey [5]. The survey was particularly developed for engineering students and has a high degree of reliability and validity. The survey is a 44-item, self-scoring questionnaire that assesses learning style preferences on four pairs of dimensions of the Felder-Silverman model. The four pairs of dimensions are: active/reflective, sensing/intuitive, visual/verbal, and sequential /global. Felder and his colleagues [2, 5] have provided a detailed description of each dimension. For example, "active" means that the student retains and understands information best by doing something actively with it: discussing, applying, or explaining it to others. "Reflective" means that the student first thinks about information quietly [2, 5].

In the present study, descriptive statistics and independent sample t-tests are performed to analyze students' responses to each dimension. The dimensions in which statistically significant differences exist between American and Chinese students are identified. Beyond this work-in-progress study, future research will be focused on studying whether or not students' learning style preferences are correlated to their academic performances in the United States and China.

II. STUDENT PARTICIPANTS

The USU student participants (n = 61) were primarily from mechanical and aerospace engineering majors (50.8%) as well as from civil and environmental engineering majors (26.2%). The BFU student participants (n = 71) were all from civil engineering majors.

III. DESCRIPTIVE STATISTICS AND INDEPENDENT SAMPLE T-TESTS

Tables I and II show the results of descriptive statistics and independent sample t-tests for each ILS dimension. Note that the eight dimensions listed in Table I and II are grouped into four pairs (as stated before). If a student shows preference for one dimension in a pair, he or she is excluded from the other dimension in the same pair. For example, in the active/reflective pair, if a student prefers "active" learning, then he or she will not be categorized as a "reflective" learner. Thus, the number of students is different in each dimension, as is shown in Table I.

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TABLE I. DESCRIPTIVE STATISTICS

Learning style dimensions	American students (totally 61)			Chinese students (totally 71)		
	n (%)	Mean	SD	n (%)	Mean	SD
Active	26 (42.6%)	4.46	2.92	39 (54.9%)	3.31	2.66
Reflective	35 (57.4%)	3.80	2.75	32 (45.1%)	1.81	1.89
Sensing	54 (88.5%)	5.63	3.15	57 (80.3%)	3.77	2.85
Intuitive	7 (11.5%)	3.00	2.00	14 (19.7%)	1.71	0.99
Visual	54 (88.5%)	6.37	2.85	54 (76.1%)	4.41	2.65
Verbal	7 (11.5%)	3.57	1.90	17 (23.9%)	1.94	1.43
Sequential	42 (68.9%)	3.85	2.34	39 (54.9%)	3.97	3.21
Global	19 (31.1%)	2.47	1.47	32 (45.1%)	3.38	2.12

TABLE II. INDEPENDENT SAMPLE T-TESTS

Learning style dimensions	t	df	p	ES
Active	1.650	63	0.104	0.20
Reflective	3.469	60.5	**0.001**	0.41
Sensing	3.261	109	**0.001**	0.30
Intuitive	1.605	7.5	0.150	0.51
Visual	3.704	106	**0.000**	0.34
Verbal	2.303	22	**0.031**	0.44
Sequential	-0.189	79	0.851	0.02
Global	-1.632	49	0.109	0.23

The effect size (ES) listed in Table II is calculated as:

$$\text{Effect size} = \sqrt{\frac{t^2}{t^2 + df}} \quad (1)$$

Table II highlights the dimensions in which statistically significant differences ($p < 0.05$) exist between American and Chinese students. These dimensions are:

- Reflective ($t = 3.47$, $p = 0.001$)
- Sensing ($t = 3.26$, $p = 0.001$)
- Visual ($t = 3.70$, $p = 0.000$)
- Verbal ($t = 2.30$, $p = 0.031$)

Positive t-scores mean that the mean score of American students is higher than that of Chinese students. The effect sizes (ES) of these four dimensions are medium:

- Reflective: ES = 0.41
- Sensing: ES = 0.30
- Visual: ES = 0.34
- Verbal: ES = 0.44

Overall, American students show higher preferences in all the above four dimensions than do Chinese students. Take the "visual" learning style preference as a representative example. Figure 1 shows the comparison of histograms for the "visual" learning style preference between American and Chinese students.

In Figure 1, a score of 1-3 indicates well-balanced preference, 5-7 moderate preference, and 9-11 very strong preference. Coincidentally, the same number ($n = 54$) of American and Chinese students preferred "visual" learning. However, as seen clearly in Figure 1, more American students chose higher scores (i.e., stronger preference) for "visual" learning than did Chinese students. The mean score for "visual" learning style preference is 6.37 for American students and 4.41 (i.e., two points lower) for Chinese students.

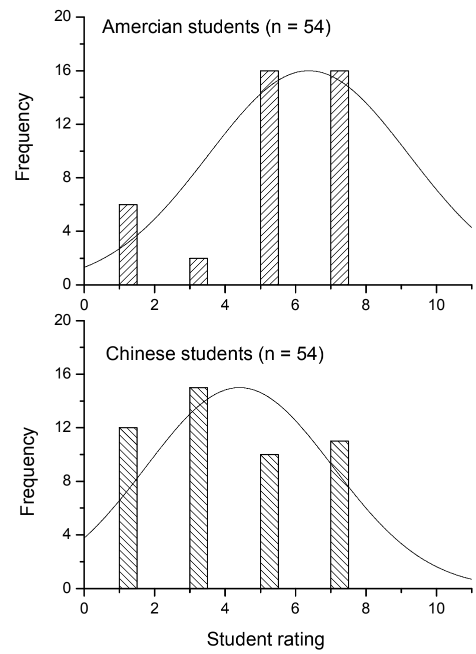

Figure 1. Comparison of histograms for the "visual" learning style preference.

IV. CONCLUSIONS

A total of 132 engineering undergraduates from two comparable American and Chinese universities participated in this work-in-progress study. The students responded to the Index of Learning Styles (ILS) questionnaire. Based on the results of descriptive statistics and independent sample t-tests for each ILS dimension, the answer to the research question is: Statistically significant differences between American and Chinese undergraduate engineering students exist in four learning style preferences. These four styles are: reflective, sensing, visual, and verbal. Medium-sized effects are found in all these four dimensions. Overall, American students show higher preferences in these four dimensions than do Chinese students.

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Development of a Smart Building Wireless Sensors Network: Cooperation between University of Washington Tacoma and Brazilian Universities

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The Institute of Technology at the University of Washington Tacoma - UWT is expanding its international cooperation by hosting Brazilian undergraduate and graduate students in the Computer Engineering and Systems program. In the first research project originated from this cooperation we propose a generic and scalable system, based on Wireless Sensor Networks (WSN). Using the data acquired from the sensor nodes this system will be able to take simple decisions, such as turn on/off heater and lights and help in other more complex decisions, such as rearranging rooms based on the occupancy. These actions aim to save resources and make buildings more comfortable and efficient. In this paper we describe how this research project is being structured and conducted in order to maximize the cooperation between Brazilian and UWT researchers. Also, we show which strategies are being adopted to make the project scalable and generic. This will allow us to aggregate multi-disciplinary people and make the knowledge and technology produced to be reusable by future project members.

Keywords—International Cooperation; Wireless Network; Sensors; ZigBee.

I. Introduction

In the academic year 2012-2013 the Institute of Technology[1] at the University of Washington Tacoma - UWT[2] expanded its international cooperation by hosting Brazilian undergraduate and graduate students in the Computer Engineering and Systems program. It was the first collaborative, multi-disciplinary, sustainable research effort in this program.

In the Fall Quarter 2012 the first four undergraduate students in Computer Engineering arrived at UWT. They are sponsored by the Brazilian exchange student program "Science Without Borders"[3] and are expected to stay for one year at UWT. These students have gone through a rigid selection process that considers among other things knowledge in English language, prior to participation in research projects and good grades. This way, the selected students have high academic performance and are experienced with research projects. Furthermore, the UWT chose students who share common interests with its expertise areas. In this specific case, the area of interest is Wireless Sensors Networks (WSN) due to research interests, previous experience and previous achievements of the Computer Engineering faculty and their Brazilian academic partners.

In the first research project originated from this cooperation, called "Development of a Smart Building Using Wireless Sensors Networks", we propose a generic and scalable system, based on WSN, capable to acquire and analyze data originated from wireless sensor nodes deployed throughout UWT buildings. Brazilian universities are cooperating with the project with professors that work conjointly with UWT team.

The set of variables measured by the sensors include temperature, humidity, luminosity, power consumption, water consumption and occupancy. The acquired information, provided by the sensors, will be useful to help saving resources and make buildings more comfortable and efficient. Furthermore, in the future, the system will be able to take simple decisions, such as turn on/off heater and lights and help in other more complex decisions, such as rearranging rooms

[1] http://www.tacoma.uw.edu/institute-technology

[2] http://www.tacoma.uw.edu

[3] http://www.cienciasemfronteiras.gov.br/web/csf-eng/

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based on the occupancy on each season or other specific period of the year.

The motivation to develop this system is the fact that the UWT buildings are not equipped with any intelligent or software-based tool to manage or control energy resources. In addition, accordingly to the U.S. Department of Energy, the buildings sector consumes 41% of the U.S. primary energy and around 73% of the electricity [1]. These numbers have been motivating many research efforts in order to make buildings more energy efficient. Some of them aim reduce heating, ventilation, and air-conditioning (HVAC) loads [2],[3]. Others, aim to optimize computer's [4],[5] and lightning [6] energy consumption, which are also responsible for a significant amount of energy utilization.

This project involves students and faculty with different skills and from different countries (Brazil and India). Also some members, especially the Brazilian students, usually have limited time staying in United States. So, the turnover of project members is the first challenge. Other challenge is develop a system that allows the addition of new sensors nodes in the future, which requires a generic and therefore scalable WSN platform.

In this paper we describe how this research project is being structured and conducted in order to maximize the cooperation between Brazilian and UWT researchers. Also, we show which strategies are being adopted to make the project scalable and generic. This will allow us to aggregate multi-disciplinary people, add new sensors and make the knowledge and technology produced to be reusable by future project members.

II. System Architecture

The system architecture is critical to the project development. A clear definition of all modules of the system is useful to organize the development team and assign tasks for each project member. Also, to preserve the scalability, this modular architecture is being planned in a way that allows new sensors and functionalities to be added without major changes in the core system. Figure 1 presents an overview of the architecture of the system.

So far, the system has three kinds of sensor boards: Power Meter Sensor Board (PMSB), Generic Wireless Sensor Board (GWSB) and Occupancy Sensor Board (OSB). All these boards will be deployed in rooms at UWT buildings and send data continuously to the Intermediary Station (IS) using ZigBee protocol[4]. The "IS" is responsible for aggregating the data received from all sensor boards installed in the rooms on each floor of a building, store this data temporarily and then send to a server using WiFi protocol.

The server is the base station of the system. It will store all data acquired in the sensor boards, provide a Graphic User Interface (GUI) with web real time access to the data being collected and other functionalities, such as, analysis of the data stored in the database, control of the room's lights and heater/air conditioner, etc.

[4] http://www.zigbee.org

The PMSB and OSB are sensor boards built specifically to measure only one variable each, respectively, power consumption and occupancy in a room. We chose to build them separately as a dedicated board because they are digital sensors and require a lot of specific signal processing techniques.

On the other hand, the GWSB is a sensor board with ten analog channels available. So, it is able to read samples from up to ten different analog sensors simultaneously with customizable sample rates.

In the preliminary tests being conducted, we plugged in the system five different sensors to measure the following variables: temperature, humidity, luminosity, room occupancy and power consumption. The first three variables are measured using three analog sensors plugged in the GWSB. The other two have their own specific sensor board as mentioned before. In the future, many other sensors can be added to the GWSB, such as water flow sensors.

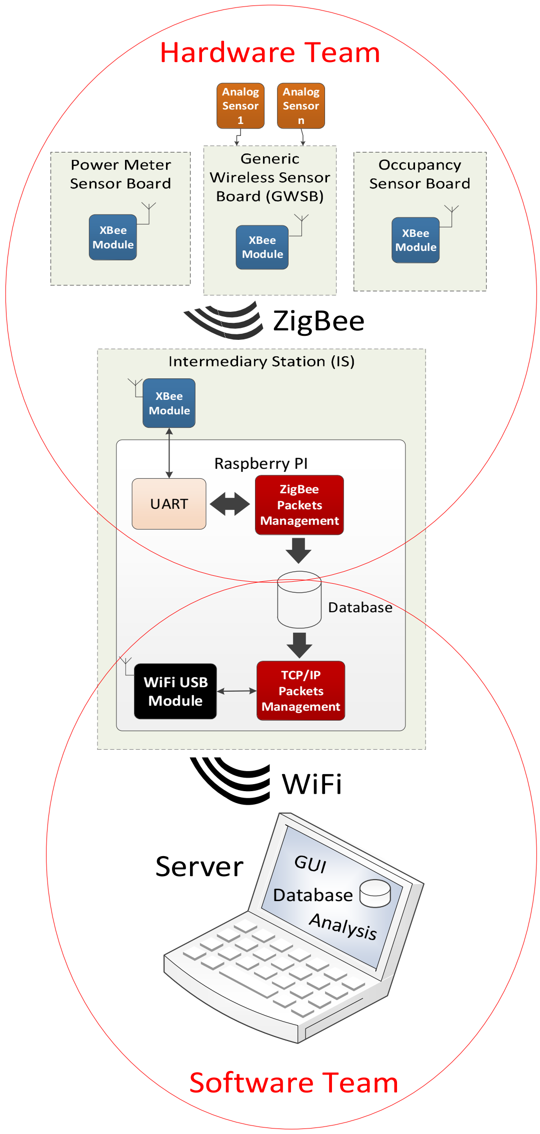

Figure 1 - System's Architecture Overview

III. TEAM ORGANIZATION

The work group currently has 4 professors and more than 12 undergraduate and graduate students. To make easier the project management of all the staff and divide tasks between the members, two main strategies are being used: the division of the team into smaller groups that meet weekly and the participation of the entire group in meetings that happen twice a month.

As highlighted in Figure 1, by the red ellipses, the development team was divided in two groups, the "Hardware Team" and "Software Team". The Hardware team is responsible for developing the embedded systems side of the system while the Software Team is in charge of the web server that will provide a user interface and the system intelligence. Each team works independently; only the system architecture and the interface between the server and the embedded systems are discussed together. Although there isn't a strict hierarchy between the members in each team, members naturally assign the status of leader to a person, usually the most technically experienced and with better communication skills. This makes easier and faster to take decisions when group members have different opinions.

There is one student responsible for supporting both groups, secure the resources (software, hardware parts, services, room reservations, meetings appointments among others project management issues) necessary for a proper project development.

Twice monthly there is a meeting with all members of the WSN Group. In this meeting critical technical aspects of the system are discussed. Also, the work carried out since the last meeting is presented to all the team. We also use these meetings to present short workshops about the technical concepts and technologies employed in the project. Such periodic meetings force the students to be more organized and active, since they should present its technical and practical advances regularly to its advisors.

Some members of the WSN Group are students from other countries, primarily Brazilians (that usually do not work more than a year on the project). So, the turnover of team members is a challenge. To minimize this problem, new students, both from UWT as from Brazilian universities, are continually invited to join the group. Workshops are organized by the most experienced members to perpetuate the knowledge and progress done in the past for the new members.

IV. COOPERATION WITH BRAZILIAN UNIVERSITIES AND FUTURE PROSPECTS

Through this project the Institute of Technology at UWT is expanding its partnerships with Brazilian Universities. It is the first collaborative, multi-disciplinary, sustainable research effort in the Computer Engineering and Systems program at the Institute of Technology, University of Washington Tacoma [7]. The goal of the UWT team is to extend the project described in this paper to all UWT installations in the next years.

Brazilian students were recruited through established, strong faculty connections and Memoranda of Understanding for long-term collaboration between UWT and some renowned institutions as the Institute for Advanced Studies in Communications (IECOM) [5], the Federal University of Campina Grande (UFCG) [6], the Department of Computer Engineering of the Federal University of the Vale do São Francisco (UNIVASF) [7] and the Department of Electrical Engineering of the Federal University of Paraíba (UFPB) [8]. When returning to Brazil after the academic year at UWT, Brazilian students should replicate the project with its faculty and try to deploy it in its native universities.

UWT is currently signing cooperation agreements with more Brazilian institutions, in order to promote the exchange of students and faculty with and other engineering schools.

In early 2013 the UWT hosted a master's student in Electrical Engineering from the University of Campinas – UNICAMP[9] (one of the most important universities in Brazil). This student, founded by a private bank, worked within the WSN Group developing the power meter used in the system. The expertise of this student in the embedded systems development was crucial for the team. It is expected the arrival of a PhD student from UNICAMP in the second half of 2013 to collaborate with the WSN research group at UWT.

In summary, we have described the partnership between UWT and Brazilian universities. Wireless Network and Energy Efficiency were identified as common interest areas between the institutions currently involved, so future projects in these areas should be expected in a near future.

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Using Computerized Lexical Analysis of Student Writing to Support Just-in-Time Teaching in Large Enrollment STEM Courses

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***Abstract*— We have been exploring a variety of computerized techniques for analyzing student writing in introductory biology. We achieve computer-to-expert inter-rater reliability (IRR) on par with expert-to-expert IRR (> .8). In Fall, 2012, we piloted the use of automated text analysis to facilitate the use of written formative assessment for Just-in-Time Teaching (JiTT) in a large-enrollment introductory biology course at a large public Midwestern university. A total of 12,677 student responses to 15 online homework questions were collected in three 300+ student course sections with four instructors. We used automated analysis to create feedback for instructors before the next class period (less than one working day), so that instructions could use this feedback to inform their instruction. Instructors used many of the questions pre- and post-instruction and the reports we provided to them allowed them to see how their students' answers changed as a result of their instruction. Focus groups with the instructors revealed that they already knew some of the topics that challenged students, as revealed in previous semesters with multiple-choice examinations. However, the instructors pointed out that the written assessments were particularly important for gaining insight as to <u>why</u> students have struggled continuously with these ideas.**

Keywords—large-enrollment introductory courses; constructed responses; lexical analysis; Just-in-Time Teaching (JiTT)

I. Introduction

Developing rich, reliable, and robust measures of the composition, structure, and stability of student thinking about core scientific ideas (such as natural selection, conservation of mass and energy, and genetics) is a challenge that may be too complex to accomplish via multiple-choice assessments such as concept inventories (CIs). For example, as Nehm & Schonfeld demonstrate, the multiple-choice Concept Inventory of Natural Selection measures whether students understand "pieces" or elements of the theory of natural selection, but does not provide any measure of students' abilities to assemble the pieces into a coherent and functional explanatory structure [1; 2]. Moreover, multiple-choice CIs introduce significant validity threats as they are constrained to "either-or" forced-choice ("misconception" vs. scientific key concept) item preference and do not typically allow the detection of students who harbor "mixed models" of correct and incorrect conceptions [1; 3; 4; 5; 6; 7; 8].

Multiple-choice assessments also require different cognitive processes (recognition, selection) than constructed response (CR) assessments in which students must represent their ideas in writing or by creating other models. CR assessments are widely viewed as providing greater insight into student thinking than closed form (e.g., multiple-choice) assessments [9] which encourage students to study by memorizing, rather than learning critical thinking and analytic skills that are crucial for success in all STEM disciplines [10].

Thus, CR assessments that capture students' explanatory models are needed to mitigate these constraints and reveal students' mixed models. In the past, financial and time constraints made CR assessments significantly more challenging to execute in large-enrollment courses than multiple-choice assessments. But today, advances in both technology and measurement research make it feasible to apply these techniques in instructional settings with the potential to have substantial educational impact [11].

In the Automated Analysis of Constructed Response (AACR) research group (www.msu.edu/~aacr) we employ cutting-edge, lexical and computer analysis technology to analyze student writing in biology and chemistry. We have been able to create statistical models of student writing that predict expert human raters' scoring with computer-to-expert inter-rater reliability (IRR) that is similar to expert-to-expert IRR (generally, > .8) [8; 12; 13; 14; 15].

In this paper, we report on our initial efforts to move these techniques from research-to-practice in a pilot study in which we investigate applying our models to support Just-in-Time Teaching (JiTT) [(JiTT) 16] by providing instructors formative feedback about students' writing through an automated

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analysis and reporting system which allows faculty to receive rapid feedback on students' writing to use in class the next day. We also describe some of the lessons learned and future directions for building on this model.

II. Methodological Details of the AACR Approach

In this section, we provide an overview of our approach to developing, validating and implementing AACR assessments as background for the work we will do in the proposed project. The entire process is captured by the Question Development Cycle (QDC) shown in Figure 1. In general, we use linguistic feature-based methods [17] to extract linguistic features from students' writing [e.g., WordNet, see 18; 19] and then use those linguistic features as variables in statistical models that predict human raters' scores of the student's writing.

A. Developing AACR Questions to Assess Core Disciplinary Concepts

In the first stage of the QDC, we *Design New Questions* to measure student thinking about important disciplinary constructs. Generally, we use concept inventories as the basis for the questions because they represent the topics that disciplinary researchers have identified as being particularly challenging for students. *Data Collection* is typically done by administering the questions via on-line course management systems into which students can enter their responses. *Lexical Resource Development* is done using lexical analysis software to extract key terms and scientific concepts from the students' writing. These terms and concepts are used as variables for *Exploratory Analysis* which aid in *Rubric Development*. We use the rubrics, both analytic and holistic, for *Human Coding* of student responses. During *Confirmatory Analysis* the *Lexical Resources* are used as dependent variables in statistical classification techniques to predict expert human coding of student responses. The entire process is iterative with feedback from the various stages informing the refinement of other components. The final product of the QDC is a *Predictive Model* that can be used to completely automate the scoring of a new set of student responses, predicting how experts would score the responses.

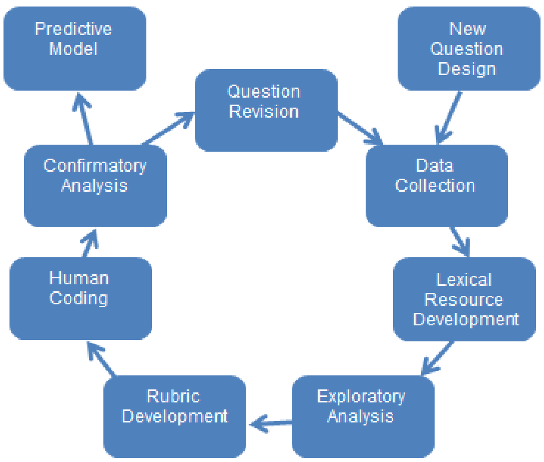

Figure 1: Question Development Cycle (QDC)

An example of an introductory biology question for which we have completed the QDC is: **Jared, the "Subway" guy, lost over 200 pounds on his diet. Where did his mass go?** This question is designed to reveal students' ability to reason about pathways and transformations of energy and matter, one of five core biology concepts [20] for which we are developing AACR assessments [21; 22]. In the following sections we elaborate on the lexical resource development and exploratory analysis phases of the QDC for the Jared problem. We first outline the process for validating the assessment and then we show how instructors can implement the AACR questions in the classroom.

B. Validating AACR Assessments through Lexical and Confirmatory Analysis

We use IBM SPSS Modeler [23] to perform the lexical and statistical analyses. Modeler provides data mining tools that can be used to build Modeler streams (Figure 2a) to automate analyses by assembling nodes that perform various tasks, such as accessing and merging data files, data conversions, lexical analysis, statistical analysis, machine learning, and reporting. Following the order of the nodes in Figure 2a, for example, we collect student responses (from on-line homework) to the AACR question to be analyzed, in this case the question about Jared's weight-loss. The responses are processed by the text analysis node.

Figure 2b shows some details of the text analysis node. The software extracts terms -- words and phrases in the students' responses that are relevant to the question (colored text Figure 2b, middle panel). These terms are stored in libraries (similar to dictionaries) that come with the software or were created by the researchers. Extracted terms that represent homogeneous disciplinary concepts are grouped into categories (Figure 2b, left panel), using both automated procedures and refinement by content experts. For example, the category glucose/glycogen in Figure 2b includes a number of terms (e.g., glucose, glycogen, sugar, and sugar molecules) that represent molecules that are metabolized to release carbon dioxide. Each student response is classified into one or more categories based on the terms used in that response (Figure 2b, right panel).

Continuing along the stream (Figure 2a), the text analysis categories are used as independent variables in statistical analysis or machine learning nodes. In the exploratory phase, as demonstrated in this example, we use cluster analyses to group responses that have the most similar sets of categories (Figure 3 shows example cluster results). These clusters help researchers refine the rubrics that are used for human scoring to build confirmatory models (e.g., discriminant analysis and machine learning techniques) that predict human scoring with computer-to-expert inter-rater reliability (IRR) as good as expert-to-expert IRR [8; 12; 15]. The final nodes of the stream select examples of student work most representative of the cluster, (i.e. closest to the cluster centroid). This information was used to build Just-in-Time-Teaching reports.

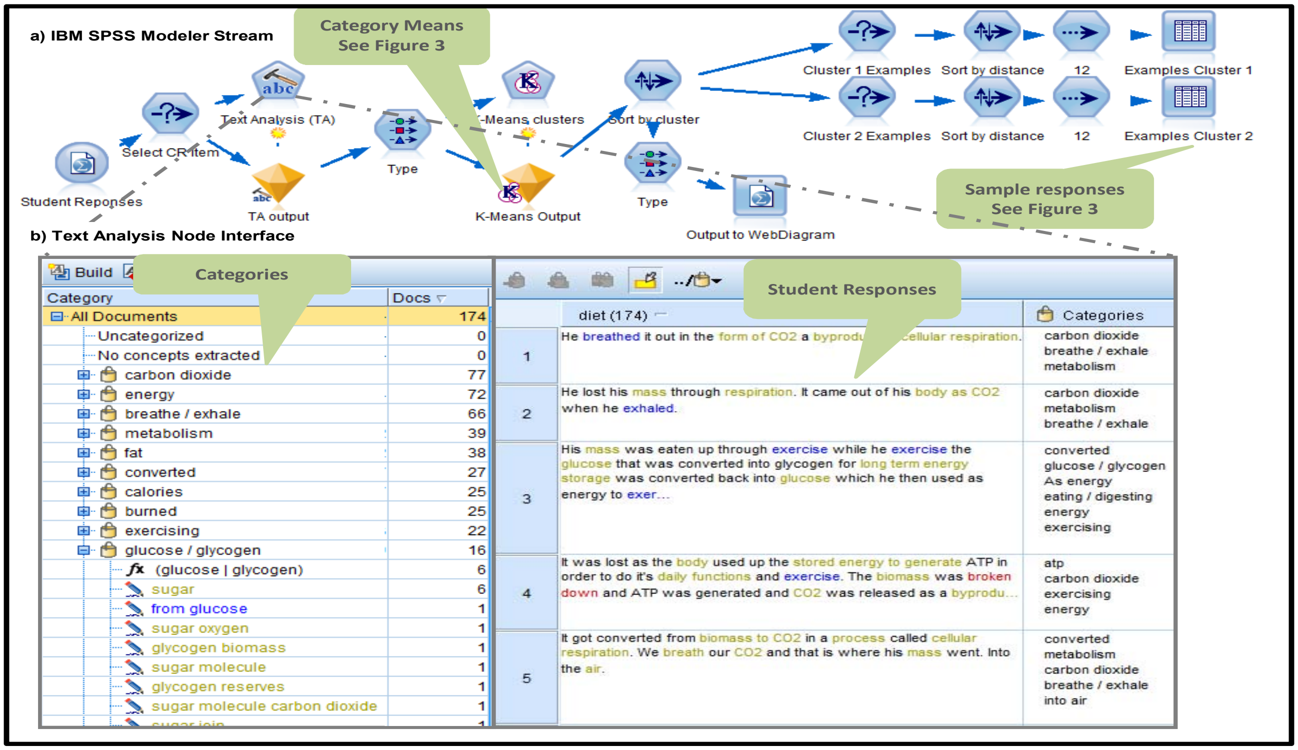

Figure 2: IBM-SPSS Modeler showing a Report Analysis Stream (a) and Text Analysis Node (b) for the assessment question: *Jared, the "Subway" guy, lost over 200 pounds on his diet. Where did his mass go?*

III. Implementing AACR Questions for Just-in-Time Teaching

To test the feasibility of accelerating the QDC (Figure 1) and rapidly making the research results available to faculty in near real time, we conducted a JiTT pilot study during fall, 2012, in three sections (N=309; N=302; N=455) of an introductory cells and molecules biology course for science majors at MSU [24]. We administered 15 different homework questions in four subject areas: biomolecules, genetics, metabolism, and thermodynamics using the university's Learning Management System (LMS). Questions were asked pre-instruction, so that the responses could be analyzed and a report returned to the instructors to allow them to address misconceptions during the next class period. Some questions were also asked post-instruction, which allowed instructors to see how students' explanations had changed. We collected 12,677 student responses and used previously created SPSS Modeler streams (Figure 2) to generate the JiTT reports. For each question we closed data collection at midnight. We began analysis and report preparation the following morning and completed and emailed reports to instructors in the afternoon for use during the next class period.

Some features from a report for the Jared question are presented in Figure 3. Reports included the question asked, the category means within each cluster (the percentage of responses classified in this category within a given cluster), cluster descriptions, example student responses that were most representative (defined by the statistical distance from their cluster centroids) and a web diagram showing the relationships

QUESTION: Jared, the "Subway" guy, lost over 200 pounds on his diet. Where did his mass go?			
Cluster 1		Cluster 2	
Mean	Category	Mean	Category
0.65	carbon dioxide	0.98	energy
0.61	breathe/exhale	0.40	converted
0.23	metabolism	0.35	fat
0.05	converted	0.13	calories
0.04	energy	0.13	glucose/glycogen
0.04	fat	0.06	sweat
0.02	glucose/glycogen	0.04	metabolism
0.01	sweat	0.00	breathe/exhale
Cluster Descriptions			
Cluster 1 responses state the mass was lost as carbon dioxide and expelled through exhalation, breathing or respiration.		Cluster 2 responses describe the fat as being converted into energy and possibly being used or released.	
Cluster 1 Examples		Cluster 2 Examples	
His mass was lost through breathing out carbon dioxide.		His mass was lost as energy exerted.	
He breathed it out in the form of carbon dioxide.		It was let out into the atmosphere as energy.	

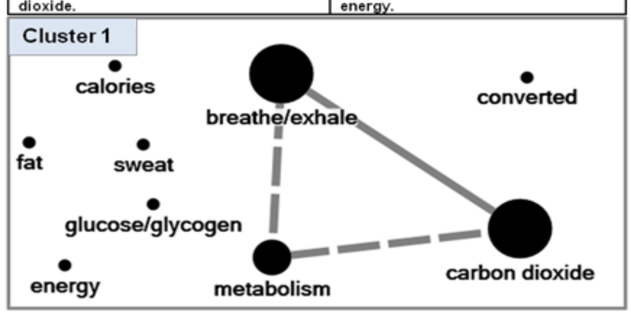

Figure 3: Subset of Pilot Study JiTT Faculty Feedback Report Features **Legend**: Circle size corresponds to the frequency of responses containing a category. Lines indicate the percentage of shared responses. Solid lines indicate >50% shared responses.Dashed lines indicate 25-50% shared responses. Nodes < 25% shared responses were not linked.

among categories in students' answers. For most questions, responses were classified into 3-5 distinct clusters. The most important categories in the predictive model (as indicated by cluster analysis results) were included in the report, along with the frequencies distributions of categories in each cluster.

For the analysis of the Jared question (Figure 3), we see that students in Cluster 1 write about Jared's mass being converted to carbon dioxide and expelled from the body. Student answers in this cluster had high means (frequencies) for carbon dioxide (65% of the responses in Cluster 1) and breathe/exhale (61% of the responses in Cluster 1) categories. The web diagram shows that responses in Cluster 1 have strong associations (solid line) between these two categories, as shown in the Cluster 1 example student responses, meaning that students in Cluster 1 tend to write about these ideas together. Cluster 2, however, had high means for the categories energy, converted, and fat. These students wrote that Jared's mass was converted into energy, revealing a common misconception for introductory biology students [21] as shown in the Cluster 2 example student answers.

IV. Pilot Study: Instructor Use of the Reports

We used the results of lexical and cluster analyses to generate rapid feedback reports for faculty to use for JiTT. Typically, data collection on the online management system closed at midnight. Analysis and report preparation began the following morning and were completed and emailed to faculty that afternoon for use during the next class period (usually one to three days away). Instructors then used these reports in a variety of ways in their instruction.

A. Faculty focus groups

We held four 1- 2 hour focus groups with the four participating faculty during which we discussed their participation in this pilot study. The early-semester focus group introduced faculty to the constructed response assessments, text analysis and the utility of the report. We also interviewed faculty about what aspects of the report they would find useful in their classrooms. We met with faculty mid-semester to identify difficulties that they had encountered using the report, allowing us to address those issues. During both the mid-semester and end-of-semester focus groups, faculty described how the report informed their awareness of students' thinking, including prior knowledge, misconceptions, and gaps in their knowledge. Faculty also discussed how they had used the information provided in the feedback report to modify their instruction. Based on these focus group discussions, we describe faculty instruction based on the analysis and report of student writing in the following section.

B. Faculty interventions and instruction in response to JiTT feedback

Faculty instructors were interested in determining students' prior knowledge about several topics prior to instruction, and identifying student misconceptions or ideas that were challenging to students. After reading the report, the instructors provided students feedback in several different ways. Some instructors created instructional materials, such as a sequence of clicker questions to address these challenges. For example, one instructor created clicker questions to use over multiple class sessions to emphasize the concept that energy is required to break bonds, and how reactions are coupled within biological systems to create a favorable reaction. This coupling is often implicit or overlooked in biology instruction at the introductory level, leaving students with the idea that breaking phosphate bonds in ATP is solely responsible for the energy released during metabolic processes. This faculty member used student sample responses from, or responses similar to those in, the feedback reports as multiple-choice options for the clicker questions. This exercise was designed to help student identify responses options that expressed ideas similar to their own homework responses. Students had the opportunity to discuss their options in groups with their classmates and then groups shared their response with the entire class, which allows them to express their ideas and get feedback from both the instructor and their peers.

Before assigning CR questions, instructors were already familiar with some of the ideas that challenged students as they had encountered these problems in previous semesters with multiple-choice examinations. However, the instructors pointed out that the written assessments were particularly important for gaining insight as to why students have struggled continuously with these ideas. One instructor was aware of students' confusion about central dogma of molecular biology concepts ("DNA makes RNA makes protein"), but was finally able to identify that students had not grasped that transcription and translation were different processes using the responses to the CR questions.

Faculty also used materials that were already prepared to address misconceptions such as the conversion of matter to energy in metabolic reactions. Our questions on metabolism were developed from multiple choice items from a diagnostic question cluster (DQC) 8, 9. Pre-existing clicker questions, created in response to the DQC project, were used by some instructors to revisit misconceptions about photosynthesis and conservation of matter during respiration.

Often with pre-instruction administration of the CR questions, a large fraction of the class was unable to give a correct or relevant response. In some instances the items reviewed material covered in the prerequisite chemistry course (e.g. exergonic reactions). Few introductory science courses have writing practice, and this may be the first attempt for many students to construct a representation of their understanding. Therefore, more opportunities to practice writing may be needed, which could be facilitated by automated analysis. Faculty also proposed future in-class activities to improve student writing skills, including critiques of poorly- and well-written responses gathered from CR questions and opportunities to write in class and turn in work for credit (e.g. minute papers).

C. Encouraging student participation

Each of the three course sections used a different type of incentive to encourage participation. We found that the two sections which gave regular homework credit had better participation (53-83%) than the section which gave extra-credit points (22-46% participation). Additionally, in the section with low participation, there were significant differences in the GPA and course grade of students who participated in homework assignments for extra credit and those who did not (Mann Whitney U –test; $p< 0.005$). In the low-participation section, students who answered CR questions on average entered the course with a higher GPA (2.56±1.37) and obtained a higher grade at the end of the course (2.62±1.06) compared to students who did not participate in the CR online homework (average GPA at start 2.49±1.15; average grade in course 2.00±1.31). This suggests that students who perform more poorly do not often take the opportunity to complete extra credit work and do not get the benefit of the additional practice. Therefore, we suggest instructors using these homework assignments should make them a required part of the regular coursework.

D. Scheduling

Automated analysis and the generation of reports within a few hours allows faculty to have data about their students' learning immediately available to them. Generally the online homework assignments were due around midnight, analysis began at 9am and reports were ready for faculty before the end of the work day for use in class the next day. The faculty reported that they needed more time than the overnight period to digest the contents of the report and modify their lesson plan. Often this was because faculty had prepared their instructional material days or weeks in advance.

We can address this in three ways

1) The homework assignments could be given earlier: one week or more in advance, especially in the case of pre-instruction assessments. This would give the faculty sufficient time to modify their lesson plans. This approach is less efficient for post-instruction assessments where immediate feedback to students during the next class meeting would be ideal.

2) During the pilot, we usually gave sets of two to six questions for each online homework assignment. Alternatively, faculty could assign just one question that targets a particular misconception. Faculty could modify their lesson plan to address this one misconception, and have material prepared beforehand in the event that there is a considerable fraction of students whose responses suggest that they hold this misconception.

3) A third option would be to design instructional material and provide support to inform faculty instruction based on the results of the constructed response assessments in their classroom. Plans for faculty professional development are discussed in more detail in the following section.

V. Professional Development for faculty using CR questions and JiTT reports

Faculty were very enthusiastic about using the CR online homework assessments to get students writing and the JiTT reports as a means of evaluating student writing. Because of the quick turnaround time between administering questions, generating the report and having the next class meeting the following day, faculty requested assistance in modifying their instruction to address areas of difficulty for students as identified in the report. Having a suite of materials that would address misconceptions identified by each question would reduce the prep-time required, which is especially important for faculty to make use of the JiTT feedback.

Therefore we are developing materials to accompany questions, so that faculty will have those available when planning their instruction. We are building a community of science education researchers and instructors who will design and test these materials, and make them available for widespread use. These faculty will be part of an online community interested in using constructed response assessments in their classrooms. Faculty will also be able to share resources they have created for their own classroom, such as those developed by faculty who participated in our pilot study. The web portal that will host these online activities is described in the Future Directions section below.

Additionally, we held two meetings with faculty early in the semester to get them familiar with the reports. We will continue to provide this support to faculty, especially as they first begin to use the assessments and instructional material. Faculty who receive support are more likely to continue with the use of innovative research-based instructional materials [25]. Support in implementing a new practice also helps faculty adopt the practice as intended [26].

VI. Future Directions

We are currently investigating the feasibility of developing an automated web-portal, where faculty could upload their own students' responses and receive a feedback report similar to what we have described in this paper. We envision this portal as place where CR questions with developed analytic resources are available for faculty to download and use in their own courses or learning-management systems. An faculty instructor could upload student responses in electronic form and, in a matter of moments, be presented with a feedback report. These reports could contain various levels of detail about the entire class performance or individual students based on the interest of the faculty. Critical to this web-portal idea is the development of a completely automated analysis procedure, which is hidden behind the user interface. A key step in moving in this direction is the validation of clusters/models by both additional student responses, as well as discipline experts. In addition to the CR questions and generated reports, we envision faculty contributing their own experiences or classroom materials in order to address the student difficulties highlighted via the feedback reports. In this way, the portal will facilitate the building of a community of practice: faculty interested in improving their own teaching along with researchers investigating students' learning of science.

Another feature we are considering for the future is how to best return direct feedback to students. Students have expressed interest in learning whether their submitted response was "correct" or "incorrect", in order to gauge their own learning. Although we do not advocate using automated analysis to assign points or "correctness" to individual responses, we may be able to provide students with formative feedback in one of two forms. We may provide a direct report to students that include which concepts they used in their explanation, which cluster their response was placed in or which other responses were most similar to their own, along with information about an "expert" or target answer. Alternatively, each response is assigned a probability of being grouped into a particular cluster, and we can use this information to guide student feedback. In the case of responses with high probabilities of being grouped into a cluster, we may report directly to students the clusters into which their responses fell. In the case of responses with low probabilities, we can recommend that an instructor review these responses before the results are reported to students. This will greatly reduce the number of responses that an instructor will have to read while still providing direct feedback to students. Providing feedback to students may be a key factor in keeping participation rates for the online homework high throughout the semester.

In addition to building an automated analysis web-portal, we want to continue to explore research questions that deal with teaching and learning. We have an assessment structure in place to capture student ideas both before and after instruction. In this way, we can measure change in student ideas and ask questions about whether completing the homework or a particular classroom intervention had an effect on student knowledge. We are also interested in exploring which student difficulties are the most resistant to change. Can we identify common "conceptual-paths" students take as they develop from naive ideas or misconceptions to more sophisticated ideas or scientific ideas? In addition to the change in student thinking, we would like to continue studying what faculty are doing in the classroom. Specifically, what exactly are faculty changing in their instruction, if anything, due to information about their students' responses contained in the feedback report? Does addressing these problems in class or via additional assignments make a difference in student learning? What methods are most effective for addressing these problems? What parts of the feedback report are most meaningful in determining whether to and how to change instruction? We see these as important questions in making progress towards rigorous, reformed science teaching that promote the best outcome for students.

VII. CONCLUSION

Writing is both an important form of communication and a critical part of the thinking process. Through writing learners organize and refine their ideas. Therefore, instructors can use writing as a tool to encourage students to think deeply about engineering [27]. Brent and Felder described how engineering writing assignments can be used to help students develop skills such as critical thinking and creativity, which are desired outcomes for all engineering students [28]. Written assessment also to allow instructors to observe how students work through the assignment [9; 29]. Despite all these affordances, writing assignments are often restricted to upper-level and graduate courses [30; 31; 32; 33]. Automated analysis can facilitate the use of writing in larger first-year courses and allow engineering students to practice writing at an early stage

If we are to heed the call for promoting higher order student thinking and providing more opportunities for students to write, while at the same time containing costs, we must find ways to leverage technology in the service of supporting and evaluating constructed response assessments. The approaches outlined in this paper demonstrate the feasibility of using off-the-shelf analytic software to allow instructors to include written assessments as a regular form of assessment, even in 400 person classrooms, and students can get practice representing their thinking in their own words. Furthermore, this innovation is highly applicable to other large-scale teaching environments such as the rapidly developing massive open online courses (MOOCs).

The text analysis resources (libraries and categories) used to conduct this study and other analyses of student writing in science can be freely downloaded (with a registered account) on our AACR group website (www.msu.edu/~aacr).

ACKNOWLEDGMENT

We would like to thank the four instructors who participated in the study and the students in their classes who completed these assignments.

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A Comprehensive ABET-focused Assessment Plan Designed to Involve All Program Faculty

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Abstract — **In this paper, we present a comprehensive and innovative assessment plan and continuous improvement process used by one of the newest engineering programs in the United States. The program was developed from the ground up to have a strong culture of assessment in preparation for ABET. In developing the assessment plan and continuous improvement process, one design requirement was that the assessment plan involve all faculty in the program in order to establish a strong assessment culture. The assessment plan includes both direct and indirect assessment measures, as well as quantitative and qualitative evaluations of student outcome attainments. The assessment plan targets not only program-level continuous improvement, but also course-level continuous improvement. Course-level continuous improvement involves *Course Evaluations* and *Course Assessment and Continuous Improvement (CACI) Reports*, which are prepared by the faculty and serve to document direct assessments of course outcomes and student outcomes. Program-level continuous improvement involves evaluation of the collection of CACI Reports that feed into the *Student Outcome Summary Reports (SOSR)*, which are annually prepared by the Assessment Committee members. Methods developed as part of our assessment plan are generalizable and included in the paper.**

Keywords- ABET; Assessment; Continuous Improvement; Student Outcomes, Program Educational Objectives, Engineering

I. INTRODUCTION

"Accreditation may be defined as a process, based on professional judgment, for evaluating whether or not an educational institution or program meets specified standards of educational quality" [1]. Continuous improvement is an important concept in education because it defines the framework for assessment and evaluation, which is required by accrediting agencies. There is one fundamental question driving the continuous improvement process. Can the program demonstrate the degree to which students have attained the anticipated student outcomes or program outcomes? The assessment evidence of student learning is used to identify student strengths and weaknesses related to each of the student outcomes for the purpose of making decisions about how to improve the program teaching/learning processes. Assessment processes that focus on the continuous improvement of the program produce results that can be systematically used by faculty and administration in meaningful ways. Although there are several challenges to developing an assessment plan and a continuous improvement process, one major challenge is for the assessment plan and continuous improvement process to be owned by the entire faculty body and not just a select few faculty who lead the assessment efforts [2]. Certain engineering programs and departments have implemented approaches to streamline the assessment process so that faculty are involved without a burdensome effect on their time [3-5]. One of the underlying factors in the development of a sustainable assessment plan is active engagement of faculty in the steps of the process so that this sense of ownership is fostered. Faculty engagement often occurs at the course-level using course assessment reports [5-7]. Some programs have also developed online tools and automated processes to carry out this reporting [8-10]. Another important aspect of a sustainable assessment plan is the establishment of a reasonable data collection and analysis schedule. The assessment plan and continuous improvement process developed in the new Department of Engineering at James Madison University (JMU) reflects best practices and is created to promote a culture of assessment.

II. JAMES MADISON UNIVERSITY ASSESSMENT CULTURE

James Madison University is an institution with a strong assessment culture, and the Engineering program was founded with clear goals and objectives and a commitment to ongoing assessment. The University's Center for Assessment and Research Studies (CARS), a nationally renowned program that offers the only Ph.D. in assessment and measurement, supports the design, administration, and analysis of assessment instruments administered at each stage. CARS staff members work with each program to design and develop assessment processes and instruments in every academic major. JMU uses many diverse strategies and assessment prompts including locally developed, regional, and national comprehensive exams; on-line information-literacy/library skills assessments; portfolio assessment; performance assessments; essay/term paper review; oral comprehensive exams; external on-site supervisor ratings; exit interviews, surveys and focus groups. Annually scheduled Assessment Days (one preceding the fall semester and one during the spring semester) at JMU establish the importance of assessment as central to academic and student development. On the annual Spring Assessment Day each February, the University (through CARS) collects general educational and developmental information from sophomores and juniors who have completed 45 to 70 credit

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hours. This day also provides an opportunity for programs to assess their students. Some academic programs use the February Assessment Day to administer assessment tests or surveys; others embed assessment activities within department courses. The Engineering Program uses both approaches. On an annual basis, the Engineering Assessment Committee prepares an Assessment Progress Template (APT) report that is submitted to CARS for rigorous evaluation and feedback. Further, the University conducts reviews of all academic programs on a five-year cycle, and evaluating progress in assessment is a key part of these comprehensive reviews.

III. CONSTITUENTS & THE CONTINUOUS IMPROVEMENT PROCESS IN THE JMU ENGINEERING PROGRAM

From day one of the Engineering program, which welcome the inaugural class of students in August 2008, assessment was integral to the program development and a key facet to curriculum and programmatic development and continuous improvement efforts. We started by identifying all the constituencies of the JMU Engineering program:

- *Industry and Employers of Program Graduates* – Our graduates must be able to make significant and sustained contributions to the success of their employers.
- *Advisory Council* – The JMU STEM Executive Advisory Council (EAC) serves as an external constituency of the Engineering program. The members of the EAC are representatives from industry and academia, and are leaders in their respective fields.
- *Alumni of the Engineering Program* – Our graduates must be prepared with the knowledge and skills for successful engineering careers or advanced studies.
- *Current Students of the Engineering Program* – Our program must provide an environment which fosters the success and accomplishment of our current students.
- *Program Faculty* - Our faculty play a critical role in identifying the needs of students as well as employers and building those capabilities into the program. The department faculty bridge and integrate all constituencies to assure the program accomplishes results.

Per the program assessment and evaluation plan, Table 1 summarizes how input is gathered from each of these constituencies. In its assessment activities, Figure 1 represents the Engineering program's continuous improvement loop, which is a six-step iterative process involving both internal constituents (i.e. faculty and current students) and external constituents (i.e. alumni, employers, industry, and ABET). The first three steps of the process involve defining and refining the Program Educational Objectives (PEOs), Student Outcomes (SOs), and Performance Indicators (PIs). Performance Indicators are measurable learning outcomes and concrete actions students should be able to perform as a result of participation in the program. These three steps are the foundation of the assessment process and ever since the establishment of the Engineering Program we have iterated and refined the PEOs, SOs, and PIs. The ABET and Assessment Committees are the two faculty groups that oversee these initial steps of the continuous improvement process, but all constituents have a role in these three steps. The fourth step in the process is defining and refining the assessment metrics for the PEOs, SOs, and PIs and as a program we have focused on both direct and indirect assessment methods to evaluate attainment of PEOs, SOs, and PIs. The Assessment Committee is the faculty group that oversees this fourth step of the continuous improvement loop, but all constituents also have a role in this step. The fifth step in the process is collecting, analyzing, and assessing data to evaluate attainment of PEOs, SOs, and PIs. Once again, the Assessment Committee is the faculty group that oversees this step of the continuous improvement loop, but all constituents have a role. The last step in the continuous improvement loop is deciding on actions, implementing the actions, and reassessing. All the engineering faculty are integral to this step given that at all levels (project, course, and program), the faculty are the ones driving the continuous improvement efforts, deciding on the actions.

TABLE I. MAPPING OF CONSTITUENTS WITH ASSESSMENT METHODS

Constituents	Assessment Methods for PEOs	Assessment Methods for SOs
Industry and Employers of Program Graduates	• Employer Survey (every two years) • Employer Interviews (as needed)	• Employer Survey (every two years, indirect)
Advisory Council	• Periodic review of PEOs • Review of placement data and overarching assessment results (annually)	• Review of overarching assessment results (annually)
Alumni	• Placement Data (annually) • Alumni Survey (every two years)	• Alumni Survey (every two years, indirect)
Current Students	• Senior Exit Survey (annually, indirect)	• Course Evaluations (every semester, indirect) • FE Exam Results (annually) • Engineering Science Concept Inventories (annually) • Capstone Project Assessment Survey (annually, indirect) • Senior Exit Surveys and Interviews/Focus Groups (annually)
Program Faculty	• Periodic review of PEOs • Review of placement data and overarching assessment results (annually)	• Student Work Assessment via Course Assessment and Continuous Improvement (CACI) Reports (every semester) • Capstone Design Project Rubrics on Design Process, Writing, and Presentation (annually) • Capstone Project Assessment Survey (annually, indirect) • Review of overarching assessment results (annually)

In assuring a quality assessment process and metrics, the Assessment Committee maintains an ongoing program that obtains multiple measures of student attainability for PEOs and SOs. The assessment methods are a mix of *direct measures*, which are defined as quantified observations and ratings of student performance/attainment, and *indirect measures*, which are both qualitative and quantitative evaluations of student achievements/attainments, such as survey data.

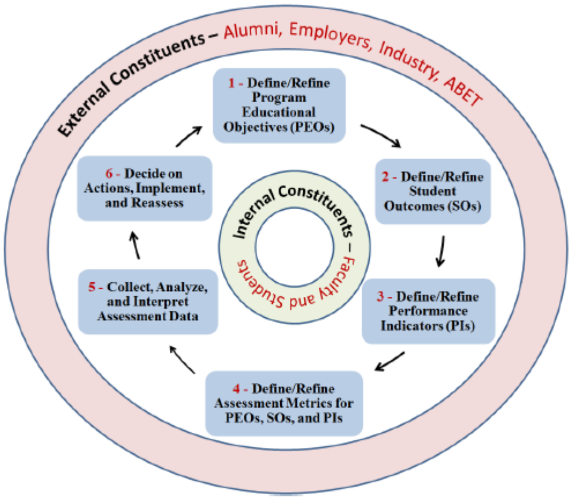


Figure 1: JMU Engineering Continuous Improvement Loop.

The assessment of SOs is performed as much as possible with direct measures, including evaluations of specific samples of student work, targeted exam questions, and evaluation of capstone projects. These direct measures are supplemented by indirect measures, such as student surveys. For the assessment of PEOs, indirect measures are more prominent, as the graduates and their employers are the best sources of information about post-graduation success. Several quantitative measures, such as number of promotions/salary increases, number of professional development activities, and membership in professional organizations also are used to measure achievement of PEOs. The following list delimits the direct and indirect measures for assessing PEOs and SOs.

Direct Measures of Program Educational Objectives:

- Alumni Survey (Specific questions)
- Senior Exit Survey (Placement Questions)
- Employer Survey

Indirect Measures of Program Educational Objectives:

- Alumni survey (Objective-focused questions)
- Admissions / Enrollment data

Direct Measures of Student Outcomes:

- Faculty Assessment of Student Work Samples via Course Assessment & Continuous Improvement Reports
- Faculty Evaluation of Capstone Projects via Capstone Design Process Rubric, Capstone Report Rubric, and Capstone Presentation Rubric
- Fundamentals of Engineering Exam Results
- Engineering Concept Inventories

Indirect Measures of Student Outcomes:

- Senior Exit Survey (Outcome-specific questions)
- Course Evaluation Surveys (Outcome-specific questions)
- Faculty Survey on Capstone Project Assessment
- Student Survey on Capstone Project Assessment
- Alumni Survey (Outcome-specific questions)

Other Assessment for Continuous Improvement:

- Freshman Entrance Survey
- Senior Exit Survey (General questions)
- Senior Exit Interviews/Focus Groups

The JMU Assessment Plan demonstrates our overarching goal of establishing connections between course-level assessment (where the key internal constituents are the program faculty and the students) and program-level assessment of the SOs (where the key internal constituents are the program faculty, the Assessment Committee, and students) and the PEOs (where the key internal constituents are the program faculty, the ABET Committee, the Assessment Committee, and students). External constituents (alumni, employers, industry, and the advisory council), described previously, are also integral to the assessment efforts of the program. In this assessment plan, course-level assessment from the students is attained via the Course Evaluations and from the faculty via Course Assessment and Continuous Improvement (CACI) Reports, which serve to document direct assessments of course outcomes and also Performance Indicators using student work, examinations, projects, etc. On the other hand, program-level assessment is evaluated also from the collection of CACI Reports that feed into the Student Outcome Summary Reports (SOSR), which are annually prepared by the Assessment Committee members. Each of these constituents has a role in this plan and these responsibilities are described below. The Assessment Committee is the principal faculty group responsible for coordination of assessment activities. The Assessment Committee reviews assessment instruments appropriate to specific PEOs and SOs, reviews the assessment process to identify areas for improvement, and provides recommendations to the Academic Unit Head and program faculty. The Assessment Committee also organizes assessment-focused faculty meetings every semester.

The assessment process is designed to inform the faculty on the strengths and weaknesses of the program in a way to bring about continuous improvements in curriculum, teaching pedagogy, advising, student services, and all other facets of the program. Annually, the Assessment Committee prepares an Assessment Progress Template (APT) report that is submitted to CARS for rigorous evaluation and feedback. The APT, which summarizes all assessment work that has been conducted during the academic year, is also sent to all engineering faculty for solicited feedback. Any recommendations or issues identified in the report are carefully considered and a course of action is developed. The assessment reports often serve as triggers for requests for additional specific assessment data and analyses to be used for specific studies or improvement projects by faculty/sub-groups within Engineering.

IV. Assessment and Evaluation Plan for ABET Student Outcomes A to K

The JMU Engineering program has developed an assessment and evaluation plan employing the best practices we have identified from several peer institutions, input from assessment advisors, CARS, and ABET resources [11]. In general, the assessment and evaluation plan ensures that the engineering faculty create, maintain, and monitor performance related to the SOs with advice and input from constituent representatives. An essential element of assessment and evaluation processes involves broad faculty involvement coupled with identification of specific responsibilities. This section presents the duties of various committees and individuals.

Assessment Committee

The Assessment Committee is the foundation for our assessment and evaluation processes and is the faculty team ultimately responsible for organizing and executing key assessment activities:

- Update assessment and evaluation plan as needed and distribute to faculty.
- Plan and conduct assessment-focused faculty meetings.
- Administer engineering science concept inventories in coordination with instructors.
- Administer the Senior Exit Survey, Alumni Survey, Employer Survey, and Capstone Project Assessment Surveys (to both capstone advisors and senior students).
- Plan and conduct Senior Exit Interviews/Focus Groups with graduating students.

Course Coordinators

Each course is assigned a course coordinator by the Assessment Committee and this faculty member plays a critical role in assessment. For all program faculty to be involved in these assessment processes, each program faculty members serves as course coordinator for at least one course per year. The course coordinator duties are described below.

- Review syllabi from all sections and instructors to ensure that these syllabi are compatible with the master syllabus.
- Oversee the coordination of assessment activities across all sections of a course.
- Prepare the course-specific questions on the Course Evaluation Survey at the end of each semester and provide these to the instructors in all sections of the course.
- Assemble and evaluate the collected assessment data.
- Prepare Course Assessment & Continuous Improvement (CACI) Reports each semester a course is taught.
- Assemble/update the course binder.
- Prepare reports at assessment-focused faculty meetings.

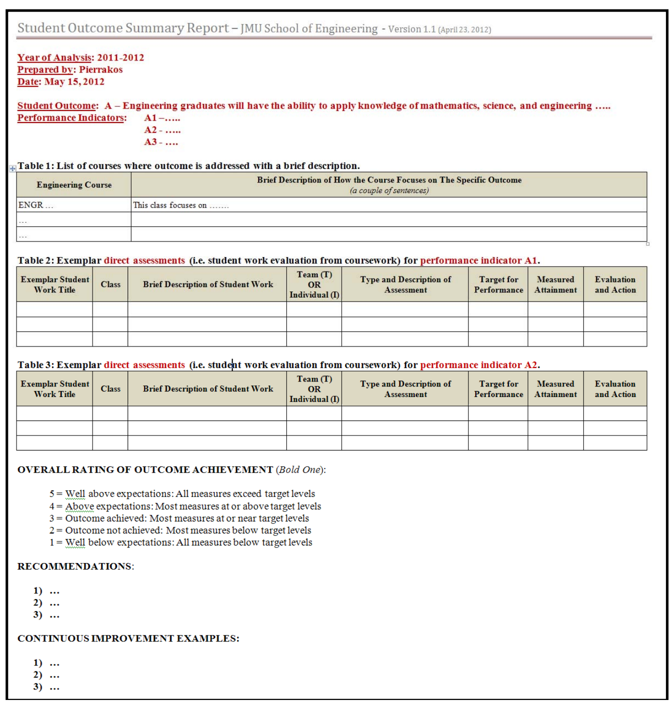
Outcome Coordinators

Each member of the Assessment Committee serves as an outcome coordinator, which requires the integration and analysis of the individual course assessment materials related to a specific Student Outcome. The responsibilities of the outcome coordinators include:

- Reviewing relevant CACI reports and prepare the Student Outcome Summary Report (SOSR) at the end of each academic year and submit to the Assessment Committee.
- Evaluating the overall degree of outcome attainment and whether the information provided supports the outcome accomplishment using the rubric in the Student Outcome Summary Report (SOSR), shown in Figure 2.
- Preparing an oral presentation for an assessment-focused faculty meeting and lead discussion related to the Student Outcome.

Assessment Committee Chair

The Assessment Committee Chair also has the additional responsibilities of preparing that annual assessment report, also known as the Assessment Progress Template (APT) which was briefly described previously. The APT is a summary of all program assessment activities and program assessment results for the academic year. The APT is submitted to the staff of the JMU Center for Assessment and Research Studies (CARS) for feedback annually. To prepare the APT, the Assessment Committee Chair reviews all CACI and SOSR reports to select exemplar assessments of student work (as the direct metrics) and indirect assessment results to provide an overarching story of program assessment and attainment of Student Outcomes. The APT is disseminated to program faculty for feedback and discussion, which often leads to the identification and actions for program continuous improvements.



Student Outcome Summary Report – JMU School of Engineering - Version 1.1 (April 23, 2012)

Year of Analysis: 2011-2012
Prepared by: Pierrakos
Date: May 15, 2012

Student Outcome: A – Engineering graduates will have the ability to apply knowledge of mathematics, science, and engineering .....
Performance Indicators: A1 –.....
A2 - .....
A3 - ....

Table 1: List of courses where outcome is addressed with a brief description.

Engineering Course	Brief Description of How the Course Focuses on The Specific Outcome (a couple of sentences)
ENGR ...	This class focuses on ....
...	
...	

Table 2: Exemplar direct assessments (i.e. student work evaluation from coursework) for performance indicator A1.

Exemplar Student Work Title	Class	Brief Description of Student Work	Team (T) OR Individual (I)	Type and Description of Assessment	Target for Performance	Measured Attainment	Evaluation and Action

Table 3: Exemplar direct assessments (i.e. student work evaluation from coursework) for performance indicator A2.

Exemplar Student Work Title	Class	Brief Description of Student Work	Team (T) OR Individual (I)	Type and Description of Assessment	Target for Performance	Measured Attainment	Evaluation and Action

OVERALL RATING OF OUTCOME ACHIEVEMENT (*Bold One*):

5 = Well above expectations: All measures exceed target levels
4 = Above expectations: Most measures at or above target levels
3 = Outcome achieved: Most measures at or near target levels
2 = Outcome not achieved: Most measures below target levels
1 = Well below expectations: All measures below target levels

RECOMMENDATIONS:

1) ...
2) ...
3) ...

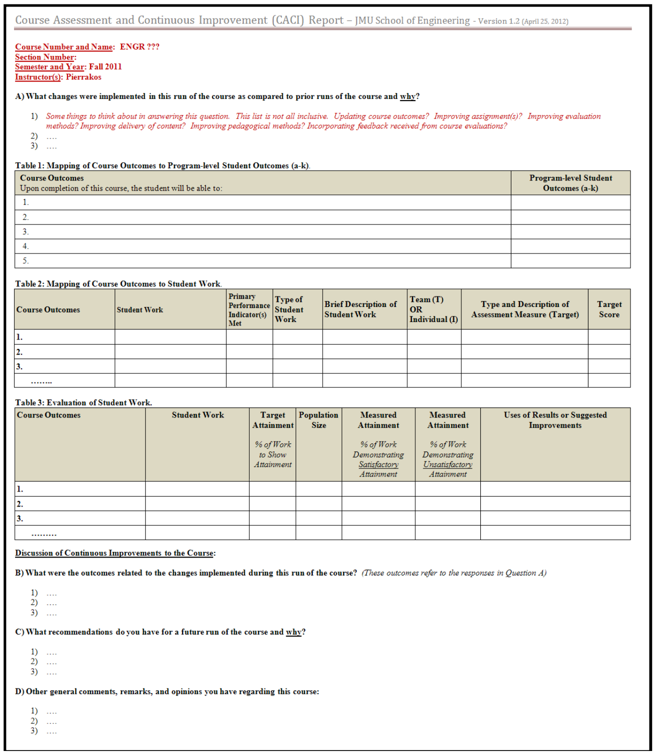
CONTINUOUS IMPROVEMENT EXAMPLES:

1) ...
2) ...
3) ...

Figure 2: Student Outcome Summary Report (SOSR) template.

Our Student Outcome assessment and evaluation plan stipulates the use of both direct and indirect methods to evaluate attainment of each SO and these metrics are described below. The following list describes the direct assessment methods for SOs used in the JMU engineering program:

Faculty Assessment of Student Work – All Student Outcomes and Performance Indicators are directly measured by faculty assessing student work in specified courses. In some cases, there are specific scoring or rating rubrics used, in other cases there are specific assignments evaluated based on grades received, and yet in other cases there is an overall faculty evaluation on course work based on a variety of sources (e.g. case studies, observations, assignments, course evaluations, etc.). Targeted exam questions are also utilized and these are selected by the instructors. Faculty capture results of these direct measures using the Course Assessment and Continuous Improvement (CACI) template in Figure 3. In these CACI reports, which are submitted by the course coordinators to the Assessment Committee at the end of each semester, the following items are captured: mapping of course outcomes to Student Outcomes, mapping of student work to Performance Indicators, description and characteristics (e.g. team-based or individual) of student work, description of assessment method, metric for assessment, target attainment, measured attainment, evaluation and uses of results, etc.


Course Assessment and Continuous Improvement (CACI) Report – JMU School of Engineering - Version 1.2 (April 25, 2012)

Course Number and Name: ENGR ???
Section Number:
Semester and Year: Fall 2011
Instructor(s): Pierrakos

A) What changes were implemented in this run of the course as compared to prior runs of the course and why?

1) *Some things to think about in answering this question. This list is not all inclusive. Updating course outcomes? Improving assignment(s)? Improving evaluation methods? Improving delivery of content? Improving pedagogical methods? Incorporating feedback received from course evaluations?*
2) ….
3) ….

Table 1: Mapping of Course Outcomes to Program-level Student Outcomes (a-k).

Course Outcomes Upon completion of this course, the student will be able to:	Program-level Student Outcomes (a-k)
1.	
2.	
3.	
4.	
5.	

Table 2: Mapping of Course Outcomes to Student Work.

Course Outcomes	Student Work	Primary Performance Indicator(s) Met	Type of Student Work	Brief Description of Student Work	Team (T) OR Individual (I)	Type and Description of Assessment Measure (Target)	Target Score
1.							
2.							
3.							
……..							

Table 3: Evaluation of Student Work.

Course Outcomes	Student Work	Target Attainment *% of Work to Show Attainment*	Population Size	Measured Attainment *% of Work Demonstrating Satisfactory Attainment*	Measured Attainment *% of Work Demonstrating Unsatisfactory Attainment*	Uses of Results or Suggested Improvements
1.						
2.						
3.						
………						

Discussion of Continuous Improvements to the Course:

B) What were the outcomes related to the changes implemented during this run of the course? *(These outcomes refer to the responses in Question A)*

1) ….
2) ….
3) ….

C) What recommendations do you have for a future run of the course and why?

1) ….
2) ….
3) ….

D) Other general comments, remarks, and opinions you have regarding this course:

1) ….
2) ….
3) ….

Figure 3: Course Assessment and Continuous Improvement (CACI) Report template.

Seven Engineering Science Concept Inventories–National engineering science concept inventories (CIs) evaluate students' understanding of fundamental engineering knowledge, so inclusion of such direct measures enables us to assess program goals A and E, given that these goals pertain to graduates having the ability to apply mathematics, science, and engineering knowledge to solve problems. The seven engineering concept inventory with the corresponding course in parentheses in which they are administered are: (1) Statics Concept Inventory, (2) Dynamics Concept Inventory, (3) Materials Concept Inventory, (4) Fluid Mechanics via the Thermal Transport Concept Inventory, (5) Thermodynamics via the Thermal Transport Concept Inventory, (6) Heat Transfer via the Thermal Transport Concept Inventory, and (7) Circuits Concept Inventory. Instructors in each of the courses where the inventories are administered select a target set of concept inventory questions to use for assessment purposes. This is done to assure that concepts covered in class are the ones that are indeed measured. For motivation purposes, students receive some type of course credit (e.g. final exam points, homework credit, or extra credit points) as decided by the course instructor.

Fundamentals of Engineering (FE) Exam – Scores from the national FE exam taken by senior engineering students prior to beginning the practice of engineering work enable us to assess Student Outcomes A, E, F given that these goals pertain to graduates having the ability to apply mathematics, science, and engineering knowledge to solve problems. A pass rate of 70% is our target performance on the FE Exam.

Faculty Evaluations of Capstone Project Reports and Presentations – Capstone projects by definition represent the culmination of students' educational experiences in the program. As such, they are an outstanding opportunity to observe student achievement of many SOs. A previous publication details the JMU two-year capstone model [12]. Using the Capstone Design Process Rubric, Capstone Report Writing Rubric, and Capstone Presentation Rubric developed by the engineering design instructors with feedback from the Assessment Committee, faculty evaluate the design process and quality of the senior capstone projects. The Capstone Design Process Rubric is used to evaluate the final capstone reports on twelve design process dimensions under four overarching categories: (1) Planning and Information Gathering, (2) Concept Generation, Evaluation, and Selection, (3) Design Embodiment, and (4) Testing and Refinement [13]. Further, the Writing Rubric evaluates the quality of the capstone reports on six writing-related dimensions and the Presentation Rubric on three delivery-related dimensions as well as the design process. The design instructors oversee the evaluation of all the senior capstone reports and all program faculty (with some external engineer practitioners as external evaluators) are involved in the evaluation of the senior capstone presentations.

The following list describes the indirect assessment methods for SOs used in the JMU engineering program:

Senior Exit Survey – The Senior Exit Survey administered as an online survey is given to the seniors in April. This survey is focused on indirectly assessing attainment of the SOs, Performance Indicators, and PEOs, as well as collecting placement information of our graduates. The placement questions in the survey pertain to career plans after graduation including employer information, position titles, starting salary information, graduate school plans, etc. The survey also includes a couple open-ended questions to collect more in-depth feedback on program and curriculum.

Faculty and Student Survey on Capstone Project Assessment – Assessing student learning as a result of participating on a two-year capstone project [12] is a critical piece to indirectly showing attainment of SOs. It is important to capture the perspective of the capstone faculty advisors as well as the student. These two sets of surveys (capstone advisor version and student version) are administered at the end of the capstone experience as online surveys. Capstone faculty advisors assess their capstone students' degree of learning outcome attainment at the end of the two-year capstone design experience. Similarly, students self-assess the degree of learning outcome attainment at the end of the two-year capstone design experience. Capstone faculty advisors' responses are compared to student responses and the results enable us to assess the extent to which the capstone design experience has enabled students to meet Student Outcomes. This survey, National Engineering Students' Learning Outcomes Survey (NESLOS) [14-15], includes 55 ABET-derived learning outcomes that map to the eleven SOs and some of the forty Performance Indicators. In this survey, we also assess the degree to which the capstone project enabled students to apply knowledge and skills from all required science, math, and engineering courses in the curriculum. Such information enables us to better understand how effectively students are applying and integrating knowledge from coursework and also helping us set some standards during project solicitation and project selection.

Alumni Survey – The Alumni Survey seeks for demographic background of alumni, appropriateness and attainment ratings of the PEOs, appropriateness and attainment ratings of the SOs, the ability of the SOs to support the PEOs, importance of PEOs and SOs to the workplace, employment details, employer contact information, and several open-ended questions. The Alumni Survey is administered to alumni as an online survey. Contact information of our graduates is collected during the Senior Exit Survey and this contact information is used in administering the Alumni Survey.

Course Evaluation Surveys – At the end of every course, instructors administer an online survey to students. The Course Evaluation Surveys include standard questions devised by the faculty as well as custom-designed questions by the course instructor(s) for the purpose of continuous improvement. The Course Evaluation Surveys include students' ratings of textbook usefulness, amount of work required in the course in comparison to other similar level courses, degree of challenge in the course, appropriateness of examinations, ratings of the value as well as the difficulty of specified course projects or assignments, ratings of students' achievement of the course outcomes, and open-ended questions. The survey employs a 5-pt Likert scale for most questions. Our goal is to achieve 70% of survey responses at the 4 or 5 level. Faculty are encouraged to include course evaluation findings in CACI reports.

Senior Exit Interviews/Focus Groups – To accompany the more quantitative and structured Senior Exit Survey, all of our seniors are also offered the opportunity to participate in a Senior Exit Interview or Focus Group to provide more general feedback and satisfaction with the program at all levels – curricular, extra-curricular, professional, etc. The questions are open-ended and semi-structured. Seniors are offered opportunities to participate in focus groups which are conducted by the Academic Unit Head and a member of the Assessment Committee who is not an instructional faculty member but rather the Student Coordinator in the program. Data from the interviews/focus groups indirectly map to SOs and PEOs.

Having described the metrics for assessing SOs, it is also important to describe the timeline and frequency of these metrics. A three-year cycle is used for assessing SOs, corresponding to 3 to 4 each year. The annual groupings of SOs for each year (i.e. Student Outcomes A, C, E, and H during year 1, Student Outcomes B, D, J, K during year 2, and Student Outcomes F, G, and I during year 3) are based on the fact that we recognize critical connections between SOs.

V. Assessment Results and Attainment of Student Outcomes

In this section, we present a sample of assessment results corresponding to Student Outcome C. More specifically, Figures 4 and 5 correspond to the summary of direct and indirect assessment results for Student Outcome C. The tables include details about the assessment methods, the target or expected student attainment results, the measured student attainment results, as well as an evaluation of the results and actions to be taken. Direct assessments of Student Outcomes (i.e. Figure 4) are primarily focused on showing attainment of the Performance Indicators by targeting exemplar student work across the curriculum. This mapping is based on the CACI reports, the SOSR, and the Assessment Committee working closely with the program faculty. The target attainment for all direct assessments was set at 70%. For program-level target attainment, all direct assessments were set at 70%, but course coordinators could set their own target attainments for courses.

For indirect assessments of Student Outcomes (i.e. Figure 5), assessment results focused on data from the Senior Exit Survey, the Faculty Capstone Project Assessment Survey, the Student Capstone Project Assessment Survey, and the Alumni Survey. The target attainment for all indirect assessments was set at 80%. Figures 4 and 5 are from the JMU Engineering ABET Self-Study.

Performance Indicators	DIRECT Method(s) of Assessment	Brief Description of Assessment Method	Course	Attainment		Evaluation and Action
				Target	Measured	
c1. Analyze and evaluate products and processes based upon economic, environmental, societal, and technical characteristics.	Reactor Design Assignment	Evaluation of adequacy of a conceptual reactor design in which students were required to determine the size and efficiency of constantly mixed flow reactors as well as batch reactors for effectively removing pollutants and minimizing the environmental impacts of anthropogenic wastes in lakes and rivers. Student attainment based on percentage of students achieving a score of 70% or higher.	ENGR 411	70%	83%	**Performance Indicators Adequately Met.** **Evaluation** – There is a focus on engineering design throughout the curriculum which is evident not only in the six design courses that serve as the spine of the design instruction but also in other courses in this table. Students are learning fundamental and advanced knowledge and skills related to design. The recent inclusion of the design challenges in the design courses has helped with better illustrating to the students the integration between engineering science and design knowledge, two domains that students initially see as independent but quickly see as interdependent. **Action** - (1) Continue to integrate design thinking and knowledge in the engineering science, engineering management, sustainability, and systems courses. (2) Continue to improve assessment methods.
	Holistic Product Design Project	Evaluation of thoroughness of a product critique using holistic design and sustainability principles. Student attainment based on percentage of students achieving a score of 70% or higher.	ENGR 431	70%	75%	
	Analysis of JMU Bus System	Evaluation of report designed to assess students' ability to apply systems concepts related to the JMU bus system. The analysis was based on qualitative assessment of economic, environmental, societal, and technical characteristics and impacts. Student attainment was based on a report rubric (4-pt scale) and the percentage of students scoring a "3" or "4."	ENGR 413	70%	62%	
c2. Identify qualitative and quantitative needs and constraints associated with a design project.	Identification of Customer Needs for Sophomore Design Project	Evaluation of thoroughness of customer needs identified and categorization of customer needs. Student attainment was based on the percentage of students achieving a score of 75% or higher.	ENGR 231	70%	91%	
	System Level Analysis Project	Evaluation of project presentation and report focused on the assumptions identified by students during their system analysis. Student attainment was based on presentation rubric (4-pt scale) and the percentage of students scoring a "3" or "4."	ENGR 413	70%	100%	
c3. Apply an engineering design process to design a system, component, or process.	Design Challenge: Infant Monitor	Evaluation of thoroughness and justification of the design process report relevant to the design challenge focused on an infant respiratory rate monitor. Student attainment was based on the percentage of students achieving a score of 70% or higher.	ENGR 431	70%	70%	
	Design Challenge: Kitchen Cabinet Accessibility	Evaluation of thoroughness and justification of the design process report relevant to the design challenge focused on kitchen cabinet accessibility for a wheelchair bound client. Student attainment was based on the percentage of students achieving a score of 70% or higher.	ENGR 432	70%	87%	
	Circuit Design Project	Evaluation of a team-based project demonstration, oral examination, and written summaries to design, build (on breadboards), test, and refine a complex circuit for an electronic system of students' choosing. Student attainment was based on the percentage of students achieving a score of 70% or higher.	ENGR 313	70%	100%	
	Capstone Project Design Process	Evaluation of the adequacy of the capstone design process, which was based on the twelve dimensions (4-pt scales) of the capstone design process rubric. Student attainment was based on the percentage of teams adequately addressing (with a "3" or "4) seven of the twelve dimensions. See Appendix 4-8 for the capstone design process rubric.	ENGR 432	70%	80%	

Figure 4: Summary for direct assessments of Student Outcome C.

Student Outcome	INDIRECT Method(s) of Assessment	Brief Description of Assessment Method	Attainment		Evaluation and Action
			Target	Measured	
C. Design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	Senior Exit Survey	Evaluation was based on an online survey where each student self-rated the extent to which she/he agreed (5-pt scale) that the JMU engineering curriculum enhanced their abilities to achieve the three performance indicators aligning with Student Outcome C. Student attainment was based on the percentage of seniors agreeing or strongly agreeing.	80%	99%	**Student Outcome Adequately Met.** **Evaluation**– Students perceive that they are adequately meeting the performance indicators aligning with Student Outcome C. **Action** – Not applicable.
	Capstone Project Survey - Faculty Assessment	Evaluation was based on an online survey where faculty rated the extent to which her/his capstone design students demonstrated an ability to achieve the learning outcomes aligning with Student Outcome C. Faculty submitted a response (5-pt scale) for each senior capstone team she/he advised. Student attainment was based on the percentage of faculty rating an adequate ability or above for their students.	80%	73%	**Student Outcome Adequately Met.** **Evaluation** - There appears to be a mismatch between faculty and student ratings of Student Outcome C learning outcomes as related to the capstone design projects. Students think that they are adequately applying the engineering design process to a product, process, or system, yet faculty advisors believe that students can be doing better. **Action** – The development of the capstone design process scoring rubric in the spring 2012 semester helped not only for assessment purposes but also with more clearly establishing design process expectations for capstone projects. This is helping design instructors, capstone faculty advisors, and capstone students set clear expectations. The design instructors plan to use this design process scoring rubric to provide students formative feedback as well as require them to self-assess their progress during the four semester capstone design experience.
	Capstone Project Survey - Student Assessment	Evaluation was based on an online survey where each student self-rated the extent to which he/she demonstrated an ability to achieve the learning outcomes (5-pt scale) aligning with Student Outcome C. Student attainment was based on the percentage of students rating an adequate ability or above for herself/himself.	80%	99%	
	Alumni Survey	Evaluation is based on an online survey where each alumnus reflects and self-rates the extent to which she/he agrees (5-pt scale) that the JMU engineering curriculum enhanced their abilities to achieve Student Outcome C. Although the Alumni Survey has been developed, it has not been administered yet. Student attainment will be based on the percentage of Alumni agreeing or strongly agreeing.	80%	NA	**Action** – Pilot the Alumni Survey in the spring of 2013 semester.

Figure 5: Summary for indirect assessments of Student Outcome C.

VI. CONCLUSION

In this paper, we presented a thorough assessment plan being utilized in the Department of Engineering at James Madison University. The plan incorporates qualitative and quantitative assessment measures, involves all program faculty in the collection and analysis of data, and outlines a manageable structure for maintenance of the process. The assessment plan was successfully used for the department's first-time ABET accreditation review in 2012. The ABET program evaluation team described the assessment plan "as the most thorough assessment plan they had seen in their 20 plus year as ABET evaluators and a plan they would take back to share with their own engineering departments. The plan itself is also subject to a continuous improvement process, and future work will include implementing methods to organize the collection of assessment data in an online format. The approach presented in this paper is adaptable to other programs and the hope is that this information can aid other engineering programs.

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Peer Assessment in Experiential Learning

Assessing Tacit and Explicit Skills in Agile Software Engineering Capstone Projects

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***Abstract*—To prepare students for real-life software engineering projects, many higher-education institutions offer courses that simulate working life to varying degrees. As software engineering requires not only technical, but also inter- and intrapersonal skills, these skills should also be assessed. Assessing soft skills is challenging, especially when project-based and experiential learning are the primary pedagogical approaches. Previous work suggests that including students in the assessment process can yield a more complete picture of student performance. This paper presents experiences with developing and using a peer assessment framework that provides a 360-degree view on students' project performance. Our framework has been explicitly constructed to accommodate and evaluate tacit skills that are relevant in agile software development. The framework has been evaluated with 18 bachelors- and 11 masters-level capstone projects, totaling 176 students working in self-organized teams. We found that the framework eases teacher workload and allows a more thorough assessment of students' skills. We suggest including self- and peer assessment into software capstone projects alongside other, more traditional schemes like productivity metrics, and discuss challenges and opportunities in defining learning goals for tacit and social skills.**

Keywords—Peer assessment; assessment metrics; self-assessment; case study; capstone project; experiential learning; project-based learning; tacit skills; teamwork; computer science education; agile software engineering.

I. Introduction

It is well known that there exists a gap between what engineering students learn and what is expected from them as they graduate [1], [2], [3]. The expectation gap [4] is especially visible in software engineering education, where practices learned while studying may even have to be unlearned later [5].

Among the expected skills are the abilities to read social cues, regulate emotional expression, and to engage in constructive dialogue with project stakeholders to discover tacit knowledge. These so-called *soft skills* are particularly important in software engineering projects that rely more on informal communication than document-driven and plan-based approaches. They are important for building and maintaining cohesion in development teams, working with external teams, and for involving other project participants and stakeholders in the software development process.

The gaps in communication and teamwork skills of new engineers were discussed already in the 1990s [6], and the most relevant skills required from entry-level IT personnel still include personal attributes such as problem solving, critical and creative thinking, and team skills and communication [7]. Teamwork and communication is also emphasized in the emerging agile methodologies, where interaction between individuals is valued over processes and tools [8]. Ultimately, students should grow into members of their communities of practice [9], adopting the tacit skills required to function in the field. This is a notable challenge for higher education.

Teamwork is usually practiced in several projects in higher education. Perhaps the most notable project is the capstone project, which is often the culmination of a degree program. Capstone projects are typically made for real customers in as realistic settings as possible, given the constraints of the educational institution. Capstone projects provide an opportunity to assess higher-order cognitive dimensions of learning as well as affective and skill-based dimensions [10]. Even if the end product of a project is the most valuable deliverable for a customer, the whole project can be a continuous and valuable learning process for the students.

As students direct their activities based on the given assessment criteria [11], the assessment design plays a key role in what students will focus on. In a software engineering capstone project, the assessed skills and knowledge should contain: (1) elementary software engineering related skills such as requirements analysis, design, development, and validation; (2) tool related skills such as the use of a version control system, development tools, and process management tools; and (3) process related skills such as process knowledge and how a selected process is followed. How the students utilize and benefit from these skills in a teamwork setting is moderated by several tacit, soft, and social skills.

In this paper, we present ongoing work on an assessment framework that can be used as a decision support tool to assess tacit skills together with explicit skills in capstone project environments. The framework has been built to help focus students' attention to important team-related aspects, and to help teachers assess student performance in capstone projects.

This paper is structured as follows. In Section II, we give an overview of our educational context and the learning objectives of our capstone courses, as well as discuss our motives to develop a new framework. In Section III, we describe related work on assessment of project-based education as well as self- and peer assessment, and in Section IV, we describe the framework. The evaluation of the framework is discussed in Section V through a multiple case study, and finally, in Section VI, we conclude this paper and outline future work.

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II. Background

Computer Science studies at the University of Helsinki are divided into a three-year bachelor's degree, and a two-year higher master's degree. The bachelor's degree is a comprehensive computer science degree, which prepares the students for both working life and future studies. There is no "specialization track" within the bachelor's studies: every student takes courses on e.g. math, software engineering, distributed systems, as well as algorithms and machine learning.

If the students choose to pursue a master's degree, they have a variety of specialization tracks to choose from. Our focus is on the software engineering specialization track, in which students deepen their understanding on e.g. software processes and quality, agile methodologies and coaching, as well as software architecture.

A. Capstone Projects

Both the bachelor's and master's degrees contain a capstone project. The bachelor's degree studies culminate in either a 7- or a 14-week *Software Engineering Project*, during which the students work in 4–5-person teams on a project from e.g. an industry partner or a research group. The 7-week version is a full-time project, where the students are collocated at one of our labs, while the 14-week version is a part-time project, and can be partially distributed. Although the students are mentored by staff, they handle all project aspects in a self-organized manner, including project management and setting customer expectations.

The capstone project for the software engineering specialization track is the *Software Factory Project* [12], [13], which simulates a teamwork environment in contemporary software development organizations. Its design aims to shift responsibility of all aspects of project operation to the student team, in order to ensure that students are exposed to the realities of software development.

The Software Factory Project is similar to the bachelor's-level capstone project, but with some characteristics that make it more challenging. The project usually begins with more ill-defined goals. Part of the purpose is to discover, together with the customer, even which software the project is to produce, and how the software can bring value to the customer and end user. Some of the projects also operate in a distributed environment together with other Software Factory nodes at separate universities.

B. Motivation and Learning Objectives

The motivation for assessing teamwork and tacit skills arose initially during the design and development of the Software Factory Project. The tacit skills are of particular importance in such courses, and thus were set as important learning objectives of the project. One of the challenges was to design an approach to assess not only project deliverables and productivity, but also performance in terms of tacit and team skills. The lessons learned in the Software Factory were incorporated, together with results from a multi-year improvement effort [14], into the Software Engineering Project.

The main learning objective for both capstone projects was originally defined as "*the ability to become a member of a software development team, function as part of it, contribute to its development, and work as part of it towards its current mission or purpose*". In addition, the software engineering project has a specific learning objective rubric, which outlines the principal themes in the course and what is required for each level of student assessment. The rubric follows the principles of constructive alignment [15], and outlines software development related skills, as well as management and tool usage.

The effort that students put on learning is heavily determined by the assessment criteria [16], [17]. However, neither the rubric nor the main learning objective supported assessing soft skills. As the main learning objective of the capstone projects consists of a set of distinct sub-objectives, assessment requires that each of them is identified and assessed independently, preferably using a small number of traits that cover the knowledge and skills required to do well in each part of an activity [17].

Our framework is based on the cognitive domain of Bloom's revised taxonomy [18], [19], which provides guidelines for agreeing on assessment and learning objectives for a course. It outlines six levels (*remembering*, *understanding*, *applying*, *analyzing*, *evaluating*, and *creating*), which are ordered from simpler to more complex; the original idea was that mastering a "higher" category requires the mastery of the previous categories.

Based on the six levels defined by the cognitive domain in Bloom's revised taxonomy, we outlined the following team skills that each participant focuses on: *presence*, *activity*, *eagerness*, *devotion*, *contribution*, and *expert maturity*. In addition, the bachelor's-level software engineering projects put additional focus on the participant behavior and its influence on *process* and *result*. A more comprehensive description of these team skills is given in Section IV.

III. Related work

Several studies have examined self- and peer assessment of teamwork in regular courses, and assessment of teamwork in projects, including capstone-like courses. Here, we briefly present some of the issues examined and results found.

One of the most fundamental questions regarding assessment is that of its purpose. Naturally, assessment can serve multiple purposes simultaneously; it can help rank students with respect to their performance, allowing selection to be made in different stages of an educational system, and it can provide important feedback to students regarding their study performance. When assessment is tied to specific learning objectives, students' activities can be directed towards activities that build knowledge and skills that are deemed relevant.

Assessment can be used on the systemic level to evaluate learning programs in terms of how well they support achievement of learning outcomes [20]. The nature of capstone projects as comprehensive experiences means that they allow assessing a wide range of abilities; they are indicative of learning program strengths and weaknesses. Analysis of capstone project outcomes can provide valuable insights for improving learning programs, and thus, improving student learning. Payne et al. suggest assessing student readiness for capstone courses in order to gather feedback on both the presence of necessary background knowledge, skills, and dispositions, and the ability to apply them to capstone courses [10]. They outline critical concepts and skills that students must be taught to assure their success in capstone courses, noting that educators and researchers should set up continuous feedback frameworks that could be used to transfer knowledge to core-course faculty on the level of preparation the students believe they have for the upcoming capstone experience.

A pertinent question is how to actually assess capstone projects: what is to be assessed and how? One approach is to map project deliverables and artifacts to general and specific learning outcomes and rubrics, and then assess the deliverables with respect to the rubric, as proposed by Murray et al. [20]. As an example, Murray et al. describe the goals of information systems capstone projects: students should be able to i) understand that projects require collaboration as well as individual effort, ii) participate as contributing members of a development team, iii) apply teamwork skills in development and implementation of a system, iv) demonstrate acknowledgment of and respect for the team members, and v) identify the qualities needed to be an an effective leader, and explain the roles of leadership and teamwork in system development and implementation. The artifacts used to evaluate these outcomes include individual reports, peer evaluations, and weekly status forms.

Self- and peer assessments appears to be viewed favorably by many teachers and researchers in terms of how well it includes students into the assessment process. For instance, Fellenz finds that peer evaluation can improve the quality of the students' experience and increase their engagement in the learning task [21]. However, a particular concern in assessing teamwork skills is the accuracy of assessment. Through a review of assessment literature, Van Duzer and McMartin [22] identified two primary types of bias as especially relevant for self-assessment and peer evaluation: self-enhancement, where one's own performance is evaluated as unreasonably optimistic, and downward comparison, a general tendency for positive self-bias and negative other-bias. Similar results are reported in many works. For example, Ryan et al. compared peer and self-evaluations of class participation against those of professors [23]. They found that faculty grades tended to be higher than peer grades, and that self-evaluation grades were typically higher than faculty grades. This study used a forced ranking system for students to rank each other while faculty did not use forced ranking.

Van Duzer and McMartin suggest some approaches to reduce self-enhancement and downward comparison biases [22]. Using language shared by respondents and testers in assessment criteria helps to reduce misinterpretation and thus improves the validity of the assessment process. Correlating self-assessments with scores by multiple raters allows evaluation of instrument reliability. Designing questions so that they rate past performance, not expected future performance, improves reliability by reducing the effect of downward comparison. Finally, asking respondents to make comparisons with an explicit group of known individuals rather than an abstract group when social comparisons are required, also improves reliability. Qualitative analysis while developing the instrument is necessary to understand the meaning of the assessment to participants. Van Duzer and McMartin developed a process with both quantitative and qualitative parts for improving and tailoring teamwork skill assessment in specific environments. They found a dramatic improvement in sensitivity when applying the process to their own instrument.

A number of approaches and frameworks for self- and peer assessment have been described in the literature. Willey and Freeman report on a tool that facilitates formative assessment via self- and peer assessment [24]. They report that formative feedback encouraged development of teamwork skills, and also discouraged free-riding and sabotage, thus promoting academic honesty. They argue that while self- and peer assessment is often implemented as summative assessment, even better outcomes may be achieved by using them as formative assessment. They observe that the administrative burden of applying self- and peer assessment can often outweigh the perceived benefit. Furthermore, they observe that feedback is often given long after the assessable work has been completed, which means that students' attention may already have shifted to other tasks.

Beyerlein et al. [25] describe an assessment framework for capstone design courses. Their framework is based on a conceptual model of knowledge representation and expertise development. They strive to examine students' performance and growth from several perspectives. They examine growth in personal knowledge and skills applied in problem solving. They examine professional development through goal-driven initiative, competence in problem-solving, integrity and professionalism, and ongoing reflection. Also, they examine team processes and dynamics as well as productivity by determining whether team resources are used strategically, and decisions made add real value to the project. They also examine how well students are able to formulate solution requirements, consider stakeholder needs, and formalize these into specifications. Finally, they evaluate deliverables in terms of desired functionality, economic benefits, feasibility of implementation, and favorable impact on society.

Another concern is students' motivation to rate their peers. Friedman et al. found that students who provided categorical ratings (multiple scores on different categories or dimensions) multiple times during a course experienced the lowest motivation to rate their peers, while students who provided holistic ratings (a single score) multiple times reported the highest motivation [26]. We may hypothesize that respondent fatigue plays a role here: a small number of items is less likely to feel overwhelming. The type of item may also be important: describing a particular behavior and asking the respondent to indicate its frequency is usually recommended – an approach used, e.g., in rating a system developed by Clark et al. [27].

Finally, also related to practical concerns, is the burden of manual work in collecting and analyzing self- and peer assessment data. Naturally, online questionnaires and semi-automated analysis tools can remove much of this manual work. Some reports exist on complete systems for self- and peer assessment management. The SPARK system, described by Freeman and McKenzie [28], emphasizes fairness in group work assessment and reduced administrative burden through automation. Similarly, the CATME system, described by Ohland et al. [29], provides automation to reduce teacher workload, but places greater emphasis on using behavioral anchors in the assessment itself. The SMARTER system [30] extends CATME and attempts to link educational research with teaching faculty actions to enhance learning of teamwork skills.

IV. Framework for Assessing Tacit Skills

Our Framework for Assessing Tacit Skills consists of a questionnaire whose items can be used (e.g. by weighted averaging) to provide assessment decision support for teachers. The framework enables assessment of tacit skills through nine indicators, used for both self- and peer assessment. We categorized the indicators to represent six different tacit skills, and decided that the assessment should impose as little overhead as possible for all participants and thus should be implemented as a short online questionnaire.

The framework factors, questionnaire items, and scales are shown in Table I. The questionnaire, which is filled in by the students, project coach, and the client, allows rating each student based on the questionnaire items. Once the questionnaire has been answered, the answers are exported for further data-analysis, where a set of scripts is used to e.g. suggest overall grades based on a given weighting, or to indicate students that have been free-riding.

The questionnaire is structured along six factors, beginning from basic factors and progressing towards higher levels of involvement and skills. The first factor, presence, is a prerequisite for becoming a member of the development team. The activity factor implies that a person is not only present, but also actively involved in the project. Eagerness reflects the attitude that the person takes towards the project: is the person not only active but also taking initiative and displaying a positive desire to get things done. Devotion reflects a deeper level of commitment: the person not only takes the initiative but actually invests effort into carrying out planned tasks. Contribution reflects actual impact on the project, whether in the form of code, documentation, or other deliverables, or in the form of project management, customer communication, or support tasks. Finally, expert maturity reflects an overall assessment of how the person performed in their role. We purposefully chose to leave the definition of this factor quite open and broad, in order to allow each individual to assess it according to the specific conditions of each particular project.

While we appreciate the objectivity and wide coverage of the approach described by Murray et al. [20] and other similarly detailed assessment schemes, we suspect that both students and teachers can quickly be overwhelmed by the amount of effort required to produce and analyze the assessment artifacts, resulting in both less effort being available for project work and formative assessment and guidance. It also feels counter to the philosophy of Agile software development methodology to employ a heavy-weight assessment framework – after all, agile projects purposely do not define artifacts to be produced until there is a proven need to produce them.

Three main criteria were defined for the framework. First, the framework should ease teacher workload. The framework should function as a support tool for teachers during assessment, and it should support assessment of project-based courses even when teachers cannot constantly observe students' activities. Second, it should allow systematic assessment of students' skills; each factor in the framework can be thought of as building on top of the previous factors. Finally, it should be easy to detect attempted misuse of the framework, so that teachers can be confident that they may use the results as valid decision support information.

V. Evaluation

The framework has been evaluated iteratively during its development. It was first evaluated in several projects in the Software Factory, and later also in the Software Engineering Project. In this section, we report on the evaluation procedures and present the most relevant evaluation results. We then discuss the validity and limitations of our evaluation and present results from evaluating the framework from a teacher perspective.

As noted, the motive for assessing tacit skills arose during the design of the Software Factory. We first conducted a pilot project in spring 2010 with 11 students, during which the framework dimensions were developed. Then, the framework was deployed to 11 consecutive Software Factory projects with a total of 77 students. The evaluation of the framework in the Software Engineering Project started in fall 2011, after which a total of 18 projects with a total of 88 students have been both evaluated by the framework and given their evaluation of the framework. Since the latter project is mandatory for all bachelor's-level students, we wanted to gain reasonable confidence that the framework worked well before deploying it there. As part of that deployment, we found that the Software Engineering Project students did not perceive teamwork-related skills as important. For example, competitive situations arose where several strong individuals attempted to pull the project in their desired direction. For this reason, factors regarding individual behavior in relation to the group were added.

Our evaluation strategy is laid out as follows. Ultimately, the objective is to find out whether the framework is suitable for the purpose of influencing learning of teamwork skills through assessment. However, before actually determining its effect on learning, we want to understand whether the framework is otherwise suitable for use in capstone projects. This includes evaluating the accuracy of assessment and utility of the framework as a decision support tool: does the framework adequately guard against biases such as self-enhancement and downward comparison, does it adequately reflect rater's understanding of the factors, and does it produce results that are in line with teachers' expert evaluations, taking into account the rich, qualitative observational data obtained when guiding students in the capstone projects?

To perform this evaluation, we proceed as follows. We check the association between self- and peer ratings to determine whether a bias is visible (see Table II). Peer ratings should help dampen bias in self-ratings. We check association between the different rating factors. There should be discernible differences between the factors both in self- and peer ratings; they should not have perfect correlation. However, there should be some association between the factors that are in fact conceptually related.

Table II shows correlations between self- and peer assessments in both the Software Factory (SF) and the Software Engineering Project (SP). Most of these correlations are as expected: there is a large degree of correlation but there are differences in the gradings. However, some correlations stand out from the others. In SF, there is quite low correlation on eagerness, and self-ratings tend to be higher (mean: 0.863) than peer ratings (mean: 0.743). In SP, self-ratings tend less towards the highest grade (mean: 0.788) and peer ratings are similar in distribution (mean: 0.786). In our interpretation, students

TABLE I. FRAMEWORK FACTORS, QUESTIONNAIRE ITEMS, AND SCALES.

Factor	Questionnaire item	Scale
Presence	How many days per week did you work on this project? How many hours did you spend on the entire project in total? (Round to nearest hour.) How much was each team member present? Also rate your own presence.	1 – Was not present at all 2 – Was sometimes present 3 – Was moderately present 4 – Was nearly always present 5 – Was always present 0 – I don't know
Activity	How actively did each team member participate in the project? Also rate your own activity.	1 – Was not active at all 2 – Was somewhat inactive 3 – Was moderately active 4 – Was quite active 5 – Was very active 0 – I don't know
Eagerness	Eagerness: a positive feeling of wanting to push ahead with something. How eager was each team member to participate in the course? Also rate your own eagerness.	1 – Was not eager at all 2 – Was a little eager 3 – Was moderately eager 4 – Was quite eager 5 – Was very eager 0 – I don't know
Devotion	Devotion: commitment to some purpose; "the devotion of his time and wealth to our project" How devoted was each team member to the course? Also rate your own devotion.	1 – Was not devoted at all 2 – Was a little devoted 3 – Was moderately devoted 4 – Was quite devoted 5 – Was very devoted 0 – I don't know
Contribution	How much did each team member contribute to the deliverables (code, documentation, tests, bugs, plans, or anything else that the project produced)? Also rate your own productivity.	1 – Did not contribute at all 2 – Contributed a little 3 – Contributed moderately 4 – Contributed quite much 5 – Contributed very much 0 – I don't know
Expert Maturity	Each team member has acted as a software development expert with some specific focus area. How mature was each team member in their expert role? Also rate your own maturity.	1 – Very low expert maturity 2 – Low expert maturity 3 – Neutral expert maturity 4 – Some expert maturity 5 – High expert maturity 0 – I don't know
Process (only BSc project)	Group dynamics: each member can influence the team spirit and the end result with their social behavior. How did the group behavior of each member influence the sensed meaningfulness of the project work?	1 – Influenced negatively 2 – Did not influence 3 – Influenced a little 4 – Influenced quite much 5 – Influenced very much 0 – I don't know
Result (only BSc project)	How did the group behavior of each member influence the end quality of the project work?	1 – Influenced negatively 2 – Did not influence 3 – Influenced a little 4 – Influenced quite much 5 – Influenced very much 0 – I don't know

TABLE II. CORRELATIONS BETWEEN SELF- AND PEER RATINGS ON DIFFERENT FRAMEWORK DIMENSIONS IN SOFTWARE FACTORY (SF) AND SOFTWARE ENGINEERING PROJECT (SP), WITH CORRESPONDING P-VALUES.

Dimension	Correlation between self- and peer rating	p-value
Presence (SF)	0.492	< 0.001
Presence (SP)	0.457	< 0.001
Activity (SF)	0.531	< 0.001
Activity (SP)	0.544	< 0.001
Eagerness (SF)	0.279	0.017
Eagerness (SP)	0.473	< 0.001
Devotion (SF)	0.433	< 0.001
Devotion (SP)	0.333	0.002
Contribution (SF)	0.582	< 0.001
Contribution (SP)	0.376	< 0.001
Expert maturity (SF)	0.461	< 0.001
Expert maturity (SP)	0.207	0.062
Contribution to meaningfulness (SP)	0.487	< 0.001
Contribution to quality (SP)	0.370	0.002

in SP could be less inclined to penalize each other, perhaps because their level of experience is lower and the course is mandatory – they may not want to give low ratings to each other on eagerness given that situation.

On devotion and contribution, the trend is similar: in SF, the correlation is stronger than in SP. In the SP data, high peer ratings were more common than in the SF data. In SF, roughly one third of students rated their peers at average expert maturity, while more than two thirds of SP students assigned each other the two highest scores. This may indicate that the competitiveness among students in the SF is higher. We observe that this information allows the teacher to assess the amount of bias in responses and that there appears to be agreement on the meaning of the dimensions.

Next, we consider the association between the variables. In the self-evaluation scores, presence correlates somewhat with activity and eagerness but less with devotion, contribution, and least with expert maturity. This could indicate that students do see these factors as separate. Activity correlates quite strongly with eagerness, devotion, and expert maturity. Devotion correlates strongly with contribution and expert maturity. Contribution correlates most strongly with expert maturity.

In the peer evaluation scores, all factors are moderately to strongly correlated. In SF, the strongest (≥ 0.9) correlations are i) activity with eagerness (0.930), devotion (0.932), and contribution (0.943); ii) eagerness with devotion (0.912) and contribution (0.911); iii) devotion with contribution (0.939); and iv) contribution with expert maturity (0.906; $p < 0.001$ in all cases). In SP, the correlations are smaller but still quite strong. The order of strength is roughly the same. We interpret these results as supporting the intended structure of the factors.

In SP, the two added factors had moderate to low correlation between self- and peer evaluation. On contribution to meaningfulness, self- and peer evaluations had a moderate correlation (0.487), while on contribution to quality, the correlation was lower (0.370). In the latter, there may be bias toward thinking that one's own contribution is the most important, and therefore one rates the others lower.

A. *Validity*

The validity of the framework is limited by the fact that it uses a questionnaire-based approach. Respondents are asked to recall their own behavior and that of their teammates, and this recall may not be perfect. However, more fundamentally, the validity is ultimately relative to context in which the instrument is deployed. The purpose of the framework is to function as a decision support tool, and teacher judgment should be used to determine the final assessment. As MacLellan notes, validity concerns not the assessment instrument used or the resulting scores as such, but rather the inferences which are derived from them [31].

To lend more validity to such inferences, the framework should provide a way to detect whether the data may be biased or incorrect. The most common reason besides unintentional bias is students' attempts to artificially influence their grades. We found some cases of attempted subversion, where a small number of students systematically rated themselves with the highest scores and others with the lowest scores. These cases were easily detected using simple, semi-automatically produced outlier analysis.

B. *Teacher satisfaction*

In our context, we have evaluated the framework with three different teachers. While the results of this evaluation are experiential and cannot be generalized, we find it important to report on these experiences to enable other teachers to determine whether our approach is of value in their context.

Our first finding relates to the goal of easing the teacher's workload. We found the framework to be non-intrusive and supporting formative assessment and feedback during the capstone courses. The framework required no extra effort during the courses, and the teachers were able to devote their time to in-situ instruction. At the end of the course, some administrative effort was needed to administer the on-line questionnaire, collect the results, and perform the required data analysis. However, since many of these tasks were automated or semi-automated, teachers could focus on the intellectual side of summative assessment: interpretation of the numeric results and comparison of them to other assessment sources, including notes taken during the course.

One of the teachers voiced concerns regarding fairness and comparability between students and projects. However, we found that when used as a decision-support tool for assessment, the framework did not introduce any fairness concerns. This was also reflected in students' attitudes – all students were given the same opportunity to grade themselves and each other, and the teacher validated the results so that unfair biases were accounted for in the final grade. Cross-project comparability is still an issue, however, but it is not unique to this framework. Each capstone project is inherently different, and maintaining the level of realism often desired in such projects means that comparisons of performance are difficult.

VI. CONCLUSIONS AND FUTURE WORK

In this article, we have described our tacit skills assessment framework, which is an easy-to-use decision support utility for evaluating students' teamwork proficiency. The framework has been evaluated with data from 18 bachelor's and 11 master's-level capstone projects, where it has been found to provide reasonable support for teachers in evaluating tacit, social, and teamwork skills. We found that the framework guarded against rater bias, that its dimensions were well understood, and that it matched teachers' expert ratings. Our results are relevant in the context of project-based courses emphasizing experiential learning and agile methodologies.

We suggest including self- and peer assessment into software capstone projects. However, although technically possible, one should not base assessment of students in capstone projects only on the values provided by the self- and peer ratings. We suggest using additional criteria that takes into account several other data sources, such as version control system commits and their quality. In addition, feedback on the overall project can be obtained from the customer as well as a possible team lead or coach. Aggregating scores into a final grade requires experimentation and the inclusion of teacher judgment.

In case participants display behavior that is not seen as beneficial for the team, additional assessment criteria can be added to the framework due to it's small size. As an example, a few participants in our current bachelor's level software engineering projects have displayed a tendency for "safety seeking", where individuals have avoided working on tasks that require learning new tools and practices. Additional incentives for moving away from the comfort zone have been introduced via a new assessment criteria "How well did the participant handle tasks that required learning new tools and practices?".

We are currently considering a replication study to evaluate the framework in a Software Factory in another country, as well as evaluating approaches to make the framework easier to use. Other possible directions include formative assessment support, and determining the association between framework factors and objectively measurable metrics such as code metrics.

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Assessment of Engineering Faculty Performance in the Developing Academically Autonomous Environment – VIT, Pune, India – A Case Study

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Abstract— **The necessity of Documenting and quantifying the accountability of faculty in Higher Education Institutes (HEI) is gathering momentum in countries all around the globe. In India, where Academic Autonomy is slowing spreading its wings outside the Indian Institute of Technologies, National Institute of Technologies and Government Engineering colleges, into the group of Private unaided Engineering Institutions, the need is felt to develop a rubric for assessing faculty performance in a Quantitative manner. Addressing to that need, various attributes are identified which are essential for assimilating a 'complete faculty performance'. This paper details out these efforts and its outcomes in one of the leading Private Engineering Autonomous Institute in the academically progressive western part of the country. The teaching performance of the faculty along with academic, co-curricular, extension and research activities is quantified into a credit based assessment system (CBAS). This system is run under Quality Management Systems adopted at the Institute. This faculty performance assessment is observed to have helped in identifying better performing as well as poor performing faculty. Also the targets for the subsequent Academic year can be set up with clarity and transparency**

Index Terms— Higher Education Institutes (HEI); Faculty Performance; Academic Development; Co-curricular and Extra-curricular contribution; Research contribution; performance Points (PP); Performance index (PI) ; Weightage based Indexing (WBI); Credit Based Faculty Assessment

I. INTRODUCTION

The Indian Higher Education System is a matured and established system. The strong emphasis on basics of Mathematics and Sciences at school level has traditionally assisted the Engineers to comprehend the Engineering concepts effectively. The contribution of Indian Engineers in Academics as well in Industry all across the globe is well recognized and respected. The traditional methods of teaching – learning with an emphasis on classroom teaching supplemented by laboratory practices have been the backbone. Yet over the last 2 decades, with globalization and emerging opportunities, the number of opportunities for able and competent Engineers has increased many folds. Many authors such as [1] have commented about this issue from a similar if not identical perspective.

Also with the advent of ICT (Information and Communication Technology) based practices, the modern teachers also have had to equip themselves to suit the needs of the new generation of Engineering students. While the knowledge management infrastructure through the use of ICT has grown, we still need to rethink of conceptual network, research agenda, strategies and models that are more adaptive and responsive [2]

In order to ensure that the local, National and Global need of engineers is met with in sufficient numbers, there has been a planned growth in the number of Higher Education Institutes (HEI) [3].

The role of the Engineering teacher is also changing into a facilitator rather than only a classroom or laboratory advisor.

For academically competent Institute such as the one considered here, Academic autonomy is granted. The Academic decisions can be taken autonomously by the Institute. Hence after the absorption of the admitted students at the First Year of Undergraduate level, the Institute designs its curriculum, sets up its own Question papers and carries out assessment and awards grades to the students at the end of 4 years of Undergraduate Engineering course. The student performance is mapped in terms of a Cumulative Performance Index (CPI) on a scale of 0 to 10. While executing this entire activity, the role of a faculty in the multi-faceted development of student is very critical. Hence as a quality conscious and progressive Institute, specific efforts are taken to monitor and evaluate the faculty performance in the campus on the basis of a novel assessment mechanism. The application of quantificational method helps to improve the effect of performance evaluation of staff members in the Institute [4].Authors in [5] share a similar opinion that a well-structured performance appraisal system that is based on quantifiable objectives & standards can lead to achieving a high level of accountability. According to the Author of this FIE conference paper, this is the blending of various appraisal areas for the holistic development of the faculty, thereby consequently the student.

II. IDENTIFIED AREAS IN THE ASSESSMENT SCHEME

The modern faculty in a progressive and developing Institute is expected to contribute in Quality Teaching as well as other essential areas. For an Institute with around 4000 students, running 23 programs (UG, PG and PhD combined) the appointed faculty is expected to commit and support the technical growth of the student as well as Institute growth.

Various elements of effective performance appraisal were identified and exploration of domains and dimensions of faculty performance was made in [6]. The major domains commonly identified were teaching, service & research along with faculty development and administration in some cases in the same paper.

With these broad set of ideas in the Assessment scheme the following domain areas suitable for the Institute working culture as shown in Fig. 1 are considered.

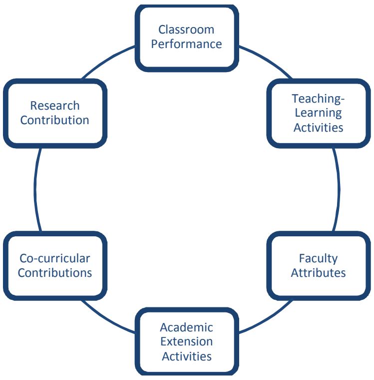


Fig. 1 – Areas considered for Assessment Scheme

A. Classroom Performance of the faculty – on the basis of the Staff Classroom performance feedback given by the students across the entire Academic year, the quantified performance rating called Performance Index (PI) is calculated.

B. Teaching and Learning Activities – The faculty involvement in Teaching learning, the adherence to academic deadline, amendment of course contents etc. along with efforts taken for slow learners are considered.

C. Faculty Attributes – An Engineering Faculty is a highly Intellectual, sensitive human being. While teaching the courses, keeping abreast with emerging technical areas is equally necessary for the faculty. The faculty as an individual, faculty playing the role as a colleague is as important in the faculty growth as well as in sustenance of the quality of the deliverables. This fact is also mapped in Faculty attributes.

D. Academic Extension Activities –Design and development of in-house projects, laboratory setups, development of Additional supplementary Course material, providing additional learning opportunities beyond the syllabus to students is as important. The liaison of the faculty with Industry around is vital, for the experiential learning of the students. In that regards, efforts taken by the faculty to provide Internship opportunities, or sandwich training or arrangement of a useful Industrial visit is considered under these activities.

E. Co-curricular Contributions - The typical organizational skills for scheduling and executing Conferences, Workshops, Short Term Training Programs for faculty, refresher courses for Industry, Certificate Courses for community around as a service to Society are all encouraged and recorded. Work carried out on the platforms of technical bodies such as IEEE, SAE, ASME, ISA etc. is considered. The Entrepreneurship initiatives taken by faculty are weighed highly.

Besides this the faculty is expected to contribute in various statutory or incidental committees at Department level or the Institute level. Based on the nature of work, corresponding 'credits' are given to the faculty.

F. Research Contribution - Although the Institute is predominantly an Undergraduate Teaching Institute, a lot of emphasis is given on Research initiatives and significant outcomes are expected from senior faculty involved in research on National and International forums. Various areas of research were discussed during the evolution of the format and considered worthy to be included. It is seen that not only does it help in quantification of the performances, they act as clues for junior faculty

Typical areas such as Publications, Consultancy, Patents, Technology Transfer, Innovations, Research Guidance etc. were considered. The assigned credits and other details are provided in the later part of the paper.

The domain areas D & E are equally important as highlighted by author in [7]

III. IMPLEMENTATION DETAILS

Area A – Classroom Performance of the faculty :

This area is of significant interest amongst academicians. The authors in [8] enlisted the common strengths and weaknesses amongst faculty, and also presented implications for continuous quality improvement.

In the chosen Institute, Faculty Feedback on the basis of regularity, delivery of basic concepts, ability of explanation of applications, communication skills, blackboard & multimedia presentation, interactiveness, class control etc. is carried out. The students rate the faculty performance on a scale of 0 to 10.

Such feedback is compiled on a question wise basis for the entire division . The faculty performance for the entire Institute faculty is ranked for each question. Performances above average and those below average are awarded positive and negative Performance points (PP) .The group of faculty in a certain band are identified on the basis of Gaussian distribution.

The ranked performances are obtained and graded for all questions. However based on the significance and impact of each question a Weightage based Indexing (WBI) is done. E.g. a greater scalar multiplier is used for question based on Communication skill, presentation and delivery of concepts while the weightage for regularity is less. Once the scaling is done, an overall performance Index is calculated.

A sample table for obtaining Performance Index as a resultant is as shown in Fig. 2

Sr. No.	**Initial**	**PP For Q1**	**PP For Q2**	**Q1*1.25 (a)**	**Q2*1.5 (b)**	**PI (a) + b)**
1	SJ	2	-1	2.5	-1.5	1
2	MK	-3	-4	-3.75	-6	-9.75
3	MP	6	8	7.5	12	19.5
4	AM	8	7	10	10.5	20.5

Fig. 2 – Sample Performance Index Calculation

This feedback activity is carried out 4 times in the academic year. The performances of all 4 feedbacks are combined and the final Performance Index is calculated. The entire activity is shown in the flow chart as shown in fig. 3

PI Calculation for One Feedback(n)

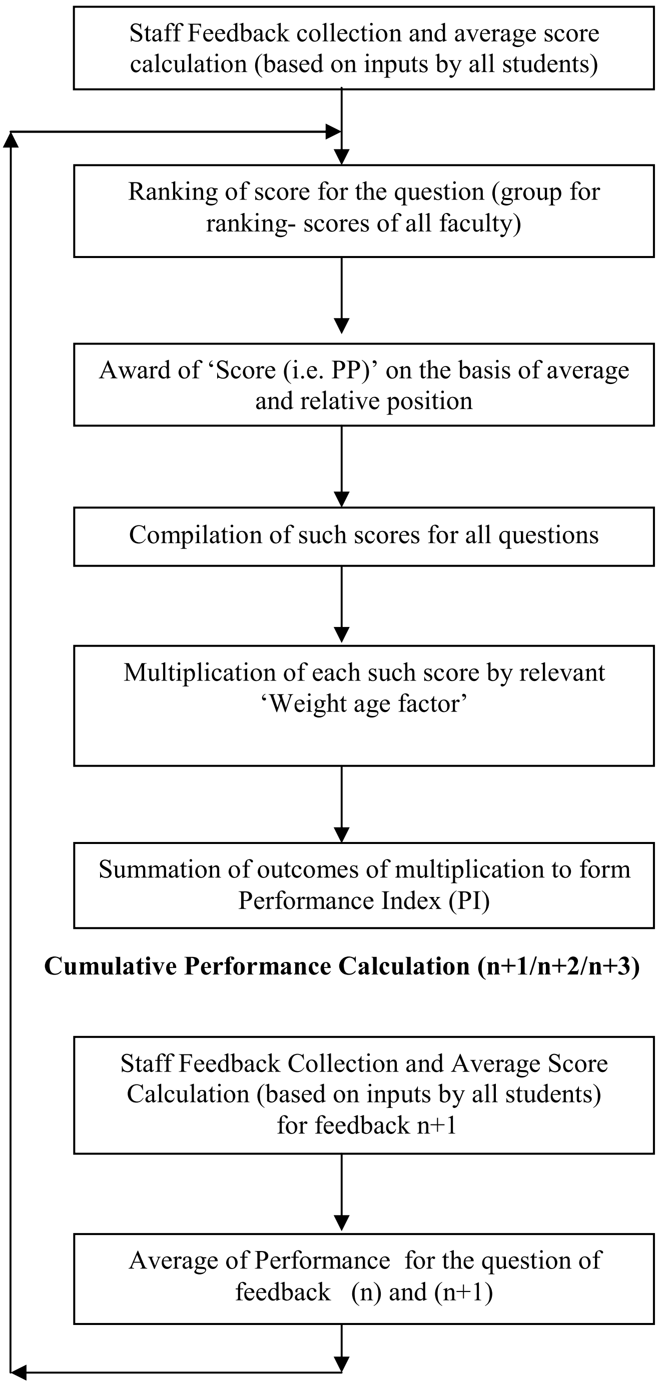


Fig. 3 – Flowchart – calculation of Performance Index

Areas B to F –

For Other areas , formats as shown in fig. 4 are designed. Based on the significance of the parameters credits are assigned.

fig. 4 (a) Area B : Teaching and Learning Activities

Sr. No.	**Parameter**	**Credits**
1	100 % conduction of assigned teaching load	10
2	Adherence to the paper setting and assessment deadlines (End Sem. Exam, Mid Sem. Exam, Class Test, etc.)	4
3	Course file and its regular updation	2
4	Release and assessment of Home Assignment as per schedule	2
5	Extra efforts for slow learners	2
	Total Number of Credits	**20**
	Performance Index (PI) = $(S_1 \times C_1 + \ldots\ldots + S_5 \times C_5) / 20$	

fig. 4 (b) Area C: Faculty Attributes

Sr. No.	**Parameter**	**Credits**
1	Teaching performance	4
2	Technical knowledge of subjects	4
3	Discipline	2
4	Regularity & punctuality	2
5	Attitude towards colleagues	2
6	Attitude towards students	2
7	Motivation towards work	2
8	Awareness of technical education sector	2
9	Willingness to accept responsibility and take decisions	2
10	Willingness to contribute besides office hours as per need	2
11	Willingness to learn	2
12	Ability to do and get good quality work done	2
13	Behavioral aspects	2
	Total Number of Credits	**30**
	Performance Index (PI) = $(S_1 \times C_1 + \ldots\ldots + S_{13} \times C_{13}) / 30$	

fig. 4 (c) Area D: Academic Extension Activities

Sr. No.	Parameter		Credits
1	Syllabus enrichment by providing additional resources to students		2
2	Use of participatory and innovative teaching - learning methodologies		2
3	Contribution towards theory and laboratory course development		2 / course
4	Contribution towards GP / PD / SD / OE / Elective course development		2 /course
5	Conduct of Continuing Education Program		4 / program
6	Design and development of Diploma courses		4 /course
7	Design & development of Certificate courses		2 /course
8	Development of quality in-house projects		2 /project
9	Academic resource person		2 / session
10	Creation of industry exposure opportunities for students		
	a)	Internship	2 / group
	b)	Sandwich training	4 / student
	c)	Industrial visit	2 / visit
11	Attending faculty development program		2 / week
12	Attending industrial training of minimum one month's duration		6 / month

Fig. 4 (d)Area E : Co-Curricular Contributions

Sr. No.	Parameter		Credits (Per Activity)
1	Organizing Short Term Training Programs (Minimum 1 week)		10 for Co-ordinator / week 2 for team members / week
2	Organizing Workshops		1 for Co-ordinator / day
3	Organizing conferences		
	a)	International	10 for Co-ordinator 3 for Team Members
	b)	National	6 for Co-ordinator 2 for Team Members
3	Organizing guest lecture		1 / lecture
4	Services to community		2 for Co-ordinator 1 for Team Members / day

Fig. 4 (e) Area F: Research Activities

Sr. No.	Parameter	Credits
Research Paper Publication		
1	Journals *Credits to be augmented as :* *1 credit per 0.5 impact factor of the journal,* *2 credits if the appraised faculty is the first author*	10/ Publication
2	International Conference *Credits to be augmented as 1 credit if the appraised faculty is the first author*	8 / Publication
3	National Conference / Magazine articles	4 / Publication
4	Reviewer	4 / Review
Book Publication		
1	Published by International Publisher *Credits to be augmented as 2 credits if the appraised faculty is sole author*	10 / book
2	Published by National Publisher which has ISBN / ISSN Number *Credits to be augmented as 1 credit if the appraised faculty is sole author*	5 / book
Research Publication		
1	Sponsored Projects	
	a) Amount Sanctioned	3 / 0.1 Million Rs.
	b) Amount Utilized	3 / 0.2 Million Rs.
2	Consultancy Projects – consultancy worth	3 / 0.1 Million Rs.
3	Completed Projects (Acceptance from funding agency) – credits to be earned on the basis of the cost of the project	3 / 0.1 Million Rs.
4	Projects Outcome (Patent Awarded / Technology Transfer / Innovative Product)	
	a) International	10
	b) National	6
I.R.G. (Internal Revenue Generation)		
1	Self sustained activities	3 credit per Rs. 25000 institute share
Development of Laboratory Experimental Setup		
1	As a part of curriculum development	4/ experimental set-up
2	As a Joint Venture with companies	6/ setup

IV. RESULTS

1. Classroom Performance of faculty

A tabular mapping of the same on the basis of various areas is done as under. Each column represents a parameter and each entry is the Performance Point (PP) given to the faculty

Staff	Regularity	Delivery	Communication	Presentation
AH	-2	8	7	9
GN	8	8	9	1
IK	6	7	8	7
DD	-6	-6	-5	-4
SG	9	1	-1	-2

In the actual database, 196 faculty for the current Academic year are considered.

Variance is calculated for all faculty to highlight the abnormality rank in a certain area.

Important conclusions such as the following can be drawn i) for faculty AH – the performance is excellent except the Regularity. ii) for faculty GN –presentation skills need to be improved. iii) faculty IK has a steady performance iv) faculty DD has a steady but poor performance v) faculty SG has only got excellent regularity

In the actual database applying the method for 196 faculty members , conclusions are derived such as

i) No. of faculty requiring communication skill training – 22
ii) No. of faculty requiring inputs for improving presentation skills – 15
iii) No. of faculty needing subject specific technical training – 18

The feedback is given by around 4000 students every time, hence covers out individual biases towards faculty.

In case of credit based activities, listed in Results pt. No. 2, 3 & 4, the faculty self Appraisal is followed by appraisal by mentor and Head of Department. This averages out self bias if any. The claims made by faculty are verified through documentation support.

2. Teaching – learning activity & Faculty Attributes -

As can be seen from the table listed above, the performance of the faculty is calculated using a Performance Index (PI) , while the faculty earns 20 and 30 credits resp. in these 2 areas.

The faculty is expected to perform on all parameters in the Teaching – learning areas.

The scores in the two areas mentioned above are recorded for all 196 faculty.

3. Academic Extension Activities and co-curricular contributions

These are open ended areas for faculty to earn credits. Based on the requirements of the Department or the Institute, as well as individual interests and abilities, the faculty members tend to involve themselves in a variety of Academic Extension activities, as well as in many co-curricular contributory areas.

4. Research Activities

As shown in the table, a faculty is encouraged to be involved in a number of research activities.

The Institute offers the faculty all basic support desired to contribute the research activities.

V. OUTCOMES OF CYCLE AT THE END OF ACADEMIC YEAR

In the recently concluded Academic Year, this activity has resulted in the following outcomes shown here on Department wise basis as well as in terms of overall Institute performance

1. Classroom Performance of faculty –
Average Institute Performance Index – 13.155
The Indices for Departments are as shown below in Fig. 5

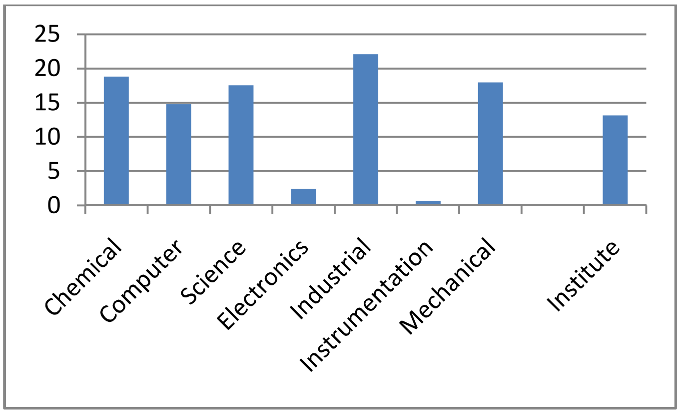


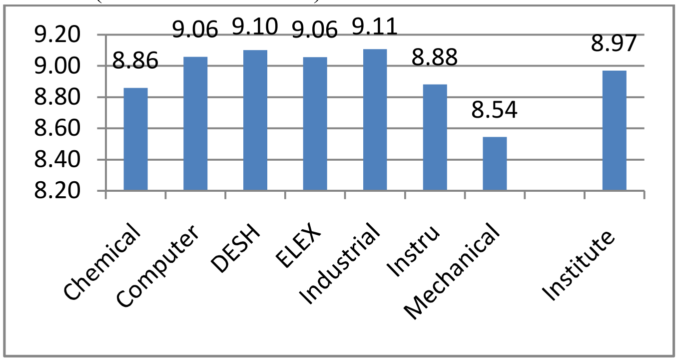
Fig. 5 – Performance Indices for Institute and Departments

Head of Department of Instrumentation and Electronics are informed to emphasize more on improvement of Quality of Teaching – Learning.

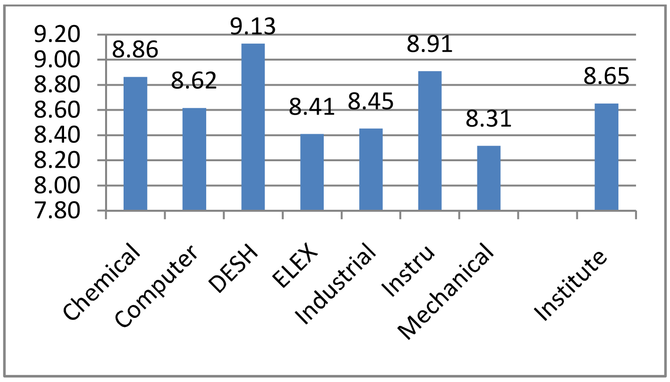
The faculty is deputed for Pedagogical training and various classroom performance improvement workshops.

A number of in-house activities are also carried out by well appraised faculty of the Institute.

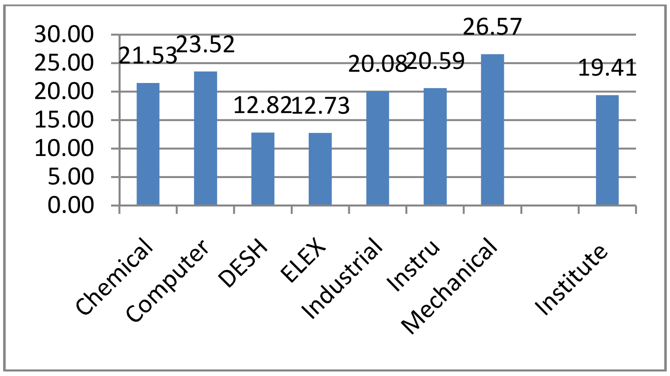
2. Teaching and Learning Activities (on a scale of 0 to 10)



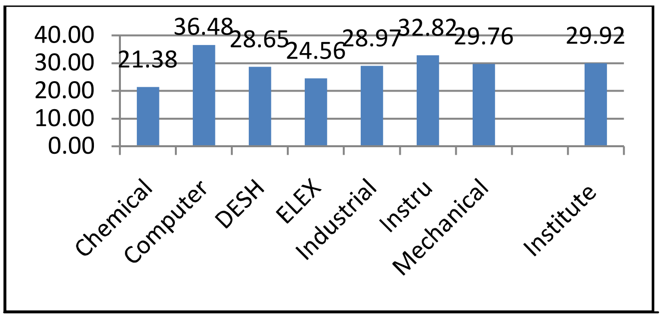
3. Faculty attributes (on a scale of 0 to 10)



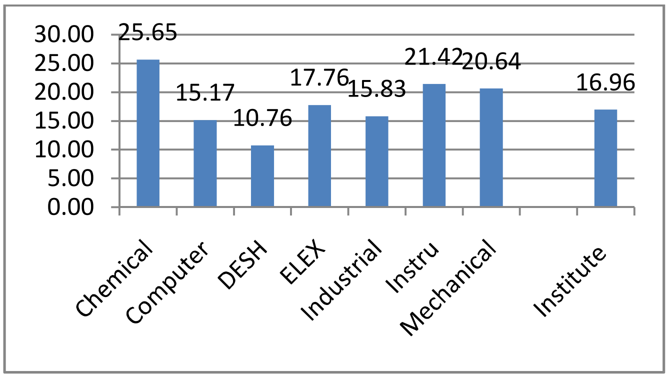
4. Academic Extension activities



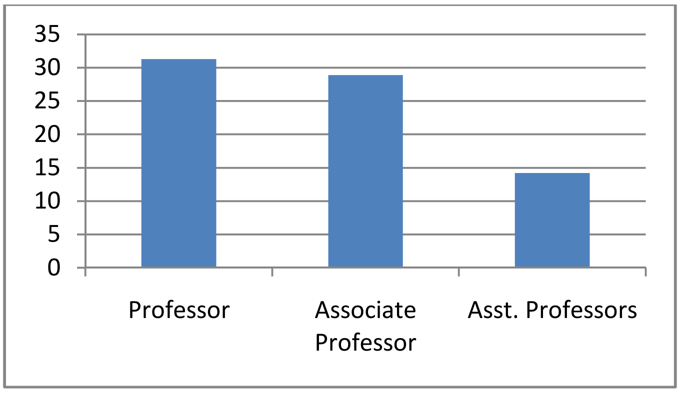
5. Co-curricular Contributions



6. Research Activities



Cadre wise Research Contributions



VI. BENEFITS

1. The planning and benchmarking in various areas or across the Departments is possible through this exhaustive analysis
2. The Institute implements ISO 9001:2008 Quality Management System. It helped streamline the entire compilation of outcomes at individual as well as Institute level
3. The preparation of documentary evidence for the National Accrediting bodies such as National Board of Accreditation (NBA) and National Assessment and Accreditation council (NAAC) is automatically done as a benefit of this activity.
4. Cadre wise targets – especially in the area of Research are given to Professors and Associate Professors in the subsequent areas.
5. Based on the identified areas of involvement of faculty, the Department and Institute activity plan is prepared.

VII. FUTURE PLANS

Some approaches such as 'Format Concept Analysis (FCA) as used by [9] are being studied for a more systematized approach. Effective conversion of the observations when collected over the span of 3 years can be made into defining the short range and long range goals for the Departments and the Institute.

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Risk management in scientific research:

a proposal guided in Project Management Book of Knowledge and Failure Mode and Effects Analysis

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Abstract— **The achievement of different university degrees (from graduate to the specialization, master's and doctoral) usually is related to the development and presentation of research results conducted by an Academic Advisor. However, their finalization or the results may be adversely affected by the lack of identification of risk that may present themselves during the process of construction and development of the research. To minimize these impacts, the present study was based on the alignment and adjustment of processes present in the Project Management Body of Knowledge (PMBoK), a specific guide that consolidates the best practices of project management from the Project Management Institute (PMI), and the use of Failure Mode and Effects Analysis (FMEA). From such elements and the identification of factors relevant to the educational institution involved and the processes related to the advisory and development of scientific research, it was sought to build a proposed risk analysis in the academic, named Academic Project Risk Management Plan (APRMP). This aims to contribute to the discussion and gathering information that can support the Advisor and the student at all stages of the research (planning, development and conclusion) that downside risks are avoided or minimized and that opportunities become clear and effective possibilities.**

Keywords—risk management; scientific research; PMBoK; advisoring.

I. Introduction

The development of scientific research constitutes a challenge for the students of higher education, graduate school, etc. especially because it has to be finished on time, with the depth degree required or even with the quality expected by the advisor. These issues affect not only the projects in academic area as projects in general. That is why it has been studied and mapped over the years by the Project Management Institute (PMI) [8], who also built project management guidelines (consolidating a guide named Project Management Body of Knowledge – PMBoK) from the best practices identified [7]. Even one of the factors influencing this scenario involves failures in risk management.

In the case of scientific research carried out for obtaining the degree, it can be point out that the risk management allows the reduction of problems throughout the investigation, and identification of factors that imply changes (whether in scope, timeline, resources , etc.), which results in increased chance of completing the search in accordance with the proposal.

The conduction of risk management is related to the mapping of factors involved in Educational Institution, especially in processes relevant to the scientific research development (under supervision) as well as the analysis of the Research Advisory Breakdown Structure (RBAS) [5] and the Academic Research Project Plan (ARPP) [5]. From this context and the use of FMEA (Failure Mode and Effects Analysis) [3]-[10] is possible, through analysis and planning meetings, set up a risk management plan in academic scientific research (RMPASR).

To deepen these introductory elements of risk management in academic research projects, this paper is organized as follows: section 2 describes the steps involved on management of scientific research projects and its overall structure; section 3 addresses from setting up risk as this is characterized in the academic field, and strategies to reduce, prevent or eliminate risks in this context; section 4 deals with the use of FMEA as a tool associated with risk management in academic scientific investigations; section 5 presents the proposal of a risk management plan for academic research; and section 6 provides the conclusions of the study as well as further work arising from this.

II. Stages for Academic Management of Scientific Research

Considering the institutional needs, as well as the people involved in the management of academic research (ie, the Advisor and the Course Coordinator, regardless of the degree involved), it becomes necessary to introduce a way of managing such process. Therefore, it can make an adaptation of processes under PMBoK [7] for the mapping and development of academic investigations.

In this sense, the Academic Management of Scientific Research Projects covers a variety of processes that can be adapted or inspired by similar elements present in PMBoK [7]. Among these are highlighted the development of a Project Charter focused on Research Advisory Breakdown Structure

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(RBAS) [1], the own establishment of a RBAS, as well as a pertinent Dictionary [5].

A Project Charter [5] formalizes the beginning of scientific research project under the supervision of an advisor (and a co-supervisor, if applicable), gathering information relevant to its early stages, in addition to being a tool for decision during the research. This deliverable includes, therefore, the project scope for academic research, the expected results (both, from the institution or the advisor), the identification of macro tasks of scientific research (for periodic control) and the deadline for finish investigation.

Such information, upon approval, is broken down subsidizing the development of a Research Advisory Breakdown Structure (RBAS) [5]. This, through decomposition and hierarchy of elements present in the Project Charter on "work packages" [7], aims not only graphic visualization of parts of the research that can be delivered over its implementation, as well as configuration of its life cycle.

From RBAS the Dictionary can be built [PMI, 2008]. This aims to map the integral elements of RBAS and have acceptance criteria. Thus, each work unit is identified as the expected result and the degree of acceptability [5].

In fact it is possible to compare the result of the Dictionary prepared with a kind of educational rubric, i.e. a structure consisting of specific criteria (scored and described) for review [2]. Considering each of the characteristics inherent in the balance is the decomposition of a task into smaller parts, and each applicability of this strategy is a written communication (organization / textual expression) [11]. It can be inferred that such a device is aligned due to its architecture, to the pertinent Dictionary described above.

It should be highlighted also that the rubrics allow student/students in process-oriented view of the evaluation process dimensions [2], as well as contribute to the development planning of quality researches [1]. Finally, it should be noted that this proposed Dictionary is, by analogy, a kind of holistic rubric. This is because it has a single score (lower levels) for performance evaluation of student/students.

The set of deliverables detailed above, therefore, provides grants that contribute to the management plan developed for an academic research project. The latter presents, through the use of scientific language, the theoretical framework adopted, the expected results and schedule (macro activities, as well as dependencies). In order to complement this deliverable, it can also provide an attachment with the quality level required by the institution, risks and opportunities, forms of communication between people involved (students, advisors, institution; synchronous, asynchronous; face, online, hybrid, etc.) and strategies for monitoring and control a scientific research project (which provides for the preparation of meeting minutes and development of research reports).

Also is possible to emphasize that the Academic Research Management Plan, as well as other types of project deliverables, run in knowledge areas provided by the PMBoK [7]: Integration Management, Scope Management (both previously worked), Time Management, Quality Management, Communication Management, Cost Management, Procurement Management, Human Resources Management and Risk Management – theme explored in the next section.

III. The Concept of Risk to its Characterization in the Academic Research Area

According to the PMI [7], risk can be characterized as an event or uncertainty (due to one or more causes) that, if happens, resulting in positive or negative impact in the project. The origin or causal element of a specific risk may stem from a circumstantial condition or requirement of a premise of the project itself or even a restriction. From the academic point of view, it can be considered the following examples:

- Circumstantial condition – lack of specific equipment (that can be purchased, borrowed, etc. in another time);
- Requirement/Premise – fluency in a particular programming language present in the student academic curriculum;
- Restriction – time required for the research, number of members in a group of researchers, etc.

The existence of risk does not necessarily imply the change or abandonment of the project. It is necessary to analyze them in relation to the degree of its acceptability and tolerance and mapping its implications, whether these are negative or opportunities, that may be obtained from the risk probabilities calculation. In this sense, a project requires a proactive approach to risk management; otherwise the severity of the event may result in project failure [8]-[6].

Therefore, managing risks in a scientific investigation to achieve a particular degree, presents a series of advantages, among which the following:

- Construction of a reliable framework for design research and decision-making throughout their realization;
- Visualization of the threats/opportunities relevant to research (which allows to establish mechanisms for the reduction or mitigation of threats and exploiting opportunities, including taking into account the terms and requirements associated with research publication, if applicable);
- Analysis of variables that integrate the risks directly related to the issue of scientific publication selection (time, scope, research results (partial/complete), scientific publication – journal or event – impact factor, and other related topics involved in decision making);
- Reduce the number of contingencies.

From the PMBoK viewpoint [7], the risk involved in the academic research can be adapted as described below:

- Management (setting as risk management will be performed in the development of scientific research under the supervision of an advisor);

- Identification (lifting of risk to research and documentation of their specifics);
- Analysis (qualitative – classification/prioritization of risks through assessment of occurrence versus impact in the context of the project – it can be classified as low, medium or high; quantitative – measuring the probability of occurrence and consequences of the estimate for the project, which depends substantially on the experience of the advisor provision by this, and a risks knowledge base relevant to the field of research area);
- Planning (establishing procedures to analyze the opportunities and minimize possible risks to the research, i.e., in a practical way to structure alternative paths that achieve the objectives set for the research planned in the time provided and with the resources available; for this the advisor and the student/students should hold meetings with regularity).
- Monitoring (involves controlling residual risks, as well as identifying other risks not mapped to this stage and, simultaneously, the institution of plans which enable the reduction of the risks impact and evaluation of the effect of risk management throughout the academic research project).

Regarding the analysis process, it is also important to highlight the historic [6] due to previous advising procedures. This can contribute positively to the performance of the advisor as a leader and mentor of scientific research as well as for monitoring throughout the process of conducting research. Also in relation to this process, the quantitative characterization of the risks can be drawn from the use of tools such as SWOT analysis (Strengths, Weaknesses, Opportunities, Threats), Decision Tree, Brainstorming [4], Failure Mode and Effects Analysis (FMEA) [3], among others.

Another detail to consider, with regard to planning, involves drawing up a contingency plan [6]. Such proposal must also consider effects or undesired side effects due to the implementation of these measures. Considering that the preparation of contingency plan depends on the preceding steps, especially a correct analysis, that consider the FMEA framework as a complementary strategy for quantitative analysis in the academic development of scientific research.

IV. Failure Mode and Effects Analysis in the Context of Academic Development Of Scientific Research

The framework named Failure Mode and Effects Analysis (FMEA) was developed by the U.S. Army in order to eliminate problems/defects/errors in equipment that could not suffer intervention after the launch into space [3]. The FMEA framework aims to prevent failures are up in products, services, processes or systems purchased by the consumer. Thus, the FMEA is a method of examining all aspects in which failures can occur [10].

In the academic context, it is essential not only to identify potential risks depending on the type of research conducted, but also the analysis of their impact and the probability of occurrence in order to establish prevention strategies and monitoring. Therefore, it is also necessary to work with the recognition of factors that may be the generators of such risks, analyzing their dynamics over time to define mechanisms of prevention, mitigation and transfer.

The application of this framework begins with the following steps: "failure mode" (problem identified), "effect" (consequences) and "cause" (source/sources of failure). Although there is no single linearity and correlation between failures and causes, what makes a list an essential element for the construction of FMEA. From this, it is possible to classify the impact, the ability to recognize the failure (including his way of detection) and frequency of occurrence, and its product generates the Risk Priority Number (Risk Priority Number) [10].

However, it should be noted that although the contribution they can bring to the FMEA analysis and management problems in scientific research, it is necessary to choose a complement dynamic to complete the process of risk analysis. It is necessary because the FMEA turns to threats, i.e. to the negative aspects of the risk. However, its use associated with the PMBoK [PMI] can contribute in different ways, each in the risk rating (which includes strategies to Prevent, Mitigate and Transfer).

The concatenation of the elements presented in the preceding sections enabled the construction of proposal for a Risk Management Plan tailored to the specific scenario of scientific research in order to obtain an academic degree (under the supervision of an advisor).

V. Proposal of a Risk Management Plan in Academic Scientific Research

As already noted before, the development of the Risk Management Plan involves combining elements of FMEA [3] and PMBoK [7]. In this sense, the Risk Management Plan must provide information that identifies the research (theme and temporary title), the author/authors, the higher education institution where the research will be performed, course and degree of the student/students, advisor (and even co-advisor if is necessary), text versioning, and responsible for approving the plan.

Such documentation also requires the enumeration of processes relevant to risk management in scientific research, as well as the construct of a Risk Breakdown Structure for Academic Research (RBSAR), as exemplified below:

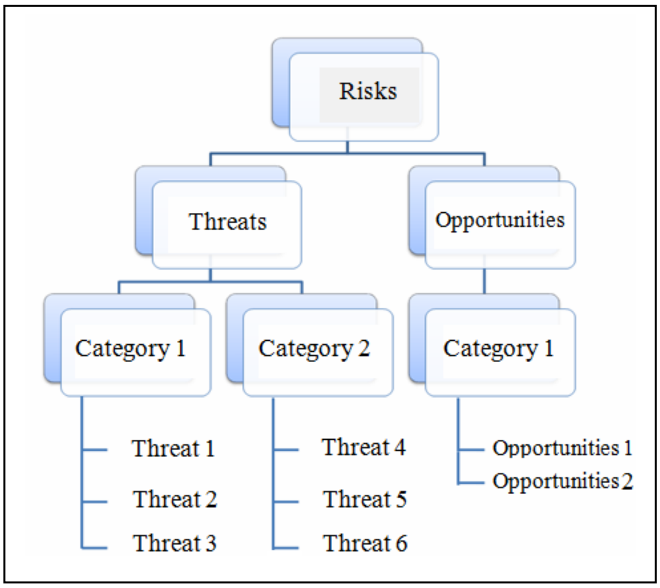

Fig. 1. Example of RBSAR

By the same token, the documentation also requires presentation of the dimensions of risk (qualitative, which involves the probability of occurrence and impact in scientific research, and the quantitative constructed based on FMEA framework).

From this, is possible to establish a plan to response to the risks identified (Table 1). This should match (in order to obtain a numeric parameter) the probability of occurrence, impact, severity (product of the probability impact for probability), the capacity of detection and identification of risk category for academic research. The product result in a risk priority number, with its dynamics must be monitored over time to allow the taking of actions required for the maintenance of academic research.

TABLE I. PLANNING RESPONSES TO RISKS INDENTIFIED

Risk <Identification of the Risk to Academic Research>							
P	***R***	***S***	***D***	***C***	***NRP***	***Description of risk response***	***T***

[a.] Label: P – Probability of Occurrence; R – Research Impact; S – Strictness (Impact versus Probability); D – Detection (Ability to identify the risk); C – Risk Category for Academic Research; NRP – Number of Risk Priority; T – Dynamic over time.

It is also worth noting that risk management should be integrated with other deliverables relevant to the scientific research development in order to establish an overview of this. This scenario is represented in Figure 2.

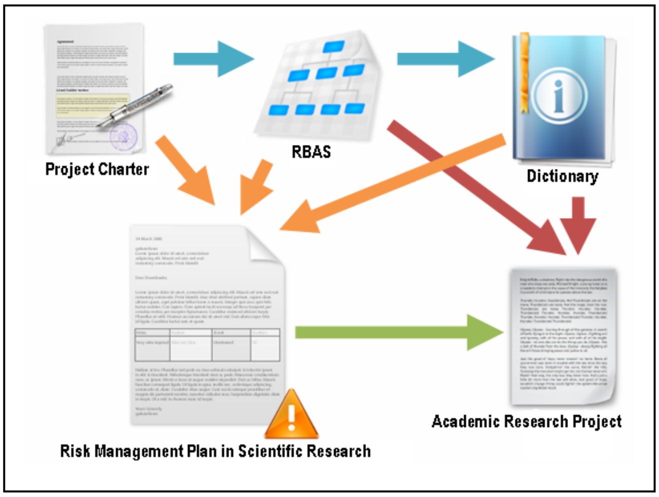

Fig. 2. Integration of deliverables of an Academic Research Project

VI. CONCLUSIONS AND FURTHER WORKS

From the analysis of elements in the area of project management and, more specifically, the PMBoK [PMI, 2008], and his combination with FMEA [3]-[10] it was possible to achieve an alignment of risk management according the specialties of scientific research development under the supervision of an advisor. This resulted in the mapping of elements that need to be included in the Risk Management Plan of Scientific Researche. It is believed that such subsidies (either in full or in part) may contribute to the reduction of uncertainties and the development and conclusion of scientific research with quality, on time schedule, and meet the established scope.

Regarding further works, it is still necessary to analyze the degree of impact exerted by the elements described in view of the proposed calibration and setting weights for these indicators that compose the proposed risk management of scientific research project.

Future studies also involve the construction of an expert system that can be used by the advisor, during the orientation process, to monitor their advisees, as well as for identifying and management of risks that may impair or constitute opportunities throughout development an academic research.

ACKNOWLEDGMENT

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Assessing Conceptual Understanding in Mathematics

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Abstract— **Modern mathematics careers are now requiring conceptual skills such as, critical thinking, modeling, and application of the content. This change in skillset needed for careers has strongly impacted mathematics curriculum and assessment. Meaningful assessment involves examining students' ability to inquire, to reason on targeted questions or tasks, and to promote conceptual understanding, not just focusing on discreet facts and principles. Mathematics assessment tools still focus solely on this procedural side of understanding mathematics instead of the equally important conceptual aspect of learning mathematics. Given that math is an active process that encourages higher-order thinking and problem solving, an assessment focusing on the growth of conceptual understanding is required. The proposed research focuses on the development of a tool that will be used to assess current U.S. calculus students' ability to apply their conceptual understanding of a mathematic concept to scientific phenomena through modeling. The assessment using Netlogo would be very useful for math educators to have good tools to assess students' conceptual understanding, as well as to develop instructional strategies used.**

Keywords—STEM; procedural knowledge; conceptual knowledge; NetLogo; Assessment

I. INTRODUCTION

Calculus is the capstone of K-12 mathematics curriculum. Within the domain of calculus, rate of change is a key concept that is introduced to students in algebra 1 and is foundational to calculus. Conceptual understanding of the reflectivity, *generativity*, and implicatively of *rate of change* is fundamental to students' study of calculus [1,2]. *Procedural* mathematics content knowledge focuses only on reciting algorithms and facts, whereas *conceptual* mathematics knowledge emphasizes students' ability to interconnect mathematics across disciplines, critically think about the content, and communicate key components of mathematics [3.4].

Mathematics assessment tools often focus solely on this *procedural* side of understanding mathematics instead of the equally important *conceptual* aspect of learning mathematics [5,6]. This is due to the restrictive nature of traditional multiple-choice assessments [7]. An alternative assessment tool that could quantify both students' *procedural* and *conceptual* understanding of mathematics could result in alternative instructional materials and methodologies.

NetLogo is a modeling computer language used to create an integrated environment. Students, acting as the modelers, are given tools to represent basic elements of a system. Then the program provides a way to simulate the interactions between these elements. With NetLogo, students write rules for hundreds or thousands of these basic elements, specifying how they should behave and interact with one another. These individual elements are referred to as *turtles* [8]. Students exploring within NetLogo have been able to develop their understanding of rates of change through modeling scientific phenomena [2;9].

II. PURPOSE OF RESEARCH

The purpose of this research is to transform a modeling unit within the NetLogo agent-based modeling program to assess students' conceptual understanding of a key mathematics concept. Students that are successful in high school calculus are likely to choose STEM fields for their college studies [10]. Students on this STEM path should be prepared to apply their understanding of various Calculus concepts to their STEM fields. Therefore, current calculus students should have the ability to connect and apply their understanding of rate of change to another STEM domain. This leads to several questions: 1. How can NetLogo be re-designed as a tool to assess students' conceptual understanding of 'rate of change'? 2. Is students' procedural understanding of rate of change a positive predictor of students' conceptual understanding of rate of change?

III. Background

A. Assessment

Current STEM curricula are beginning to promote the inclusion of higher-order thinking skills [11]. Higher-order thinking skills, related to sophisticated cognition, are difficult to measure with the use of multiple-choice tests. Standard, paper and pencil tests do not accurately measure 21st century skills. These tests are usually composed of low-level facts and recipe-like procedures [7]. This is not the only shortcoming of the current educational climate. State curriculum standards in each discipline are neither inter-related nor prioritized to emphasize core understandings and performances all students will need to succeed in the 21st century, despite the call for interrelated curriculums [11]. There is also a call for students to exhibit higher-order thinking skills, since a successful problem solver must be able to apply different approaches to a problem [12]. Students must demonstrate unusual, original, and creative solutions to various real-life problems, which is difficult on a multiple-choice test.

As a consequence of this misalignment between call for reforms and current assessments, teachers are using weak but rapid instructional methods to pass these limited scope assessments instead of preparing students for 21st century citizenship. These summative, "drive by" tests provide retrospective feedback, rather than immediate feedback that could influence future instruction [7].

Some International tests, such as Program for International Student Assessment (PISA), make attempts to emphasize core ideas and measure higher-order thinking skills. US students are scoring below many of their International peers on this test, but these test do not have the high stakes and accountability standards that state mandated standardized tests posses [7]. Therefore, these lower scores do not impact curriculum and instruction. Modern technology could provide a platform to improve US standardized tests to include assessment of higher order thinking skills, but a lack of resources, as well as, a fear of academic dishonesty has resulted in banning technology from testing. If the goal of assessment is to measure particular expectations, and the current call for students is to exhibit higher-order thinking skills, the assessments themselves need to change.

B. Modeling

Research suggests that modeling tasks "provide opportunities for greater diversity of thinking than is usually found in problem-solving tasks and that the development of students ideas occurs along multiple pathways" [12]. Students develop conceptual understanding of various mathematical concepts when they are engaged in modeling activities that require they research, create, and revise models [12,13].

Modeling is "nominally generative," meaning students are asked to use a prescribed model (single pathway) to create computed outcomes that are often mechanically compared to the actual data collected [15]. Ideal modeling occurs when the learners create a range of models and use them to generate model outcomes. In an agent-based modeling approach-student can model at the individual (elemental) level, rather than an aggregate approach [8]. Modeling tasks need to be composed of multiple-pathways and multiple-outcome tasks. The underlying constructs of othese modeling tasks should be mathematically or scientifically significant [15].

Central to computational thinking is the idea that, given a complex problem, which consists of many different, interconnected parts, one can meaningfully and sensibly decompose the problem into more solvable sub-problems [11]. Breaking down a problem is not a haphazard process. Deep understanding of the systems involved and how they interrelate is required in order to meaningfully break up the problem into pieces that still make sense in relation to the whole. Students that are successful in high school calculus are likely to choose STEM fields for their college studies [10].

Computational thinking and computational problem solving involve a process of revision and iteration. "Use-modify-create" is a pedagogical model that allows students to become familiar with a type of program by using it, then modifying it a bit to make it their own, and finally creating their own program from scratch. In this process, students are applying computational thinking to solve problems and using higher-order thinking skills.

Modeling provides a new perspective of the methodology of math [16]. A detailed analysis of modeling provides characterization of problem solving as a coherent system for constructing models in any mathematical domains. Modeling begins with a physical situation with which we wish to understand [17]. Understanding comes from making, analyzing and evaluating a model for the situation. The situation may be presented to us in any form; for example, predicting the path of a projectile in the study of quadratic functions. From examining the situation, our first task is to come up with a suitable model in diverse ways. Sometimes, we can simply adapt a familiar model to the situation. In any case, students' understanding of what constitutes a model is a useful guide for what to do. The first step of this process is to identify the system [17], then specify precisely what it is we want to model, and then identify the properties of interest and specify variables to represent them. When a model has been constructed, it must be analyzed to understand its structure and implications. The final step of analysis is validation, which is the process of assessing the adequacy of a model to represent a particular system and situation. A full assessment of the model's validity will include an assessment of what is neglected in the model as well as the accuracy of the representation.

III. Research Methodology

A design-based approach will be used to answer the question, How can NetLogo Hotlink Replay be re-designed as a tool to assess students' conceptual understanding of 'rate of change'?

Instructional designers will begin with the NetLogo modeling activity for rate of change in which students model the effects of introducing an infection into a population and manipulate various components (i.e. initial number infected, identifying the infected). While exploring with this activity, students are able to develop a conceptual understanding of the calculus topic of rate of change [18]. Researchers will use a design-based approach to repurpose this activity into an assessment of students' conceptual understanding of rate of change, using an extension of Hotlink replay [9]. Year 1 of the project will focus on development of this tool through iterations of design, utilize, and revise.

Programmers will incorporate prompts and challenges into the Hotlink replay interface. For example, students may be prompted to create a model of an infected agent entering a population and moving randomly throughout the population after viewing the visualization of their model, students may be asked to change the components such as making the graph steeper.

Student participants will be chosen from either algebra 1 classes or calculus classes at the end of the year. The participants will complete the first iteration of the assessment, then they will be interviewed on the topic of rate of change with an interview protocol that focuses on procedural (i.e. the use of slope formula to calculate slope) and conceptual (applying rate of change to graphical representations of biology concepts to make conjectures) understanding of rate of change. Qualitative analysis of the transcriptions will be done to identify evidence of conceptual and procedural understanding of rate of change. The same students will then follow a think-aloud protocol while taking iterations of the assessment. Over year 1, three iterations of design, utilize, and revise will be used to transform the modeling activity into an assessment of procedural and conceptual student understanding.

Once the assessment has been revised and the research suggests that the score associated actually matches the qualitative analysis of students' conceptual understanding of 'rate of change,' then scores on the assessment will be used to answer the second research question: Is students' procedural understanding of rate of change a positive predictor of students' conceptual understanding of rate of change?

During year 2, the algebra 1 and calculus student participants will be assessed using the designed NetLogo modeling assessment as well as taking traditional, multiple-choice assessment on the topic of rate of change. This traditional assessment will be designed mirroring the types of multiple-choice questions on traditional standardized assessments that test understanding of 'rate of change'.

The teacher participants will assign each student 4-digit number to de-identify the student scores. If collected data show normal distribution, a series of paired t-test for within group comparison will be performed to determine if significant difference existed between procedural scores versus conceptual scores. When the normality assumption is violated nonparametric method like the Wilcoxon signed ranks test will be used. We will use SPSS 21 version for analysis. The SPSS data output will demonstrate basic descriptive statistics for samples and variables, correlation table, and the matched mean difference between the pairs.

IV. Implications

Research suggests that the ideal classroom environment is the use of technology to assess student learning and inform math instructors' ability to prepare students for STEM career paths. One of the primary objectives of this proposed work is to redesign a NetLogo simulation to assess students' conceptual understanding of mathematics. This assessment will assist the educational community to establish students' understanding of rate of change and potentially design a new math curriculum. Our vision is that this assessment could result in a change in the mathematics curriculum. With the possibility of teaching students concepts earlier or have students take algebra 1 in 8th grade.

This project can potentially create a tool that will assess a skill that previous tools could not assess in mathematics. Since mathematics is key for engaging students in STEM careers and majors, having a tool that identifies the best and brightest will impact the future of the STEM field in the United States. The most innovative aspect of the proposed work is the use of NetLogo to assist student conceptual development of rate of change. This closer look at instruction using NetLogo will inform new forms of assessments designed to measure students' conceptual understanding.

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Sustainable Energy Engineering Internships for Community College and High School Students

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***Abstract*— As a result of a partnership between the University of California Santa Cruz (UCSC) and a Hispanic-serving Institution, Hartnell College, a micro-grid and test bed facility are being constructed at Hartnell's Alisal campus. The facility will provide a real-world student training center on renewable energy technologies where students can participate in research to develop new, experimental renewable energy generation systems. Over the next several years, Hartnell's Sustainable Engineering laboratory courses will be transitioned to focus on the microgrid and test-bed. Related courses and lab modules developed at UCSC will also be integrated into the program. An early outcome of this collaborative partnership was the internship support of teams of high school and community college students working with UCSC graduate students on several different sustainable energy projects over the summer of 2012. Program mentors and interns all reported a high degree of satisfaction with their internship experience.**

Keywords—renewable energy, sustainability, microgrid, green technology, research internships, undergraduate research experiences

I. INTRODUCTION

Hartnell College, located in Salinas, California (see Fig. 1), is a Hispanic-serving, 2-year institution with an enrollment of approximately 10,000 students. Its Alisal Advanced Technology campus is bounded on three sides by agricultural fields and on one side by an underserved, urban minority neighborhood. See the lower inset in Fig. 1.

In 2011 Hartnell was awarded a 3-year grant from the National Science Foundation (NSF) to fund the Salinas Valley Consortium for Sustainable Energy, Education and Research. The aim of the Consortium is to create career pathways in electrical and sustainable design engineering. Partnering with local research institutions, non-profit organizations and high schools, a key component of this grant is to establish the sustainable energy laboratory and microgrid. To expand upon the growing success of Hartnell's sustainable engineering programming, Hartnell partnered with UCSC to develop a summer internship program focused on sustainable energy research and specifically 3 of UCSC's microgrid pilot projects in the California Central Coast region (see Fig. 1).

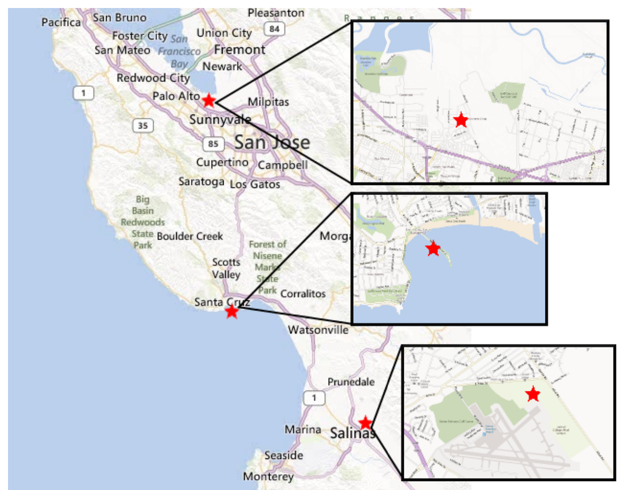

Figure 1 CenSEPs Microgrid Locations (north to south: NASA Ames, Santa Cruz Municipal Wharf, Hartnell's Alisal Campus)

The theoretical basis operationalized in conducting the internship program centers on "educational models that go beyond teaching codified "what" facts to models that emphasize "how": that train students in the transdisciplinary, collaborative ways of knowing-how." [6]

II. SUSTAINABLE ENERGY RESEARCH PROJECTS

To better prepare this unique assemblage of interns to produce high quality research outputs, all interns participated in various phases of research activities specific to each project along with a "professional development" program which discussed issues such as project presentation and project management. To complement the research activities and professional development, interns listened to presentations by energy researchers and engineering professionals relevant to the projects, and participated in field trips to renewable energy installations in the San Francisco Bay Area.

The three internship projects varied in the degree of definition and the role of interns in the projects evolved over the program. At the start of the program, after mentors introduced the projects in more detail, interns were asked to rank their first and second preference out of five possible overall projects. Students were assigned to teams of 3 to 4 interns each based on either their first or second choice project. Teams met 40 hours per week for 8 weeks and stipends motivated interns to complete tasks at project milestones.

A. Techno-economic modeling of facilities and microgrids[1]

The Alisal campus consists of three main buildings, each with its own energy demands. The energy needed to operate the industrial welding shop, multiple computer labs and servers, coupled with the lighting and HVAC system needed to condition these spaces, results in significant costs to the campus. Through energy demand models, student interns investigated opportunities to reduce energy costs, which could lead to a reduction of the campus' carbon footprint. Using HOMER micropower optimization software interns modeled the campus electrical systems. The software enabled students to understand the design trade-offs between different renewable energy system configurations, including Hartnell's microgrid, and identify the best economic scenario. Through simulations of varying configurations of wind turbines and photovoltaic arrays, students determined the optimal arrangement. The Hartnell administration will utilize this model in future energy planning for the Alisal campus.

B. Assessing electric vehicle charging station potential to store and be charged by renewable energy microgrid

Student interns conducted a feasibility study of integrating Hartnell's renewable energy microgrid with an electric vehicle (EV) charging station thereby reducing the carbon footprint of the EVs, through the leveraging of renewable sources. Using available wind and charging station data along with other assumptions, students tested the feasibility of integrating a microgrid with the charging station through extensive simulations with HOMER software. Interns determined that the planned wind-only microgrid requires additional components, including storage, in order to create a fully renewably-powered charging station. Student interns also made significant contributions to the data access platform that is in development including establishing the protocol connecting the EV station data to a centralized data collection server.

C. Designing sensor assemblies to facilitate wind turbine site selection and education modules

The goal of this research project was to establish a procedure to assess the wind energy production potential using technical criteria and converting it to a laboratory lesson. To measure wind speed, a key parameter, interns designed and erected a mobile 30-foot aluminum pole holding three equally-spaced anemometers and a temperature sensor, which was tested at multiple sites on Hartnell's Alisal campus. They also utilized acoustic sensors to establish an acoustical base line for the campus. The optimal location for the turbine was determined by the result of wind data analysis and sound pressure level recording devices using HOMER software. Student interns also updated an existing wind energy production laboratory module and created the basis for a new laboratory module on wind energy site selection to be used by both Hartnell and UCSC.

[1]Research project descriptions were adapted from each group's final Internship Symposium poster abstract.

III. RESEARCH OUTCOMES

Through the preparation and presentation of a research poster, groups shared their internship research projects in a final symposium, which convened all summer interns from all organizations taking part in the Consortium partnership. Student interns were administered pre- and post-internship surveys by an external evaluator consisting of 27 questions with a Likert scale for responses to assess their internship experience[3]. Of those interns who participated in both the pre- and post-internship surveys, 82% were male and 17% were female. Moreover 7 interns reported their ethnicity as Hispanic/Latino, followed by Caucasian/White (3 interns), Asian (1 intern), and Indian (1 intern).

A. Internship Experiences

Student interns who were administered both pre- and post-internship surveys to assess their internship experience (N=12) reported the following statistically significant ($P < .05$) changes in response to the following statements.

TABLE I. SIGNIFICANT CHANGES IN INTERN RESPONSE FROM PRE- TO POST- INTERNSHIP SURVEYS

Statement or Question	mean change	significance of change
I could use more help to get prepared for transferring to a university.	$\Delta m = -0.92$	p=.034
I am already very aware of academic scholarships, science internships, and other professional opportunities available to me.	$\Delta m = 0.75$	p=.032
I know what the work life is of a practicing scientist or engineer.	$\Delta m = 0.92$	p=.020
How confident are you now about your decision to pursue a STEM[2] career? (Note: N=11)	$\Delta m = 0.36$	p=.038

Seven of the 13 interns who completed the post-internship survey provided comments at the end of the survey. Six of the seven comments were highly positive in nature. The critical comment was constructive and offered suggestions on how to improve the effectiveness of the symposium component culminating the program.

Also of interest, further pre- and post-internship survey analysis focuses on student interns' intended university major and the highest degree to which they aspired. Analysis reveals notable changes in responses in the following statements or questions:

- Interns' plans to transfer to a 4-year institution increased from 11 to 12 interns after the internship program. Two interns participating in the survey indicated they had changed their responses regarding their intention to transfer as a result of participating in the research experience this summer from, from "not sure yet" to "yes."

[2] STEM is Science, Technology, Engineering and Mathematics.

- Most interns indicated they were considering plans to transfer to either a California State University or University of California campus in both the pre- and post-internship surveys, with two outliers considering other or private college options. This finding is consistent with overall matriculation trends for all Hartnell graduates.

- The proportion of interns who had decided on a major after the internship increased from 7 to 9 interns. Majors identified included mechanical engineering (3), Electrical Engineering (2), Civil Engineering (2), Biology (1) and Applied Physics (1).

- Asked whether the interns would be a STEM major for their bachelor's degree, 100% of interns responded "yes," an increase of 17% between pre- and post-internship.

- Four of twelve interns changed their responses when queried about their plans for the highest degree they planned to pursue as a result of their research experience this summer. "Two increased the highest degree they aspired to from 'Bachelor's Degree' in the pre-internship survey to 'Master's Degree' in the post-internship survey. Two went from 'Undecided' to either 'Bachelor's Degree' or 'Research doctorate" in the post-internship survey".[3]

The following comment summed up the experience for one intern, "It was a great satisfaction to work in the summer in what I feel passionet *[sic]* about. Thank you for providing me with the tools to continue with my career goals."[3]

IV. Conclusion

Building on previous engineering praxis work from our research center[4][5][6][7] and others[1],[8], the authors conclude that even top performing high school and community college students stand to benefit from an applied "how to do sustainable energy research" internship experience. The changes in student intern responses between pre- and post-internship surveys lead us to believe that the internship program was helpful in assisting students to clarify the expectations and pathways to a STEM-oriented major at a 4-year university, build aptitude and confidence in STEM abilities, and train interns in professional and research development. However, no change was observed in increasing consideration of local universities as a transfer possibility or identification of local universities as a top choice for interns planning to transfer, one aim of the program.

Based on the early findings of this work in progress and further reflection, the authors also recommended the following actions take place in refining the internship program for summer 2013:

1. With construction on the Hartnell microgrid now complete, program developers should focus projects on microgrid application in the Salinas Valley agriculture community.
2. Increase outreach to women students by engaging the partnering institutions' local chapters of Women in Science and Engineering and Women in Engineering.
3. Maintain a relevant and diverse field trip and guest speaker component in the program.
4. Provide feedback on Symposium structure to help increase effectiveness and efficient use of time.

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System Normalization and Iron Saturation Based on Generalized Coupled Circuits Analysis as Fundamentals for Electric Machines Modeling Course

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***Abstract*— This paper describes the use of a suitable approach to teaching generalized magnetically coupled electric circuits as an introduction chapter to the electric machines modeling and simulation course for power engineering students. The teaching methodology focuses on some common concepts and fundamentals of electrical machine theory such as machine inductances (self, leakage and mutual), equivalent circuits, magnetic circuits, iron saturation, reciprocal per unit system, state modeling and simulation, so that the modeling approach of each type of classical machine can easily be deduced from the general theory established by the chapter on magnetically coupled electric circuits.**

***Keywords*— Magnetically Coupled circuits; iron saturation; per unit system normalization, state space model, application and simulations**

I. Introduction

Magnetically coupled electric circuits are central to the operation of transformers and electrical machines, as specified by Prof. Krause et al. [1]. A good understanding of the theory underlying magnetically coupled circuits greatly simplifies both the teaching and the learning of transformers and electrical machines [2]-[4]. Therefore, for power engineering students, special attention should be paid to teaching magnetically coupled circuits, with an emphasis on their electrical machine structure, as the first chapter of the electrical machines course where transient modeling and simulations are included. The modeling of the equivalent electric circuits of electrical machines is based on magnetically coupled circuits. The modeling and simulation of electrical machines are great challenges for power system engineering students around the world. Currently, in many universities around the world, the magnetically coupled circuits are only taught in the 'electric circuits', which is a common undergraduate course for first year electrical engineering programs [2]-[4]. Although transient behaviors are included in 'electric circuits' course, the study of electric machines for undergraduate power engineering students is most of time still limited to the steady state performances [5]. Furthermore, there are not sufficient pedagogical links between the courses 'electric circuits' and many undergraduate textbooks treating electric machines which in general don't content magnetically coupled circuits [5]-[6]. Very few authors have realized the importance to insert the magnetically coupled circuits as the first chapter of their research textbook [1], [7]-[8]. However, even though the magnetically coupled circuits developed in [1], [7] included the saturation phenomenon and simulation analysis, their electrical models given in block-diagram form, are not flexible to adapt to the rotating machines study and control purposes.

As shown in the present work, the course on magnetically coupled circuits offers interesting opportunities to introduce main fundamentals of the electrical machines modeling and simulation. In this paper, generalized concepts that could be applied to all electrical machines analysis such as the state model, electrical equivalent circuits, per-unit system normalization, iron saturation, numerical simulations are introduced in a course on magnetically coupled circuits to facilitate the understanding and interest of future power engineering students commencing the study and analysis of electrical machines. Repeating these concepts over time when analyzing every type of electrical machine (redundancy principle) will increase the student's understanding of the pedagogical objectives to be achieved.

II. Equations of Generalized Magnetically Coupled Circuits

Magnetically coupled electric circuits with an adjustable number of coils are shown in Fig.1. The flux equations for n coils are given in (1) and reorganized in (2) while the voltage equations are defined in (3) [1]:

$$\begin{aligned}
\lambda_1 &= N_1\phi_{f_1} + \left(N_1/\Re_m\right)\left(N_1 i_1 + N_2 i_2 + \cdots + N_n i_n\right)\\
\lambda_2 &= N_2\phi_{f_2} + \left(N_2/\Re_m\right)\left(N_1 i_1 + N_2 i_2 + \cdots + N_n i_n\right)\\
&\cdots\\
\lambda_n &= N_n\phi_{f_n} + \left(N_n/\Re_m\right)\left(N_1 i_1 + N_2 i_2 + \cdots + N_n i_n\right)
\end{aligned} \tag{1}$$

$$\begin{aligned}
\lambda_1 &= \lambda_{11} + \lambda_{12} + \cdots + \lambda_{1n} = \left(L_{m_1} + l_1\right)i_1 + L_{12}i_2 + \cdots\\
\lambda_2 &= \lambda_{21} + \lambda_{22} + \cdots + \lambda_{2n} = L_{21}i_1 + \left(L_{m_2} + l_2\right)i_2 + \cdots\\
&\cdots\\
\lambda_n &= \lambda_{n1} + \lambda_{n2} \cdots + \lambda_{nn} = L_{n1}i_1 + \cdots + \left(L_{m_n} + l_n\right)i_n
\end{aligned} \tag{2}$$

$$\begin{aligned}
e_1 &= r_1 i_1 + L_{11}\frac{di_1}{dt} + L_{12}\frac{di_2}{dt} + \cdots + L_{1n}\frac{di_n}{dt}\\
e_2 &= r_2 i_2 + L_{21}\frac{di_1}{dt} + L_{22}\frac{di_2}{dt} + \cdots + L_{2n}\frac{di_n}{dt}\\
&\cdots\\
e_n &= r_n i_n + L_{n1}\frac{di_1}{dt} + L_{n2}\frac{di_2}{dt} + \cdots + L_{nn}\frac{di_n}{dt}
\end{aligned} \tag{3}$$

with:

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$$L_{m_i} = \frac{N_i^2}{\Re} = N_i \frac{\phi_{m_i}}{i_i}; L_{ij} = L_{ji} = \frac{N_i N_j}{\Re} \;\; (i \neq j) \tag{4}$$

$$l_i = N_i \frac{\phi_{f_i}}{i_i} \;\; ; \; L_{ii} = N_i \frac{\phi_{m_i}}{i_i} + N_i \frac{\phi_{f_i}}{i_i} = L_{m_i} + l_i \tag{5}$$

The following relationships are derived between various variables and parameters of the coils:

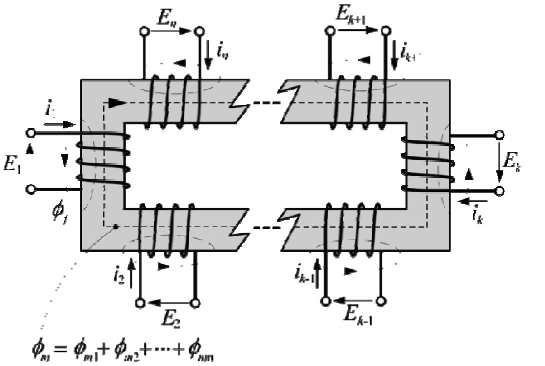

Fig.1. Coupled electric circuit with adjustable number of windings

III. Equivalent Circuit referred from Coil 1

The main objective when modeling an electrical system such as magnetically coupled circuits for the study of electrical machines is to derive flux and voltage equations such that the equivalent circuit without a galvanic link as illustrated in Fig.2 can be drawn. The Kirchhoff mesh and nodal laws can therefore be applied to the equivalent circuit model obtained for analysis and the solution of the physical magnetically coupled circuits. In order to achieve this goal, flux and voltage equations (2) and (3) will be modified so that the current, flux and voltage of a given coil can be observed or referred from coil 1. The concept of 'referred circuit' obtained by creating fictitious variables and parameters allows the galvanic link of Fig.2 to be removed between coils and, thus creates their electrical connection. In such a context, the ampere-tours ($N_j i_j$) in a given secondary coil *j* can be mathematically replaced by the fictitious primary ampere-tours ($N_1 i'_j$) so that the current in the coil *j* is given by its equivalent $i'_j = \left(N_j / N_1\right) i_j$ referred from coil 1.

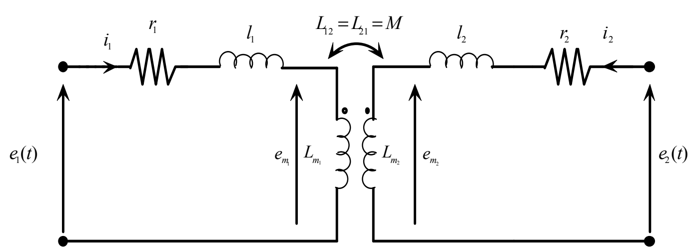

Fig. 2 Equivalent circuit of two magnetically coupled circuits without electrical connection (with a galvanic link)

$$\begin{aligned}
\lambda_1 &= \left(l_1 + L_{m_1}\right) i_1 + L_{m_1} i'_2 + L_{m_1} i'_3 + \cdots + L_{m_1} i'_n \\
\lambda'_2 &= L_{m_1} i_1 + \left(l'_2 + L_{m_1}\right) i'_2 + L_{m_1} i'_3 + \cdots + L_{m_1} i'_n \\
&\cdots \\
\lambda'_n &= L_{m_1} i_1 + L_{m_1} i'_2 + L_{m_1} i'_3 + \cdots + \left(l'_n + L_{m_1}\right) i'_n
\end{aligned} \tag{6}$$

$$e_1 = r_1 i_1 + \frac{d\lambda_1}{dt}; e'_2 = r'_2 i'_2 + \frac{d\lambda'_2}{dt}; \cdots; e'_n = r'_n i'_n + \frac{d\lambda'_n}{dt} \tag{7}$$

where:

$$\begin{aligned}
&a_{ij} = N_i / N_j; i \neq j; e'_i = a_{1i} e_j; i'_i = i_i / a_{1i} \; i \neq 1 \\
&\lambda'_i = a_{1i} \lambda_i; \;\; r'_i = a_{1i}^2 r_i; l'_i = a_{1i}^2 l_i; i \neq 1 \\
&L_{m_i} = L_{m1} / a_{1i}^2; L_{1i} = L_{i1} = L_{m_1} / a_{1i}; i \neq 1
\end{aligned} \tag{8}$$

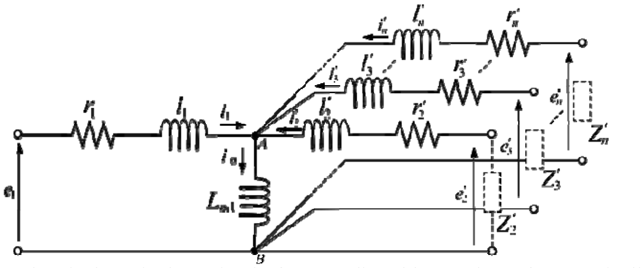

Fig.3. Electrical equivalent circuit for an adjustable number of magnetically coupled coils referred (observed) from winding #1 (primary)

According to the energy conservation principle, the power in the fictitious circuit and in the actual secondary should be the same ($e'_j i'_j = e_j i_j$). Introducing the above fictitious current and voltage referred from coil 1 in (2) and (3), the latter equations can be organized as given in (6) and (7) with the primary and secondary *j* both in motor mode (for example, in Fig.2, coils 1 and 2 absorb power from external sources). The equivalent circuit of the generalized magnetically coupled circuit of Fig.1 referred from coil 1 (in the motor mode) is given in Fig.3. It's important to observe that Fig.1 is quite close to electrical equivalent circuit of a variable reluctant synchronous machine with adjustable damper windings or multi-rotor windings induction machine. The magnetizing inductance L_{m_i} is also called the mutual inductance since $L_{m_i} = a_{ij} L_{ij}$.

IV. Normalization of Generalized Coupled Circuits: Per Unit System

A. Definition of Base Values

Normalization schemes are frequently used in power systems modeling and simulation. The per-unit systems applied for the normalization of electric machine equations are not more often clear to students. The great advantage of the normalization scheme is that the system equations are the same independently from which coil they are referred. The classical magnetically coupled circuits such as electrical machines and transformers are defined by the rated values of their individual circuits (*i*): apparent power S_{iN} (VA), voltage E_{iN} (V), current I_{iN} (A), and the rated pulsation $\omega_n = 2\pi f_n$ (rad/s); where f_n (Hz) is the nominal frequency of the primary winding voltage $e_1(t)$ (coil 1) supplied by the external network. In single-phase circuit analysis, as it's the case in this study, the base quantities for a given coil (*i*) are defined in Table 1. From this table is observed that for two arbitrary distinct coils *i* and *j*: $E_{ib} / E_{jb} = I_{jb} / I_{ib} = a_{ij} = 1 / a_{ji}$ thus:

$$E_{1b}I_{1b} = E_{2b}I_{2b} = E_{3b}I_{3b} = \cdots = E_{nb}I_{nb}$$
$$S_{1b} = S_{2b} = S_{3b} = \cdots = S_{nb} \qquad (9)$$

The above relationship (9) is fundamental and general in electrical machines analysis when system normalization is concerned. It states that: in the per-unit normalization, the VA bases of coupled circuits should be equal.

TABLE I: BASE VARIABLES OF COIL #*i*

Quantity	Base	units	Dimen.
Power	$S_{ib} = S_{iN}$	[VA]	[*ei*]
Voltage	$E_{ib} = E_{iN}$	[V]	[*e*]
Current	$I_{ib} = \frac{S_{ib}}{E_{ib}} = I_{iN}$	[A]	[*i*]
Impedance	$Z_{ib} = \frac{E_{ib}}{I_{ib}}$	[Ω]	[*z*]
Pulsation	$\omega_b = \omega_n = 2\pi f_n$	[rad/s]	[*1/t*]
Time	$T_b = \frac{1}{\omega_b}$	[s]	[*t*]
Flux	$\lambda_{ib} = E_{ib}T_b = \frac{E_{ib}}{\omega_b}$	[Wb-turns]	[*et*]
Inductance	$L_{ib} = \frac{\lambda_{ib}}{I_{ib}}$	[H]	[*et/i*]

B. Normalization of Voltage Equations

For given base voltages and currents E_{1b}, I_{1b}, E_{2b}, I_{2b}, $\cdots$, E_{nb}, I_{nb} for circuits of Fig.1, the voltages equations (3) of generalized coupled circuits can be organized as expressed in (10) where the index (*u*) indicates a per unit quantity:

$$\begin{aligned} E_{1b}e_{1u} &= r_1 I_{1b} i_{1u} + \omega_b L_{11} I_{1b} \frac{di_{1u}}{\omega_b dt} + \omega_b L_{12} I_{2b} \frac{di_{2u}}{\omega_b dt} + \cdots \\ E_{2b}e_{2u} &= r_2 I_{2b} i_{2u} + \omega_b L_{21} I_{1b} \frac{di_{1u}}{\omega_b dt} + \omega_b L_{22} I_{2b} \frac{di_{2u}}{\omega_b dt} + \cdots \\ &\cdots \\ E_{nb}e_{nu} &= r_n I_{nb} i_{nu} + \omega_b L_{n1} I_{1b} \frac{di_{1u}}{\omega_b dt} + \omega_b L_{n2} I_{2b} \frac{di_{2u}}{\omega_b dt} + \cdots \end{aligned} \qquad (10)$$

with:

$$\begin{aligned} r_{iu} &= \frac{r_i}{E_{ib}/I_{ib}} = \frac{r_i}{Z_{ib}}; L_{iiu} = \frac{L_{ii}\omega_b}{E_{ib}/I_{ib}} = \frac{L_{ii}}{\lambda_{ib}/I_{ib}} = \frac{L_{ii}}{L_{ib}} \\ L_{iiu} &= \frac{L_{ii}}{L_{ib}} = \frac{L_{ii}\omega_b}{Z_{ib}} = \frac{X_{ii}}{Z_{ib}} = X_{iiu} \end{aligned} \qquad (11)$$

According to relationships (11), the reciprocity of the mutual inductances should be preserved in (12) (since $L_{ij} = L_{ji}$). Another important result obtained from the per-unit system normalization is that mutual inductances should be equal as expressed in (13) (derived from (12)).

$$\begin{aligned} \omega_b \frac{L_{ij} I_{jb}}{E_{ib}} &= \omega_b \frac{L_{ij} I_{ib}}{E_{ib}} a_{ij} = \frac{L_{m_i}\omega_b}{Z_{ib}} = L_{m_i u}; (i \neq j) \\ \omega_b \frac{L_{ji} I_{ib}}{E_{jb}} &= \omega_b \frac{L_{ji} I_{jb}}{E_{jb}} a_{ji} = \frac{L_{m_j}\omega_b}{Z_{jb}} = L_{m_j u}; (i \neq j) \end{aligned} \qquad (12)$$

$$L_{m_1 u} = L_{m_2 u} = \cdots = L_{m_n u} = L_{mu} \qquad (13)$$

C. Normalized Equations

The voltage equations (3) in (SI system) can be organized as given in (14) in the reciprocal per-unit system (pu) without index (u) and minuscule symbols for leakage inductances. The voltage equations (14) are formatted in the matrix form (15), where J_n in (16) is an n order matrix with all entries equal 1.

$$\begin{aligned} e_1 &= r_1 i_1 + l_1 \frac{di_1}{\omega_b dt} + L_m \frac{di_1}{\omega_b dt} + L_m \frac{di_2}{\omega_b dt} + \cdots \\ e_2 &= r_2 i_2 + L_m \frac{di_1}{\omega_b dt} + l_2 \frac{di_2}{\omega_b dt} + L_m \frac{di_2}{\omega_b dt} + \cdots \\ &\cdots \\ e_n &= r_n i_n + L_m \frac{di_1}{\omega_b dt} + \cdots + L_m \frac{di_n}{\omega_b dt} + l_n \frac{di_n}{\omega_b dt} \end{aligned} \qquad (14)$$

$$e(t) = Ri(t) + \frac{1}{\omega_b}\frac{d(\lambda)}{dt} = Ri(t) + \frac{1}{\omega_b} L \frac{d(i)}{dt} \qquad (15)$$

With:

$$\begin{aligned} g &= \begin{bmatrix} g_1 & g_2 & \cdots & g_n \end{bmatrix}^T \\ R &= diag\left(r_1 \quad r_2 \quad \cdots \quad r_n\right) \\ L &= diag\left(l_1 - L_m \quad l_2 - L_m \quad \cdots \quad l_n - L_m\right) + L_m J_n \end{aligned} \qquad (16)$$

V. SATURATION MODEL OF GENERALIZED COUPLED CIRCUITS

In order to introduce the saturation phenomenon in previous coupled circuits, neglecting the voltage drop in leakage inductance l_1 and resistance r_1 , the coil #1 voltage in (14) yields:

$$e_1 = L_m \frac{1}{\omega_b}\frac{d\left(i_1 + i_2 + \cdots + i_n\right)}{dt} = L_m \frac{1}{\omega_b}\frac{d\left(i_{10}\right)}{dt} \qquad (17)$$

Assuming a coil #1 sinusoidal input voltage and current, (17) can be written into complex form (18):

$$\overline{E}_1 = jL_m \frac{1}{\omega_b}\left(\omega_b \overline{I}_{10}\right) = jL_m \overline{I}_{10} = jL_m \overline{I}_m \qquad (18)$$

In (18) the magnitude of the magnetic current I_m only depends on the magnitude of terminal voltage E_1 and not on the state of the circuit (loaded or not). Consequently, if E_1 is maintained constant, the unloaded ($i_2 = i_3 \cdots = i_n = 0$) magnetizing i_{10} current will remain the same even if other windings are loaded. Thus:

$$I_{10} = I_m \Rightarrow i_{10} = i_m = i_1 + i_2 + \cdots + i_n \quad (19)$$

$$X_m = L_m = \frac{E_{10}}{I_m} = \frac{E_{10}}{I_{10}} \quad (20)$$

Using the no-load magnetizing characteristic $E_{10} = f(I_{10})$ obtained experimentally (no load is connected to secondary coils of the coupled circuits), the magnetic saturation curve $L_m = f(i_{10})$ given in Fig.4 can be drawn point per point from (20).

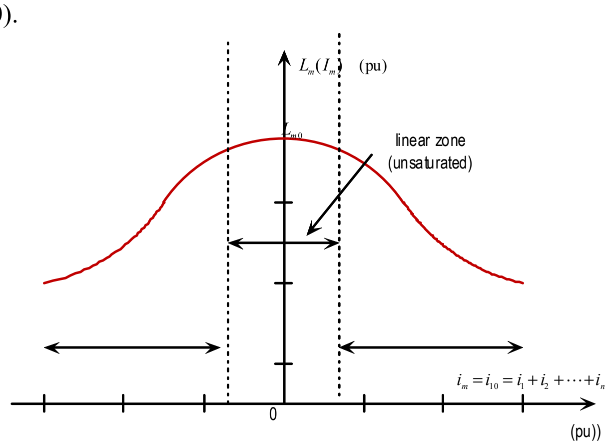

Fig.4. $L_m = f(i_{10})$ characteristic of the unloaded coupled circuits (in pu)

The curve in Fig.4 can be easily modeled as polynomial function given by (21) where parameters α_2 and α_4 are computed from curve fitting using *polyfit* function of Matlab program and the characteristic $L_m = f(i_{10})$. L_{m0} is the unsaturated magnetic inductance of the circuit which is obtained from no-load characteristic of Fig.4.

$$L_m = \frac{E_{10}}{I_m} = \frac{E_{10}}{I_{10}} = L_{m0}\left(1 + \alpha_2 I_m^2 + \alpha_4 I_m^4\right) \quad \text{(pu) (21)}$$

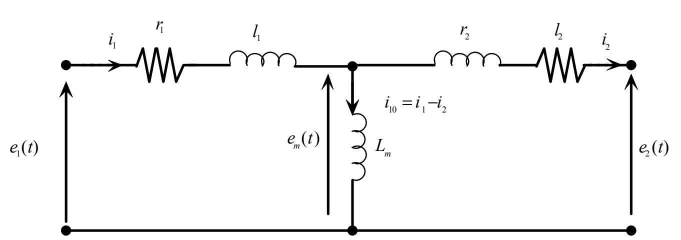

Fig.5. Equivalent circuit of two magnetically coupled circuits (transformer or per phase equivalent circuit of wound-rotor induction motor)

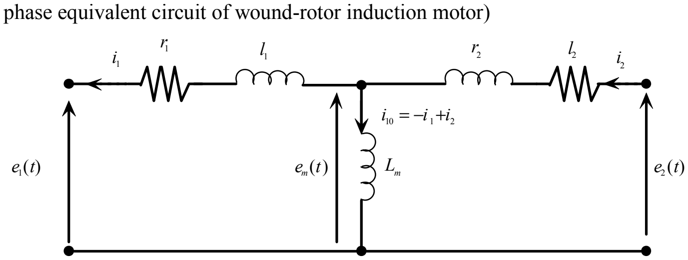

Fig.6. Equivalent circuit of two magnetically coupled circuits (AC generators)

It's to note that the magnetizing current i_{10} depends on the structure of the coupled circuits under study as shown by examples of two magnetically coupled coils of Figs.5 and 6 where it takes the following expressions respectively:

$$i_{10} = i_1 - i_2 \,; \quad i_{10} = -i_1 + i_2 \quad (23)$$

VI. Saturated State Space Modeling of Magnetically Coupled Circuits

A. State Space Model of Magnetically Coupled Circuits

Let us consider a dynamic linear system defined by the differential equation (24); the so-called standard form of the state space model of a linear dynamic system, a well-known control theory suggested for undergraduate engineering students in [9], can be summarized as given in (25). The electrical matrix equation (26) derived from (15) can be organized in standard state form (27):

$$\dot{x}(t) = \frac{dx(t)}{dt} = f(x(t), u(t), t) \quad (24)$$

$$\begin{aligned} \dot{x}(t) &= Ax(t) + Bu(t) \\ y(t) &= Cx(t) + Du(t) \end{aligned} \quad (25)$$

$$\begin{cases} i(t) = L^{-1}\lambda(t) \\ e(t) = RL^{-1}\lambda(t) + \dfrac{1}{\omega_b}\dfrac{d(\lambda)}{dt} \end{cases} \quad (26)$$

$$\begin{aligned} \frac{d(\lambda(t))}{dt} &= \left(-\omega_b R L^{-1}\right)\lambda(t) + \left(\omega_b I_n\right) e(t) \\ i(t) &= \left(L^{-1}\right)\lambda(t) \end{aligned} \quad (27)$$

with:

$$\begin{aligned} &A = -\omega_b R L^{-1};\ B = \omega_b I_n;\ C = L^{-1};\ D = \mathrm{O}_{n,n} \\ &i = [i_1 \quad i_2 \quad \cdots \quad i_n]^T;\ u = e \end{aligned} \quad (28)$$

Where $\lambda(t)$ is the state vector, $e(t)$ the input control variable and A, B, C and D, the state matrix, the state control matrix, the state output matrix and the state output control matrix respectively.

B. Saturated State Model of Magnetically Coupled Circuits

Leakages inductances in (14) $l_i; i = 1 \cdots n$ due to magnetic losses in the air gap are not concerned with the saturation phenomenon. The magnetic saturation can be taken into account in the state model (27) at each instant t_k by adapting the corresponding value $L_m(t_k)$ of the magnetic inductance computed from (21) in matrices A and C (28). The implemented process to account for saturation is the following:

1. Obtain the characteristic $E_{10} = f(i_{10})$
2. Obtain the curve $L_m = f(i_{10})$ of Fig.4
3. Obtain the reactance L_{m0} from $L_m = f(i_{10})$

4. Compute parameters α_2 and α_4 using the function *polyfit* of Matlab program and $L_m = f(i_{10})$ data
5. Define a time vector $\left[t_0 \cdots t_{k_F}\right]$ using n values for $n-1$ steps of simulation.
6. Set $k=0$; $L_m = L_{m0}$ and compute matrices A, B, C using circuit parameters and steady state conditions $\lambda_0 = \lambda(t_0)$
7. Simulate the state system (27) using the function $lsim(.)$ of Matlab control toolbox in one time step interval $[t_k \quad t_{k+1}]$.
8. Set $k=1$ and use currents obtained from step 7 to compute $i_m(t_k)$ given by (19) and $L_m(t_k)$ from (21)
9. Compute state matrices A, B, C
10. Repeat step 7 until $t_k = t_{k_F}$

VII. EXAMPLE OF NUMERICAL APPLICATION USING MATLAB

In order to provide students with a sample application, numerical simulations were performed on a 60-Hz, 110-V/55-V/55-V, and 330-VA single-phase transformer with two secondary windings (Fig.7) whose parameters are listed in Table II. Two different tests were performed. First, the two secondary windings were short-circuited and a 50-V DC voltage was applied to the primary. In the second test, the DC voltage was replaced by a 60-Hz 110-V AC voltage. Per unit inductance and resistance matrices computed form base values of Tables III and IV are respectively:

TABLE II: PARAMETERS OF THE TRANSFORMER

L_{m_1}	0.09 H	$L_{m_2} = L_{m_3}$	22.5 mH
l_1	0.01H	N_1	1000 turns
$l_2 = l_3$	2.5 mH	$N_2 = N_3$	500 turns
r_1	10 Ohms	$r_2 = r_3$	2.5 Ohms

TABLE III: BASE VARIABLES OF COIL #1

Variable	Base	Value
Voltage	$E_{1b} = E_{1n}$	110 V
Current	$I_{1b} = I_{1n} = \dfrac{S_{1b}}{E_{1b}}$	3 A
Power	$S_{1b} = E_{1n} I_{1n}$	330 VA
Impedance	$Z_{1b} = \dfrac{E_{1b}}{I_{1b}}$	36.7 Ω
Pulsation	$\omega_b = \omega_n = 2\pi f$	377 rad/s
Flux	$\lambda_{1b} = \dfrac{E_{1n}}{\omega_b}$	0.292 Wb-turn
Inductance	$L_{1b} = \dfrac{\lambda_{1b}}{I_{1b}}$	0.093 H

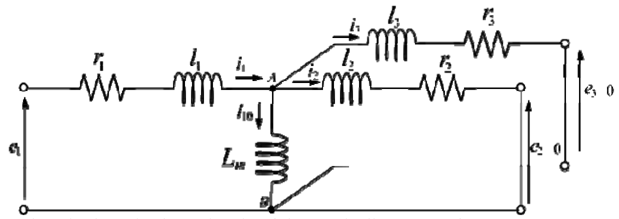

Fig.7. Electrical equivalent circuit of three windings transformer

TABLE IV: BASE VARIABLES OF COILS #2AND #3

Variable	Base	Value
Power	$S_{2b} = E_{2n} I_{2n}$	330 VA
Voltage	$E_{2b} = E_{2n}$	55 V
Current	$I_{2b} = I_{2n} = \dfrac{S_{2b}}{E_{2b}}$	6 A
Impedance	$Z_{2b} = \dfrac{E_{2b}}{I_{2b}}$	9.167 Ω
Pulsation	$\omega_b = \omega_n = 2\pi f$	377 rad/s
Flux	$\lambda_{2b} = \dfrac{E_{2n}}{\omega_b}$	0.146 Wb-turn
Inductance	$L_{2b} = \dfrac{\lambda_{2b}}{I_{2b}}$	0.0243 H

$$L = \begin{pmatrix} 1.03 & 0.93 & 0.93 \\ 0.93 & 1.03 & 0.93 \\ 0.93 & 0.93 & 1.03 \end{pmatrix}; \quad R = \begin{pmatrix} 0.272 & 0 & 0 \\ 0 & 0.272 & 0 \\ 0 & 0 & 0.272 \end{pmatrix} \quad (31)$$

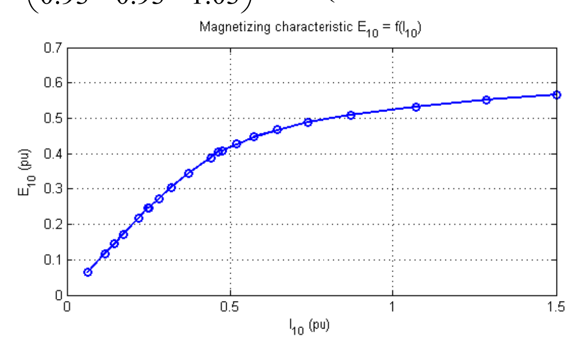

Fig.8 The no-load magnetizing characteristic of the transformer

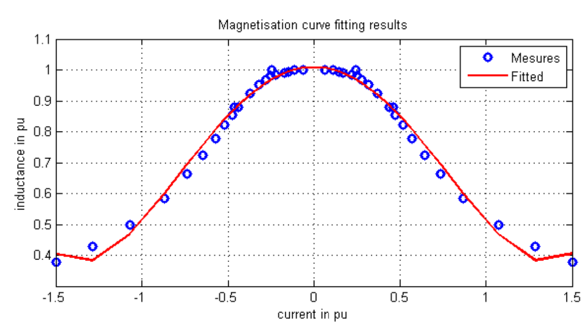

Fig.9 The no-load magnetizing characteristic $L_m = f(i_{10})$ of the transformer

In both cases, simulation of the current of each winding and the magnetizing current of the transformer was requested. The no-load saturation characteristic of the transformer is provided in Fig.8 while the curve $L_m = f(i_{10})$ is plotted in Fig.9. Voltages of the secondary windings are set to zero (short-circuit) for the first test. The primary simulated current is shown in Fig.10 while the magnetizing current and the secondary currents are given in Figs.11 and 12 respectively. It is to be noted that the two secondary windings are the same. After the peak due to the sudden applied voltage, the secondary current becomes zero (DC signal). For the second test, the sinusoidal voltage yields sinusoidal currents as shown in Figs.13-15. The magnetizing current is given by $i_{10} = i_1 - i_2 - i_3$. The impact of the saturation phenomenon is observed on various figures.

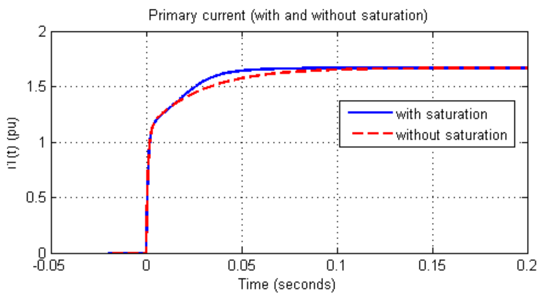

Fig.10. Current of the transformer primary following a 50-V step change of the primary voltage with the secondary windings in short-circuit

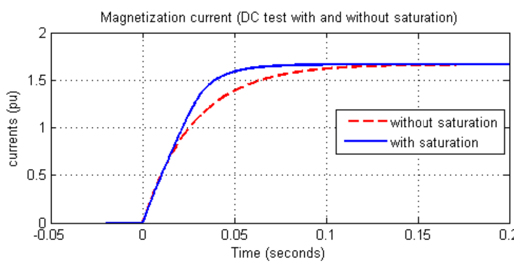

Fig.11 Magnetizing current following a 50-V step change of the primary voltage with the secondary windings in short-circuit

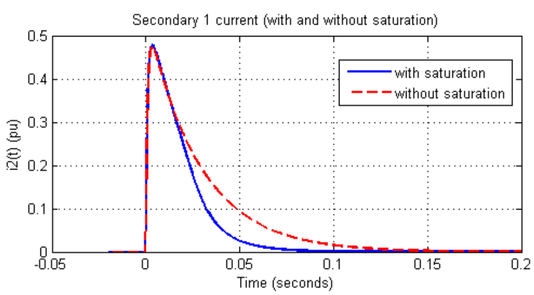

Fig.12 Current of the transformer secondary following a 50-V step change of the primary voltage with the secondary windings in short-circuit

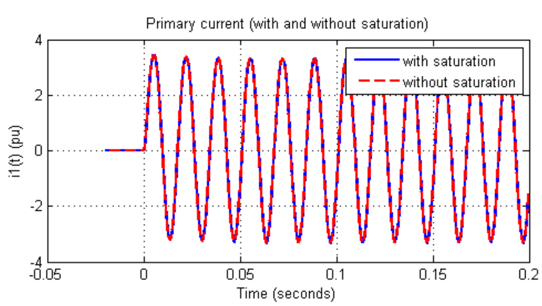

Fig.13 Current of the transformer primary following a 110-V sinusoidal voltage of the primary winding with the secondary windings in short-circuit

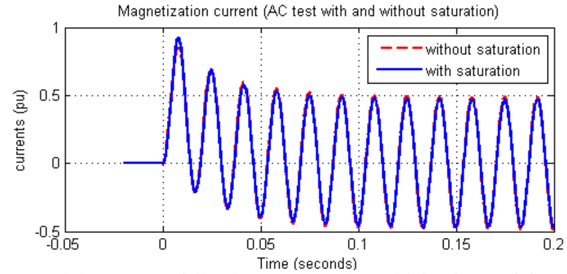

Fig.14 Magnetizing current following a 110-V sinusoidal voltage of the primary winding with the secondary windings in short-circuit

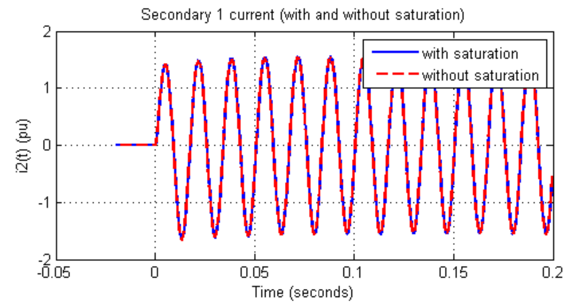

Fig. 15 Secondary windings current of the transformer following a 110-V sinusoidal voltage of the primary winding with the secondary windings in short-circuit.

VIII. Conclusion

A suitable approach to teaching magnetically coupled circuits to power engineering undergraduate students is proposed in this paper in a more general approach. The work attempts to show that the understanding and teaching of dynamic modeling and simulation of electrical machines can be greatly improved if special attention is given to the teaching methodology adopted for magnetically coupled circuits, where various concepts in machine theory can be easily introduced. The paper emphasizes on per-unit system normalization concept frequently used in power system theory and not often well explained to students. All fundamentals raised are common to classical AC machines and can be easily well adapted to their modeling and simulation. Only simulation results are provided in this work. It is planned to carry out experimental setup to more assess the present framework study.

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Real World Photovoltaic Energy Engineering

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Abstract - **Photovoltaic solar energy has recently enjoyed a technical and economic progression achieving a high level of reliability. With the aim of obtaining a better knowledge of this type of energy by part of the students from the Electrical, Electronic and Mechanical Engineering Degrees of the School of Design Engineering ETSID in Valencia, Spain, they are offered an elective subject in which they are asked to conduct a "field practice" in which they design an isolated installation that will fully supply the house in which they live including. In addition they perform a photovoltaic installation connected to the electrical network.**

In both cases students must obtain market prices and find out the supply equipment commonly used. With this data they should develop a proposal similar to the one supplied to a customer requesting an installation of this kind. Hence this is a field project where factual data is required and enables students to talk to companies supplying the electrical and photovoltaic materials. These assignments include the final assessment of the cost of the power generated, so that students can identify if the final price in photovoltaic is higher or lower than the cost of electricity supplied by the electricity distribution companies.

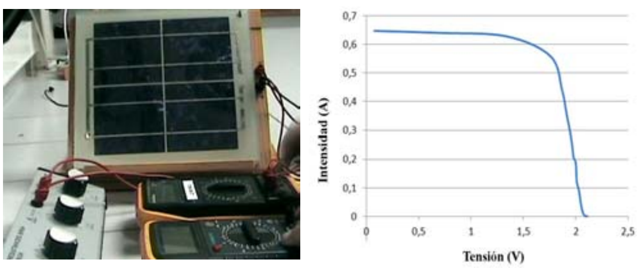
Keywords: Engineering, Electricity, Energy, Solar Photovoltaic, Field Practice

I. Introduction

Problem Based Learning enables a practical learning by means of which students learn by fulfilling tasks that make them have an active attitude in achieving their competences [1] as well as getting more committed in the process.

The Photovoltaic Energy Engineering programme at the School of Design Engineering ETSID (Valencia, Spain) gathers 120 students of Electrical, Electronic and Mechanical Departments giving them the opportunity to work and take measures on low voltage commercial photovoltaic panels, investigating their voltage V-I and power curves, [2]. Then the students check that the data provided by the manufacturers (Figure 1).

Figure 1. Small Photovoltaic solar pannels with which students do lab work



UPV facilitates the access to its solar panel located at ETSID (Figure 3). In this way UPV students see how the equipment connected directly to the main power works and are able to examine the components of the panel. The electrical energy produced is consumed directly by facilities in ETSID [3] through 6 inverters that work simultaneous and independently. ETSID solar panel of 17.5 KW has been running for 14 years, [4] and [5].

Figure 2. Photovoltaic system in UPV.

Since photovoltaic solar energy is under continuous change, it is very importand the task of students collecting relevant information about the solar panel market (including technical features of equipment and its accessories) and later on carry out two assignments.

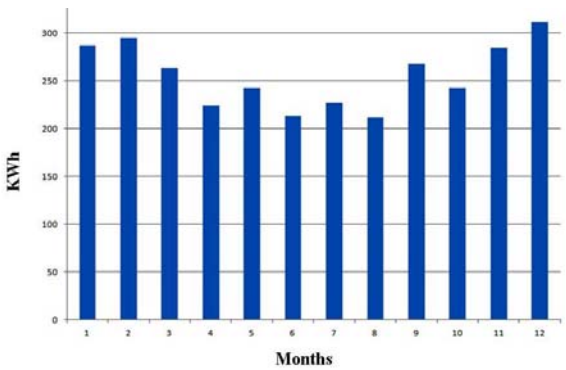
II. Description

The first assignment for students consists of designing a grid system for their own residence so that it becomes completely independent. The second part is to connect such an independent system to the general electrical system, allowing at the same time to consume the energy generated

a) Off-grid installation

The installation must be designed with the data of the student's own home. First, the student must obtain the monthly consumption of housing a full year. This data may be read from the utility bills issued and charged to them as users. But in order to get familiar with domestic electricity consumption, they are required to identify usage of electric devices (light, electronics and appliances including stand-by consumption) in their own environment and observe their daily energy consumption, [6]. Measured time multiplied by electricity voltage results in an average daily/monthly/annual energy consumption that has to be compared with the utility bills.

Figure 3. Annual domestic energy consumption



Next, the students have to design the photovoltaic system that provides energy for domestic use. The calculation of data is not complicated and follows directly from the knowledge acquired in classes. The monthly energy demand must meet the criteria taking under the consideration cases of the highest and the lowest solar radiation during the year. These values are provided by national and international websites such as IDEA [7] and PVGIS [8]. Hence the number of solar panels required is settled as well as the regulators and inverter to be used and the capacity of the batteries that guarantee the autonomy of the system. At this stage the students need to contact suppliers, obtain technical data (Figure 4), economic costs of the equipment and be able to interpret all the data.

Figure 4. Characteristics of a photovoltaic solar panel that the student must obtain from manufacturers and / or distributors

Electrical Characteristics

STC	PLUTO190-Ade	PLUTO185-Ade
Optimum Operating Voltage (Vmp)	37.8 V	37.3 V
Optimum Operating Current (Imp)	5.03 A	4.96 A
Open - Circuit Voltage (Voc)	45.4 V	45.2 V
Short - Circuit Current (Isc)	5.43 A	5.39 A
Maximum Power at STC (Pmax)	190 W	185 W
Module Efficiency	14.9%	14.5%

The outcome will also include the analysis of the economic costs of installation, this being a relevant part as each manufacturer and distributor differ in prices in beginning, depending on the type of customer, supplier and discounts given. However actual market prices are lower and very similar, with little variation among different manufacturers.

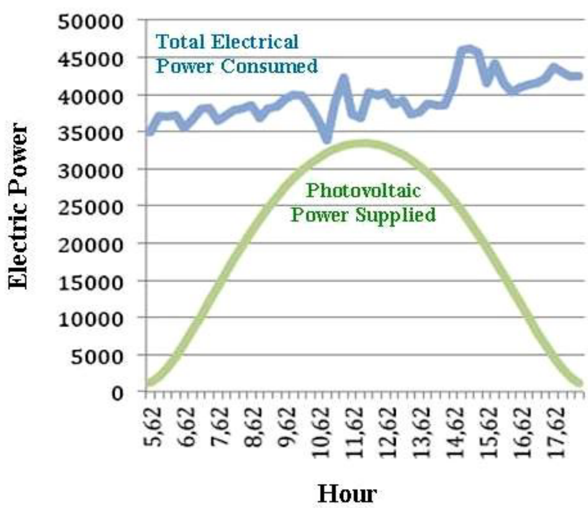
b) Installation connected to the general electrical system

The second task also concerns solar PV energy, but with a very different perspective. It is a networked installation not used to satisfy a given consumer, but seeking to produce as much energy as possible and get a direct economic benefit as the difference between the cost of installation and the income obtained each year.

The current Spanish regulation provides two options to private solar PV energy generators: selling power to the grid at market price and power consumption facilities [9]. The latter is more interesting in economic terms since the energy generated is not sold to the grid, but it does reduce the energy consumed by the facility owner. The electrical and photovoltaic calculation is conceptually the same but the implementation is very different.

The work to be performed by each student is to design the optimal photovoltaic system which in this case consists of solar panels, inverter and auxiliary equipment. This must be done taking into account this field data on market prices and specifications; in the line prior to the installation it explains isolation. Finally an estimate of the amount of energy to be produced and which may not be consumed by the user of the installation must be fulfilled.

Figure 5. Energy produced versus energy consumed



It will happen that at some given moments and/or days all the energy generated will be consumed (Figure 5) whereas in others there will be a consumption higher than what will be produced. The student must make its estimate based on actual installation criteria and the fact on whether they are dealing with a public or industrial building, a shopping center or a private house. This calculation brings out the concept of net energy balance [10].

This situation requires the student to assess the type of application and its advantages and disadvantages. The study must also consider the economic performance of installation, getting the time period in which the photovoltaic plant owner is able to recover the investment.

Additionally the student is required to obtain the cost of KWh generated over a broad time period. Initially set at 25 years, the warranty period the manufacturers usually provide for solar panels, but also asked to perform a second calculation for a period of 40 years. They should have in mind the loss of efficiency and service life of the equipment. Some of them must be replaced after a certain period of time. For example, inverters may have an estimated life of between 15 and 25 years, depending on its manufacturing technology.

This result is important because today the final cost of KWh generated is around 5 cents USA dollars. It is a fact that attracts their attention leading them to exchange information and results with other classmates. This is indeed a very low value, compared with the 19 cents that the consumer pays for the energy from power companies in Spain. It is also an interesting item that brings out the concept of grid parity, [11] and [12].

III. Results

We course check the first phase of work in which students try to solve everything through the Internet, without having to make personal calls to providers or go in person to the offices of the distributor or manufacturer. Overcoming that shyness is one of the important results of the field work, since once they have completed their degree they must do this at work continuously to obtain data providers.

The students' opinion on the subject is obtained through polls. They were asked on the usefulness of the field practice for their education. From them we learnt that 43.2% of students considered it very useful, 27.1% just useful and 12.8% that it was not a relevant contribution. It turned out that 43.7% of the last 12.8% argued that the task was too much time consuming.

It is worthwhile noting that in 78.6% of the cases there was a coincidence between the high grades of the field practice and the high grades in the subject, thus leading us to think that this field practice helps improving the education process.

The students do perform partial presentation of the field tasks which enables a close follow up of the learning process which gets its recognition in the final results.

Finally over 80% of students enrolled succeed in passing. This percentage increases to 88% if we refer to students that are incorporated from the beginning to do the field tasks.

IV. Conclusion

The field practice seems to motivate the students to work harder and be more involved in the learning process. As a result we find a very satisfactory outcome in all students, particularly interesting in mechanical and electronic engineering students, which have not taken specialty electrical subjects but showed their satisfaction with the education provided and in some cases, this lead them to ask to do their final project in the field of PV energy.

The general acceptance of these field tasks have led to design peer assessment methods [14] and self-evaluation for the next academic year, which have already successfully been applied in other subjects as diverse as Electro-pneumatic installations or Music for Image. In this way each student can take a step further and evaluate their peers as well as to assess themselves.

In order to carry out this process we are proposing that each student will present his/her work to the rest of classmates. Each student will have performed the field practice and know the effort he/she has taken up. Checking the work done by other classmates should also give each student a wider perspective to assess their own work, and be aware on whether they match the effort carried out by other students.

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An online simulator for thermoelectric cooling and power generation

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***Abstract*— We present an online simulator that can be used to teach the principles of thermoelectric energy conversion, and analyze the detailed performance of Peltier coolers or thermoelectric power generators with simple user interfaces [1]. The simulation tool is implemented on nanoHUB.org, so it can be run on any web interface without the need to install commercial software. The simulation tool solves the heat balance equations at the top and bottom sides of the thermoelectric device using 1D thermal network model and the electric circuit model to analyze the steady-state temperatures of the device and the thermoelectric energy conversion efficiency. Both cooling and power generation modes can be solved upon user's input. Using this simulator, users are able to optimize the performance of a thermoelectric device with a variety of different design parameters such as the device dimensions and material properties. In particular, this simulator can be very useful to teach the importance of the thermoelectric figure of merit, ZT, of the material used on the performance of the device. This simulation is also instructive to show that as material properties improve Carnot limit can be achieved at negligible output power, while efficiency at maximum output power converges to Curzon-Ahlborn limit.**

Keywords*— *online simulator; thermoelectric; cooling; power generation;

I. Introduction

As the world strives to solve the energy problem, there has been a growing interest in strengthening education in renewable energy technologies and related fields [2]. Since most of the energy technologies are interdisciplinary, conventional approaches to the higher-level teaching of such subjects may not be applicable. For example, the efficiencies of state-of-the-art energy conversion systems are determined not only by the materials used, but also by the design of device- and system-level electrical circuits connected to it. For this, an interdisciplinary education encompassing a broad range of science and engineering fields is necessary to meet the ever-rising demand of energy technology engineers and researchers.

An online simulator is a very useful method for energy technology education. First, it can provide students an easy access to the complicated energy systems in a virtual environment. Second, the operation principles or performances of the systems can be easily understood and evaluated for undergraduate students without directly solving the difficult mathematical equations. Third, online simulators can be directly used in real research activities for graduate students where the system optimization and evaluation in terms of various design parameters for the system are crucial.

One of the great examples of an energy system that can take full advantages of an online simulator for education purposes is thermoelectric (TE) energy conversion system. Recently thermoelectric energy conversion has received much attention for waste heat recovery and for micro-chip cooling applications [3]. More than 55% of energy generated in the society is wasted in the form of heat so thermoelectrics could play an important role in future energy landscape [4]. Analysis of a thermoelectric device is complicated because one needs to solve the coupled thermal and electric transport equations taking into account heat flow and electrical energy supplied to a load. An online simulator for TE devices may be very useful for students to have an easy access to devices that couple electron and heat transport and energy conversion applications.

In this paper, we present an online simulator that can be used to teach the principles of thermoelectric energy conversion, and analyze the performance of thermoelectric devices. The simulation tool can be used on any web interface without the need to install MATLAB or other commercial software, as it is implemented on nanoHUB.org with simple and easy user interface. We are currently developing several course modules at UC Santa Cruz and Purdue University that utilize this online simulator to teach undergraduate students the principles of thermoelectric energy conversion devices. Lastly, we will also show the methodology to propose student project using the online TE simulator as well as the expected outcomes and evaluation plan.

II. Simulation of Thermoelectric Devices

A. Principles and modeling of thermoelectric devices

The underlying physics of thermoelectric cooling is Peltier effect. When a current flows through an interface between two dissimilar materials, thermal energy is absorbed or dissipated depending on the direction of current flow in order to compensate the difference in thermal energy transported by electrons in the two materials. The thermal energy Q transported by a current I in a material having a Seebeck coefficient S at absolute temperature T is given by $Q=STI$. Thus, the absorbed or dissipated heat at the interface between material 1 and material 2 by the Peltier effect becomes the

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difference of the transported thermal energies or Q_1-Q_2=(S_1-S_2)TI. In addition, there are other thermal transport effects: Joule heating and thermal conduction. The Joule heating is I^2R in a material with electrical resistance R. This heat is equally divided and propagated to the two ends of the material. When a temperature gradient is created through a material, heat conduction Q_{cond} occurs from the hot side to cold side proportional to the temperature difference ΔT, so that $Q_{\text{cond}} = \Delta T/\psi$, where ψ is the thermal resistance of the material.

Fig.1(a) shows a typical structure of a thin film TE device fabricated on a conducting substrate. A top metal contact is deposited on top surface of the thin film TE element, and a ground contact is deposited at the bottom of the substrate, so that both electrical current and heat flow vertically through the whole structure. In our simulator, we solve the heat balance equations obtained at the top surface of the TE element and at the interface between the TE element and the substrate from the 1D thermal network model shown in Fig. 1(b). The heat balance equation depicts that the Peltier heating/cooling, the Joule heating, and the heat conduction are all in balance.

It is important to include the heat and current 3D spreading effect in the substrate, because the substrate is much larger than the TE device on it. A closed-form thermal spreading resistance in a substrate is adopted from Lee *et al*. [5] with assumption of an infinitely large substrate and a perfect heat sink underneath it. The electrical spreading resistance is obtained from Vashaee *et al*. [6], which is based on ANSYS finite element simulation.

B. Simulation method and boundary conditions

A thermoelectric device works as both a cooler and a power generator. In the cooling mode, a current is injected into the TE device. Two boundary conditions can be simulated: one is that the cooling power Q_1 is known, from which T_1 and T_2 are calculated by solving the coupled heat balance equations. The other boundary condition is that the top surface temperature T_1 is known, from which T_2 and the cooling power Q_1 are calculated. Then the coefficient of performance (COP) is obtained by

$$\text{COP} = \frac{Q_1}{W}, \tag{1}$$

where W is the work done by the electrical current to achieve the cooling performance given by

$$W = IV_{OC} + I^2 R_i . \tag{2}$$

where V_{oc} is the open-circuit voltage induced internally in the device by the Seebeck effect, $V_{oc}=S_{\text{TE}}(T_1-T_2)+S_{\text{sub}}(T_2-T_{\text{amb}})$, and R_i is the total internal resistance of the device, $R_i=R_c+R_{\text{TE}}+R_{\text{sub}}$.

In the power generation mode, a heat energy Q_1 is injected into the device from the top, which creates a temperature gradient across the device and generate a voltage by the Seebeck effect. A load resistance R_L is connected to the device, so that a current flows through the load to generate a power output, $P_{\text{out}}= I^2R_L$. The current is obtained by an electrical circuit model, in which the open-circuit Seebeck voltage source has an internal resistance and is connected to the external load.

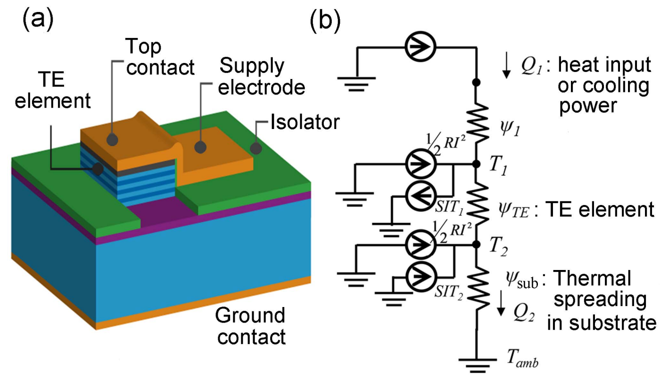

Fig. 1 (a) Schematic of a thin film TE device on a substrate and (b) the corresponding 1D thermal network model

There are two boundary conditions for the power generation mode as well. One is that the heat input Q_1 is known, and then we calculate T_1, T_2, and I by solving the coupled heat balance equations. The other option is that T_1 is known, and we calculate Q_1, T_2, and I. Then the thermoelectric energy conversion efficiency η is obtained by

$$\eta = \frac{P_{out}}{Q_1} . \tag{3}$$

In both the cooling and power generation modes, users can select an option that there is no substrate.

A practical TE module consists of multiple n-type and p-type TE elements that are connected electrically in series, and thermally in parallel [3]. The online simulator presented in this paper has also the capabilities of simulating multi-element modules having both n- and p-type elements. Users are asked to input the dimensions and material properties of the n- and p-type elements as well as the number of the elements.

C. Implementation on nanoHUB.org

We have implemented the simulator on nanoHUB.org. NanoHUB provides an easy and simple Java-based graphical user interface. We wrote the simulator core in MATLAB script, and integrated the code with the user interface of nanoHUB using Rappture toolkit [7]. Users can access and run the program by simply visiting the website. Upon the start of the program, an introduction page is shown up to give users a brief overview and instructions on how to use the simulator as shown in Fig. 2(a).

Then, users can select from a pull-down menu a simulation option in either cooling or power generation mode for single element simulation or multi-element module simulation. In the second page of the simulator (Fig. 2(b)), users are asked to choose an independent variable, for which all the outputs are calculated and plotted as its function, and the range of the independent variable to simulate, and enter material properties and dimensions of the TE elements. Then simulation is performed when the simulate button is pressed by user, and the resulting output data are plotted as a function of the independent variable as shown in Fig. 2(c) as an example.

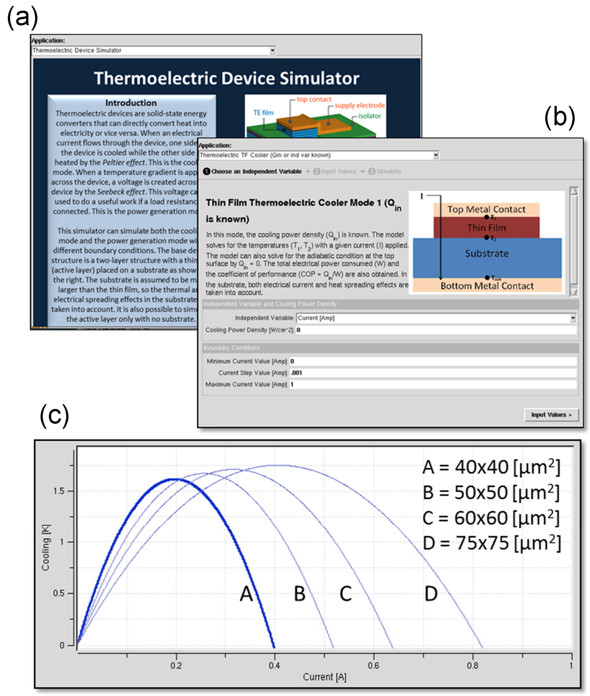

Fig. 2 (a) Introduction page of the online TE device simulator on nanoHUB.org, (b) material properties and simulation option page, and (c) an example of simulation results (net cooling vs. current) for various sizes of TE devices.

III. Practices, Evaluation and Future Work

This online simulator is built and designed for use in classes where students are taught the principles of TE devices and the detailed performance analyses of the system. For that purpose, we offer a variety of independent variables for users to choose from in this simulator, so that students can do performance optimization and comparison of TE devices in terms of the selected independent variables in a simple and easy way. For example, a user can choose the load resistance as an independent variable in the power generation mode, and find out that the power output is maximized when the load resistance is equal to the internal resistance of the device, the so-called load-matching condition. For another example, the material properties such as the Seebeck coefficient S, electrical conductivity σ, and thermal conductivity κ can be chosen as an independent variable for a user to learn how the thermoelectric energy conversion efficiency is determined as a function of those properties. This way, students can learn the importance of the figure or merit $ZT=S^2\sigma T/\kappa$ of the material for enhancing the efficiency of the device.

This simulator is suitable for undergraduate-level students who are beginning to learn the principles of thermal transport physics and thermoelectric energy conversion, as well as for graduate students who are doing research on their own design of TE devices and systems. In particular, students from materials and chemical engineering departments who grow or synthesize their new TE materials can benefit from using this simulator as they want to predict realistic performance of the future devices that utilize their materials. Additionally, the undergraduate classes in physics and electrical engineering departments are good places to use this simulator, in which students do not have to use commercial engineering software such as MATLAB or Mathematica, but simply go on the website and run the simulator. Also, this simulator can be useful as a supplementary software in conjunction with hands-on thermoelectric energy conversion experiments in introduction to renewable energy classes [8].

Students should have basic knowledge of classical physics on thermal transport and thermodynamics prior to using this simulator. Understanding of basic electrical circuits is also necessary. The simulator is very versatile and it allows students to study the limit of thermoelectric power generation as the material properties are improved. Carnot limit (1- T_{cold}/T_{hot}) can be achieved at negligible output power, while efficiency at maximum output power converges to Curzon-Ahlborn limit (1-$\sqrt{T_{cold}}/\sqrt{T_{hot}}$) [9].

A suggested method of evaluating what students have learned from the simulator is to give each student a questionnaire before and after the use of simulator, which contains a set of questions relevant to the subject of the class. Also, students can take an on-site quiz in a computer lab with the internet access at the end of the academic term, where they run the simulator in a real time and solve the problems related to the performance of TE devices. The simulator provides users functionalities that export the simulation results into text or MS Excel files. Students can generate plots with this simulator.

The online simulator has been installed for public use on nanoHUB.org [1]. It will be constantly upgraded. We are planning to use this simulator in classes at UC Santa Cruz and Purdue University and continue to upgrade it based on the feedback received back from students, researchers and instructors.

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Remote Experiments in Secondary School Education

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***Abstract*—This paper describes the current influence of the remote laboratory on practical learning aspects of secondary sector of education. The key challenges faced by the teaching of science include insufficient hands-on laboratory usage in classrooms. The main objective of the paper is to present learning approach of adaptation and usage of remote experiments of WebLab-Deusto in curriculum of secondary school. The activity was organized in collaboration with secondary school teachers of P. Andrés Urdaneta School. Educators can benefit from different teaching methods (collaborative, inquiry-, and project-based learning) integrated in WebLab-Deusto.**

The teaching of Ohm´s Law in Physics curriculum of secondary school was one of the topics executed during this research. The remote laboratory assignment for students was developed on Virtual Instrument Systems in Reality (VISIR) Open Lab Platform. The existing remote laboratories are more or less copies of hands-on ones. VISIR is a remote laboratory created by Blekinge Institute of technology (BTH) for designing, wiring and measurement of electric circuits. This main feature of VISIR allows one building a scenario of performing basic DC and low frequency AC circuits experiments related to Ohm's and Kirchhoff's laws. Moreover, the students will become familiar with instruments, components, manuals, data sheets, circuit wiring, and other laboratory work.

In the paper the main principle of VISIR will be presented; the remote experiments executed by students will be shown. Finally, the result of integrating of remote experiments for study in Urdaneta School will be discussed.

Keywords—remote laboratory, remote experiment, STEM, secondary education, Ohm's law, VISIR

I. Introduction

In order to successfully compete in a global economy, Europe aims to be amongst the most highly skilled regions in the world. Recent study shows that the occupational structure of EU employment of the engineering sector tends to shift towards knowledge- and skills-intensive jobs from 27.3% in 2007 to 32.4% in 2020 [1]. Industry requires well educated science, technology, engineering and mathematics (STEM) graduates. At the same time the percentage of drop off students in STEM is high - almost 30% for the science education and 50% for the engineering. Indeed the first encouragement students get in the school through the class instructions, practical assignments, laboratory work, and extra curriculum activity. A teacher is a source of knowledge and inspiration for the students in the education. Because of that teachers should have access to high quality and real-life-based resources to support student´s curiosity using up-to-date research and developments in STEM, multimedia interactive instruments including an experimental laboratory.

The OLAREX (Open Learning Approach with Remote Experiments) project consortium realized that the new strategies in the STEM educational field are needed; the knowledge and skills requirements exchange between school and industry through the university expertise should be established. For these purposes the consortium has been granted by Lifelong Learning Programme of the European Union [2].

The OLAREX started at November 2011 [3]. The institutions from different EU countries (Spain, Lithuania, Austria, Bulgaria, Hungary, and Poland) are involved in the project. For now the secondary schools teachers from all partner institutions already benefited from the first piloting session participating in the courses and modules designed during the project.

The aim of this paper is presenting the results of the implementation of the OLAREX module "Ohm´s law: How does the current flow?" and to discuss how OLAREX facilitates integration of remote experiments in teacher professional practice.

II. OLAREX Project Activity

The main project purpose is to innovatively implement ICT-based (Information and Communications Technology) learning materials, remote experiments, and e-didactic methods into formal and non-formal lifelong learning settings. It will enhance and modernize STEM curricula, foster student creativity and motivation, and develop professional skills and insights about the impact of evolving technologies.

The organized training for teachers will build the e-didactic competences in the STEM by providing remote lab work explanations, offering practically-oriented approaches for strengthening educational programs and technical practices.

This work was supported by Lifelong Learning Programme of the European Union within Key Activity 3 - ICT (OLAREX project 518987-LLP-1-2011-1-ES -KA3-KA3MP). However, any opinions, findings, conclusions, and/or recommendations are those of the investigators and do not necessarily reflect the views of the European Commission.

During the training, teachers integrate at least one learning module into their curriculum, test them in their classrooms, and encourage their students to apply what they learned in a final project. The six comprehensive learning modules with remote experiments – in English and the national languages of the partners – have been prepared based on the target groups' requirements. Learning and teaching materials have been incorporated into an e-platform - personalized learning environment.

III. NEEDS ASSESSMENT SURVEY, SPAIN, 2012

The presented survey was performed in Spain, in March-April, 2012, to analyze the knowledge and skills requested from secondary school students; a demand on teacher ICT competence development; a role of administration staff in ICT integration in school curriculum; e-learning materials and remote experiments needs as well as education methods.

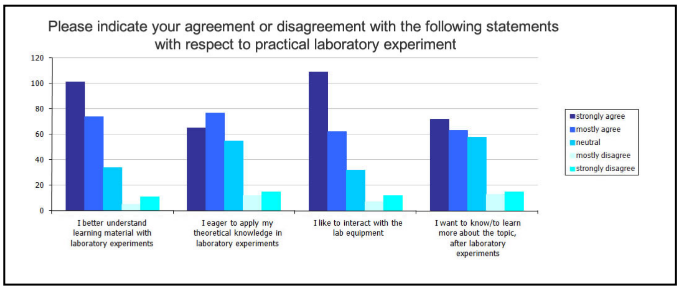
Most secondary schools in Spain show interest in remote experiments. More than 62% of the participated in survey teachers informed that they had an interest to test remote experiments in their curriculum. They also are interested to get more information about the Open Courseware and free online lectures, and how to use it in their curriculum.

At the same time, it was indicated that obstacles influencing the ICT integration in curriculum are lack of knowledge in using ICT instruments for education purposes, insufficient number of software/applications copies for educational use, and lack of knowledge on hardware and software characteristics. Usually students execute experiments in the frame of traditional hands-on laboratories. However, the laboratory equipment is expensive and its maintenance is complicated. The remote laboratory reduces the costs significantly, makes lab experiments available almost at any time and everywhere, personalizing the learning pathways [4], [5]. When the project started, the secondary schools of Basque Country, Spain, do not use remote experiments in the curriculum.

All target audiences of the survey stated a high interest in the remote laboratory and experiments believing that this tool can enhance STEM curriculum and teaching methods in class instruction and at the same time can develop a student competence which are required by industry.

242 students out of 464 participated in survey (52,4%) pointed out that they use hands-on laboratory activities and experiments laboratories in the class. Students, who had or have laboratory experiments, evaluated their experience with the words "strongly agree", "mostly agree", "neutral", "mostly disagree", "strongly disagree"- by answering on the questions :

- I better understand learning material using laboratory experiments
- I am eager for application of my theoretical knowledge in laboratory experiments
- I like to interact on the lab equipment
- I want to know/to learn more about the topic, after laboratory experiments



The results are presented on Fig. 1.

Fig. 1. Evaluation of the expirience to hands-on laboratory

The 44% of all survey participants like to interact using the laboratory equipment. 46% strongly agree and mostly agree that they better understand learning material. 37% of responders strongly agree and mostly agree that they are eager for application of their theoretical knowledge in laboratory experiments.

173 students out of 462 (37%) have heard of remotely accessible laboratories before, while 283 students (almost 63%) never have heard about it. However, despite on the huge number of those who never have heard about the remote experiments, after a brief presentation of the remote laboratory, more than 67% of all responders would be interested testing and applying remotely accessible experiments. It shows us the willingness of students to use new tools to support their practical assignments.

Teachers were another respondent group in the survey. In Spain, more than 100 teachers filled in the online questionnaire and responded that: 56% of responders do not use a practical laboratory component currently in their curriculum; while 44% apply the laboratory experiments in the class. Usually teachers apply laboratory activity in Mathematics, Biology and Technologies.

If remote experiments are available in the school, 50% responds that they are interested, 7% are very interested and 6% are completely interested applying them in class instruction (Fig.2).

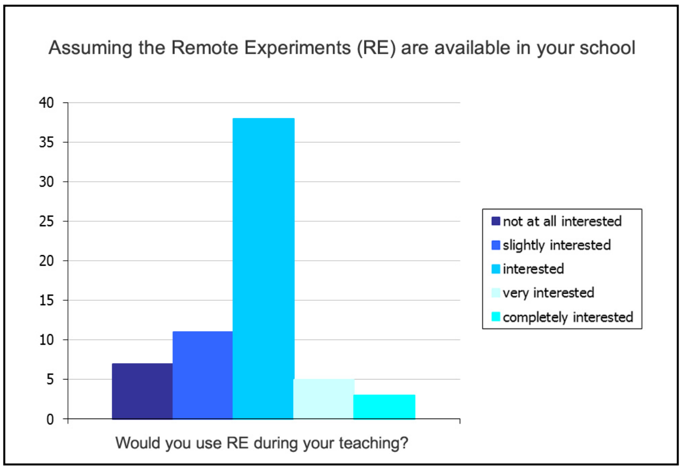


Fig. 2. Teachers´ interest to implement the remote experiment in class instruction

The main purpose of the study was to understand in the participated countries the ICT knowledge gap, necessity and willingness to apply the remote labs for learning and teaching. Based on the reports' conclusions the partners identified the methods, instruments and content approach, and expected ICT competence demands for the primary target groups: secondary school teachers and their students. The profiles of teachers, students, administrative representatives and companies responding the survey is available on the project website.

IV. Remote Experiment in Secondary School Instruction

Based on the survey, five courses on e-didactical competences for secondary school teachers were developed. One of them is "Transforming curriculum with remote experimentation: how to integrate it in secondary school classroom". This course aims to develop the competences such as the use of different types of remote and online labs, and to present them to students. During this online course the teacher activity is focused on an implementation in class instruction one of the six STEM modules:

- Black body radiation of common light sources (simulation activity)
- Farm Experiment: from an egg to a baby chick, step by step (remote experiment activity)
- Working as a computer – Logic gates (remote experiment activity)
- Analogue circuits measurements (remote experiment activity)
- How does the current flow? (remote experiment activity)
- Easy Java Simulation for Phys&Sports (simulation tool)

In this paper we will present the module "Ohm´s Law: How does the current flow?" tested in collaboration with secondary school teachers of P. Andrés Urdaneta School. The provided module is a didactic support module for implementing the remote experiments in a classroom. Teachers can use its structure as a whole element without any changes. They can apply some parts such as exercises, experiments, problems, or only ideas of topics for student´s final projects. Average learning time for the module is around 20 hours: 10 hours of theory, 5 hours of execution of exercises, tests, experiments, and one final small project (5 hours of work) are included in the module. The learning module covers following topics: electrical current, Ohm's law for direct and alternative current, electrical resistance, capacitors, signal generators, digital circuits and measurements within the VISIR. Each module unit provides both theoretical and practical approaches including a problem solving by simulations and using remote experiments.

The main learning outcomes of this activity are: (1) the skills to design experiments confirming the hypotheses; (2) the practice to work with laboratory materials and equipment, including the VISIR; (3) the knowledge of digital circuits of direct and alternating currents.

V. VISIR Open Lab Platform

Electrical experiments are common at schools and universities. Usually students execute experiments in the frame of traditional hands-on laboratories. The existing remote laboratories are more or less replicas of hands-on ones. Virtual Instrument Systems in Reality (VISIR) Open Lab Platform is a remote laboratory created by Blekinge Institute of technology (BTH) for designing, wiring and measurement of electronic circuits. A student designs circuits using virtual instruments and wires on the interface of the devices-gadgets such as: Smartphone, tablet, iPad, and PC. Then, VISIR Open Lab Platform converts the student's design into a real wired circuit and sends the measurement results to the interface of the student device. Thus, VISIR Open Lab Platform is a real electronic lab environment which can be accessed at any time and from anywhere over the Internet [6].

There are three main scenarios for practical learning using VISIR Open Lab Platform [7]. However we will only present the usage of the VISIR by secondary school students. They can use VISIR Open Lab Platform for performing basic DC and low frequency AC circuit experiments related to Ohm's and Kirchhoff's laws. Moreover, the students will become familiar with instruments, components, manuals, data sheets, circuit wiring, and other laboratory work [8].

The main part of VISIR Open Lab Platform architecture is online workbench (Fig.3) that is similar to hands-on laboratories at any school. Workbench for electrical experiments contains power sources, measuring instruments and a solderless breadboard (Fig.3). A virtual instructor protects the online workbench from student's harmful errors and damages during experiments.

The VISIR Open Lab Platform provides a virtual component box and virtual breadboard for controlling the switching matrix and for "wiring" circuits remotely using the mouse pointer. Users select components using the button "+" from the library of components and put them into the component box.

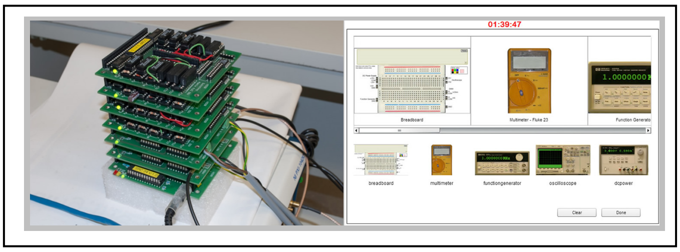


Fig. 3. The online VISIR workbench at WebLab - Deusto, University of Deusto

The VISIR Open Lab Platform offers virtual front panels of the desktop instruments and the multimeter in image format

(Fig.3). Adobe Flash animations enable students to turn the knobs and buttons, and make settings using the mouse pointer. In order to avoid misunderstanding and provide immersion of the remote experiment, the virtual panel is an exact virtual copy of devices which students use at hands-on laboratories. In order to build holistic immersion of the experiment sessions of the remote activity should be organized as a hands-on laboratory - one workbench per student or student´s team [9]. Each remote student or student´s team creates the experiment using laboratory interface and sends a message containing a description of the desired circuit and the instrument settings to the VISIR workbench (server). The experiment result or an error message is returned to the requesting client computer after performing the procedure. The student should wait in queue to execute the experiment in case of server occupation.

VI. Results of Implementation in School

The laboratory practice on remote experiments was taking place during two weeks in March 2013. Forty eight students of 2nd year of Baccalaureate (grade 11) of Urdaneta high school (Loiu, Bizkaia, Spain) [10] participated in it. A group of Urdaneta high school teachers in STEM areas have volunteered time within their busy schedules, to design and implement one curriculum topic – Ohm´s Law, which requires the laboratory practice, learning, and understanding of the technology [11].

The activity is divided into three parts. In the first part a teacher presents WebLab-Deusto remote laboratory: how to login in the remote laboratory, how does library of components work, how wire the digital equipment such as multimeter, DC power, function generator, etc. In this first part, students experiment at home in order to become comfortable with the remote experiment approach. The second part includes the work on the design of electrical circuit connected in series. The students get an exercises list including ten different series circuits that they execute using simulation tool- Falstad Analog Circuit Simulator Applet [12] and WebLab-Deusto remote laboratory, and compare the results accomplished with two different tools. This assignment allows one to study the Ohm´s law using inquiry-based learning approach as well as to analyze the difference between a simulation and a remote experiment. The next activity provides a set of experiments for parallel circuits. The students use the same instruments and report template as for the series experiments. The final project includes creating by student circuit´s schemes based on proposed requirements, designing “invented” circuits in WebLab-Deusto (Fig.4), using the components library of the WebLab-Deusto; analyzing obtained results, writing a report and a conclusion how his/her hypothesis fits the results obtained during experiments.

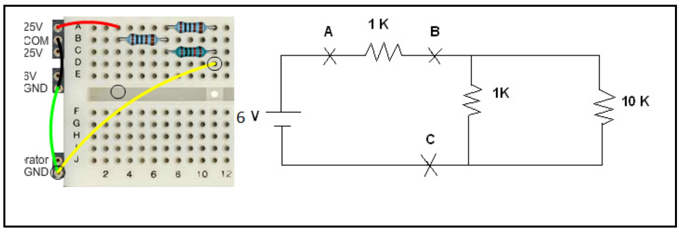


Fig. 4. Presented by Urdaneta school student circuit schema and circuits built in WebLab-Deusto environment

During the practice teacher can control an execution of an assignment by students. They can check how often students work in laboratory, how much time they spend, what errors occurred during the activity, the source of the errors - system failure or student´s mistake (Fig.5)

2013-03-21 18:31:55:959030	2013-03-21 18:31:56:527444	<dmm_function value="ac volts"/> <dmm_resolution value="3.5"/> <dmm_range value="10"/> </multimeter> <dcpower> <dc_outputs> <dc_output channel="6V+"> <dc_voltage value="6"/> <dc_current value="0.5"/> </dc_output> <dc_output channel="25V+"> <dc_voltage value="6"/> <dc_current value="0.5"/> </dc_output> <dc_output channel="25V-"> <dc_voltage value="-6"/> <dc_current value="0.5"/> </dc_output> </dc_outputs> </dcpower> </request> </protocol>	<protocol version="1.3"> <error> The circuit cannot
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2013-03-21 18:29:59:946587	2013-03-21 18:30:00:501985	<protocol version="1.3"> <request sessionkey="1e23e2be93122a32bcf0ca8ff11b9a35"> <circuit> <circuitlist>W_X DC_COM A9 W_X DC_-25V DC_COM W_X 0 DC_-25V W_X 0 0 W_X A17 0 W_X A9 DMM_VHI W_X A17 DMM_VLO R_X A13 A17 1k R_X A9 A13 10k</circuitlist> </circuit> <multimeter> <dmm_function value="ac volts"/> <dmm_resolution value="3.5"/> <dmm_range value="10"/> </multimeter> <dcpower> <dc_outputs> <dc_output channel="6V+"> <dc_voltage value="0"/> <dc_current value="0.5"/> </dc_output>	<protocol version="1.3"> <error> The circuit cannot

Fig. 5. Statistics of execution of remote experiments by student

Although the practice in environment of remote laboratory was organized for the first time, 72% of students show successfully performed exercises and laboratory work. The preliminary analysis of implementation of Remote Laboratory in class instruction in Urdaneta School shows positive feedback on presented trial: due to flexible connection to the laboratory, student´s access was massive during several days before the deadline of the final project. Most connections were done after 6pm. Such open schedule will be not possible with hands-on laboratory. Students can design circuits several times and experiment safely; discover functioning, components and equipment the remote laboratory before the actual activity will start; share and discuss their final project during lessons; obtain understanding of research cycle from hypothesis statement until analysis of the results, discussion, conclusion and report writing. However the remote laboratory needs holistic understanding of the difference between computer simulation and real experiments provided with Internet. Several sessions were needed in order students can recognize that it needs time (just several seconds) to send signals to server, complete the experiment and get it back on the screen of their computer, tablet or Smartphone. Namely, this misunderstanding was a reason of student´s disappointment on the first stage of VISIR execution at high school level. We decided in the next semester to improve the strategy of introduction of remote laboratory in secondary school classroom.

VII. Conclusions

OLAREX project contributed to teacher training on how to use remote laboratories and to improve practice at secondary schools considerably. Teachers showed great interests in using remote labs at their classes. Considerable effort was made by project consortium, and great appreciation was received by the teachers, to have both, training on application of remote labs, and having the context of ICT courses, training on integration of remote labs and facilitating teachers to do so.

In this paper we discussed the aspect of integration of remote laboratories into the secondary school curriculum using WebLab-Deusto. Thanks to modern communication instruments, common resources including remote experiments are available for students anyplace and anytime.

Our future work can be conducted in three directions: (1) provide this teaching approach to several EU countries (by providing teachers online technical and content supports); (2) improve introductory and visionary activity for remote laboratories in secondary school to allow a holistic immersion to the topic; (3) personalize the web interface of the remote laboratories and experiments. This year we have got the first results of using the remote experiment in the secondary school physics instruction. The 72% of successfully performed exercises and laboratory work students show that this tool is valuable supplementary instrument in the education of school sector. Next phase requires teacher´s individual effort and motivation. The future will reveal how these efforts will be met in local and national contexts.

Acknowledgment

We thank Olatz Alzola Colinas from Urdaneta Secondary school, Spain for her help implementing the module in her class instruction.

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Infusing System Design and Sensors in Education

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***Abstract*—INSIGHT, an innovate graduate STEM Fellowship Program integrates sensor technology and computer science within in a K-12 standards-based science, technology, and engineering curricula. Graduate STEM Fellows are teamed with science, technology, and physical education teachers for two years to carry out hands-on classroom activities utilizing technology and engineering practice with a focus on the use of sensors, computing, and information technology aligned with K-12 state curriculum standards. One of the projects main goals is the establishment of sensor, computing, and information technology as a foundational high school skill by accelerating the integration of sensor technology content into K-12 classrooms. This project encourages participation in engineering and technology from a wider, more diverse group of students from rural Kansas. This paper shares detailed examples of summer institute and academic-year K-12 activities that have been successful. It also provides a preliminary assessment of the project.**

***Index Terms*—cyber-physical systems; K-12 curriculum; education; real-time embedded systems; sensors**

I. Introduction

The importance of Computing Science continues to grow for our nation, economy, and security; yet conversely the topics and techniques of Computing Science are increasingly being pushed out of K-12 curriculums [1]. Kansas is no exception. While serving 477,857 students through 286 school districts, the state offers no licensure for teachers in computing science education. Those schools that do offer computer science coursework typically do so through the Career and Technical Education pathways program, yet these are sparsely implemented through the state: Web and digital communications (53 districts), Programming and Software Development (10 districts), Network Systems (2 districts), and Information Support Services (1 district). Further, these offerings are only offered on an elective basis. Finally, there are no specific requirements to teach in these pathways courses, so most teachers are drawn from other backgrounds and have minimal, if any, preparation to teach the subject.

Sensor technologies represent one route for reaching students in K-12 settings. Sensors, as an integral part of embedded systems, require broad, cross-cutting knowledge drawn from multiple disciplines [2]. Working from specific sensor uses within one of these disciplines (such as biometric or agricultural sensors) offers a way to introduce these cross-cutting technologies into more traditional class settings (i.e. physical education and agricultural education), and also introduce the Computing Science principles needed to evaluate, interpret, and act upon the sensor's output. Although integrating computing science topics into core curriculum subjects does increase the numbers of students exposed, doing so still faces many of the challenges faced by stand-alone computing science courses: rapidly changing technology, a lack of staff support, and few quality curriculum resources [4]. It is critical for the success of such a program to develop an infrastructure to support teachers as well as adapt to changing technology [5].

The National Science Foundation's program to support Graduate Teaching Fellows in K-12 Education (GK-12) provides a mechanism for establishing such an infrastructure. This program seeks to improve graduate students' communication, teaching, collaboration, and team-building skills by engaging graduate student fellows in K-12 classrooms, working directly with K-12 teachers and students. These Fellows take on the role of visiting experts, bringing their knowledge and research activities into the classroom and becoming a resource for teachers interested in expanding their methodologies, developing new curriculum materials, and integrating technology and computing science principles within their teaching. The fellows also serve as role models for the students they work with, both sharing exciting opportunities within their field and answering general questions about university student life, as shared by one fellow in his/her weekly journal:

> When I did the VR head tracking lesson, once we were done there was some free time where the science club students just asked me about what it was like being a grad student and a programmer. It was neat to see kids interested in a topic that I love, and I tried to show them some examples of code that I thought they might find neat. I also talked a bit about the limitations of Minecraft. It was something they had played, and they wanted to know why some things in that game were done the way they were. I'd done enough reading on the subject to be able to tell them, and they seemed to think it really cool that they now knew the reasons for why things were the way they were in that cube filled world.

These experiences are especially important for disadvantaged students who may not have role models from their social and family environment from which to draw [6]. As one teacher in the program observed:

> . . . we are not educating our rural students with thoughts towards these fields of study. I think alot of that has to do with exposure, there is very little in rural areas. We have teachers, nurses, professionals, but not a lot of exposure to fields that we really need our students to think about. When you ask Fifth graders what they want to do when they grow up, engineering/tech. degrees aren't usually mentioned.

When the fellows themselves are drawn from underrepresented populations (such as the female fellow from the first quote), students can better understand that STEM disciplines are not out-of-reach for themselves.

II. INSIGHT GK-12 Fellowship Program

The Infusing System Design and Sensor Technology in Education (INSIGHT) GK-12 STEM Fellowship Program at Kansas State University is a synthesis of these ideas using the focus on improving graduate students' communication skills to integrate computing skills into the core K-12 curriculum. The program helps prepare teachers to integrate sensor technologies into their everyday classroom activities by providing lessons developed with low cost and ease of implementation in mind, and through partnering teachers with graduate students in Computing Science and Biological and Agricultural Engineering. Teachers in the program are recruited from disadvantaged areas of Kansas, specifically rural and urban areas with high minority populations. Both teachers and fellows serve within the INSIGHT program for two years.

A major component of the project is the INSIGHT Summer Institute, an intensive two-week training program for both partner teachers and Fellows that introduces many of the various sensor technologies and computing science principles utilized within the project; along with hands-on lessons, pedagogical techniques and challenges, lesson planning strategies, and team-building experiences. These are the tools teachers need to implement STEM subjects within their classrooms:

> The program has helped me in several ways. I've always tried to nurture the future engineers and scientists in my class and INSIGHT along with my fellow have given me some extremely effective strategies to accomplish this. I've also greatly improved my own use of technology with my students beyond the traditional use of computers. As always, being able to cooperate and communicate with others (teachers and university personnel) is invaluable in solving problems and creating new programs and lessons.

As with many intensive training experiences, the confidence and enthusiasm generated during the two weeks begins to fade as time passes and the practical challenges involved become more obvious. This is where the partnership between an INSIGHT Teacher and Fellow comes to the fore the interaction between the two helps alleviate both the teacher's concerns about utilizing unknown technology in the classroom (as they have a technology expert who can ensure that aspect runs smoothly) and the fellow has an experienced teacher to help her/him understand how to communicate effectively with the class (and offer support should the Fellows falter). Further, it allows teachers to present STEM content within a real-world framework:

> The most noticeable impact of the INSIGHT program on my teaching is my increased awareness of and ability to connect my content to actual real-time, real-world applications. My ability to describe and discuss the ways in which new technologies are being utilized to improve both quality and efficiency of life is improving as a direct result of my INSIGHT experience.

Finally, as teachers grow more confident in the use of sensor technology within their classrooms, they can begin to take on more of the instructional tasks leading to the continuation of such efforts even after teachers have left the program at the end of their two years:

> The biggest impact the INSIGHT program has had on my teaching has been to expose me to new technology to use in my classroom. For example, [my fellow] came over today and Friday to work with my Drafting students, and taught a lesson on MIT's AppInventor. The students had an opportunity to explore the program and they ended up creating a drawing and sketching app. This was a very good experience for them, and is something I plan to use in the future.

Most of INSIGHT's contributions to a teacher's classroom strategy take the form of small curricular modules. This allows for manageable inclusion into an already-existing curriculum; facilitates the in-classroom interaction between the teacher, fellow, and students within a discrete block of time; and perhaps most importantly, allows the module to be documented and disseminated as a stand-alone lesson plan.

III. Sample Curriculuar Modules

This section offers a sampling of some of the modules that have been developed and/or delivered by INSIGHT fellows and partner teachers. Detailed lesson plans can be found online on INSIGHT's website (http://gk12.cis.ksu.edu).

A. Using WiiMotes to Learn Newton's Laws

This lesson takes advantage of the WiiMote a commercial game controller equipped with a three-axis accelerometer that uses Bluetooth to connect to a Nintendo game console. When paired with a computer and software capable of interpreting its output like the open-source application WiiPhysics, the WiiMote becomes a powerful and inexpensive sensor to use in education.

In this case, the WiiMote is mounted to the top of a toy car and launched using the tension in a bungee cord. As the car races forward, real-time acceleration data is streamed wirelessly to a computer running WiiPhysics.

The real-time data is graphed by WiiPhysics as the car is moving, helping students better understand the often-confused

Fig. 1. WiiMote mounted on a toy car.

Fig. 2. Using a rubber band for propulsion.

Fig. 3. Launching the toy car.

concepts of acceleration and velocity. Further, the collected data can be saved from the WiiPhysics application as a CSV file, allowing the students to further manipulate their data within a spreadsheet application.

WiiMotes can be mounted to a number of other apparatus to further examine in real-time the concept of acceleration, including spinning it on a rope or wheel to examine and measure centripetal force.

Further, a WiiMote equipped car can be used to explore acceleration mitigation strategies. One teacher and fellow pair

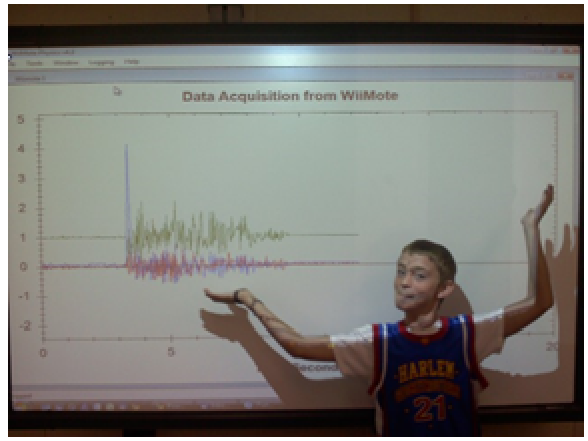

Fig. 4. Real-time data from the WiiMote captured and displayed using WiiPhysics.

carried out a crash barrier contest where students competed in building the most effective crash barrier system from kits containing popsicle sticks, straws, gumdrops, rubber bands, tape, glue, and other miscellaneous supplies. Unlike traditional implementations of such a contest in which the outcome is treated as a binary variable (i.e. in an egg drop the egg breaks or remains whole), the use of a WiiMote allows the actual deceleration to be continuously measured, resulting in a far more robust picture of how the barriers perform.

B. Catapult Design

This module utilizes the engineering design process highlighted in the upcoming Next Generation Science Standards (HS-ETS-ED) [7]. Students in an Introduction to Technology class wanted to build a catapult. Before beginning construction, the student studied historical catapult designs and identified a style that would be possible to build with the materials they had on-hand. Then, they identified the aspects of the design that they could easily alter the length of the throw arm, the angle of release, and the tension provided by the rubber bands.

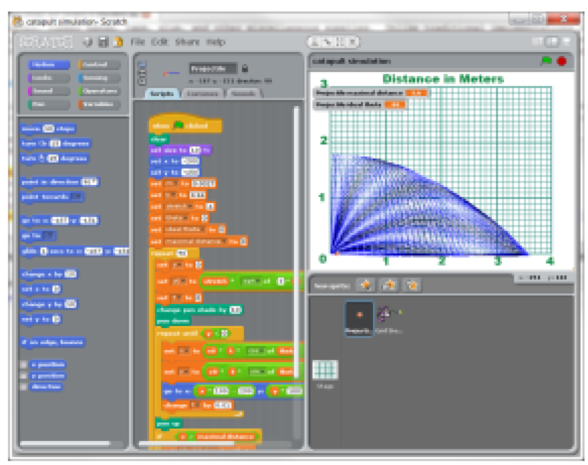

Fig. 5. Catapult simulation built using the Scratch programming language and environment.

Working from this design specification, the students programmed the ballistics calculations within the Scratch programming language, allowing them to compute the expected distance for a projectile to travel given applied values. Their fellow helped them to understand how to systematically alter these variables within their model using loops, allowing them to algorithmically identify ideal solutions. When the students expressed a difficulty interpreting the raw numbers, the fellow worked with them to incorporate visualization within their simulation animating and graphing a projectile launch conforming to the underlying mathematical model of the simulation.

Utilizing these results, the students then designed and constructed a physical catapult corresponding to their ideal design. The catapult was then test-fired, and real-world data collected on the results and compared with the computer model. Causes for discrepancies found between the real-world and computer simulation were discussed (air resistance, wind) and the model revised to account for additional factors.

C. Acceleration in Sports

WiiMotes, and their ability to measure acceleration, can also be used in other settings than the physics classroom. One unusual arena that the INSIGHT program teachers and fellows have exploited is physical education, where WiiMotes strapped to strategic locations can collect real-time acceleration data of athlete's technique. This can help an athlete understand how their technique for bowling, serving, and other activities affects their performance.

Fig. 6. Strapping a WiiMote to a bowler's arm.

INSIGHT participants have used the combination of WiiMotes and WiiPhysics to collect data from a wide range of athletic activities from badminton to water polo (where the WiiMote was sealed in a waterproof bag and placed within a cavity in the ball). Projecting the WiiPhysics real-time graph upon a wall or other surface within view of the athlete allows them to tweak their technique and immediately gain feedback on the result.

Access to real-time acceleration measurements can help diagnose and correct poor technique in student athletes; serving an important role in not only improving performance but also in preventing injuries. An important example of this can be found in weightlifting where discontinuities in an acceleration graph indicate poor form likely to lead to muscle pulls and strains. By mounting the WiiMote to the weight bar and projecting the acceleration graph within easy view of the weightlifters they can better monitor their lift.

Fig. 7. Collecting real-time acceleration data on a bowler's technique.

Fig. 8. Real-time acceleration data being measured in water polo and badminton.

Fig. 9. A WiiMote mounted to a bench-press bar, and the real-time lift data projected onto the ceiling, in easy view of the lifter.

D. Rocketry

Another thematically linked series of modules developed by our fellows tackles the field of rocketry. The first module utilizes stomp rockets foam rockets propelled by a blast of compressed air generated by stomping on a rubber bladder. These are used to develop an understanding of basic ballistic equations students measure the angle of launch and the weight of the stomper and then use these to calculate an expected distance and angle for the rocket to travel. This is compared with actual results.

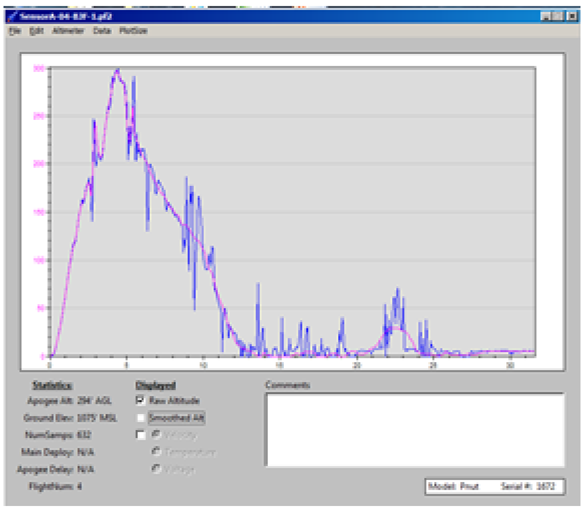

Fig. 10. Flight data measured by an in-rocket altimeter.

The follow-up module utilizes model rockets equipped with a hollow near the nosecone, within which a small altimeter board is placed. This sensor measures the altitude of the rocket as it travels along its flight path. While the students utilized pre-built rockets, another module could be incorporated within which students construct their own rockets, and attempt to maximize or minimize flight characteristics (maximum altitude, time of flight, fuel consumption, rocket weight), which again ties into the engineering design processes included in the Next Generation Science Standards [7].

IV. Results

In the 2010 school year, INSIGHT fellows and partner teachers held 49 of these curriculum modules, followed by 82 in the 2011 school year INSIGHT recruits two-year cohorts in a staggered pattern, so for the 2010 school year - our first year - we had only 6 fellows, while in 2012 we had 10, giving us a per-year average of 8.6 modules/fellow in 2010 and 8.2 modules/fellow in 2011. However, these numbers should only be considered a rough measurement of overall activity, as there is great variation in how fellows have contributed to their teachers' schools - fulfilling roles as diverse as tutoring pull-out sessions for gifted students to facilitating after-school science and engineering programs.

While the evaluation of the INSIGHT project has been largely a qualitative endeavour in the form of teacher/fellow interviews and journal statements (which are the source of the quotes appearing throughout the paper), some quantitative analysis has been performed on Likert scale response surveys given to teachers and fellows participating in the program before and after the 2012 INSIGHT Summer Institute. Only participants who answered both pre- and post-institue surveys were included in the analysis. Due to the small sample sizes and scale-limited responses, Wilcoxon signed-rank tests were performed (at .05 level of significance) for differences in pre- and post-institute responses [8].

Of especial interest is the shift in self-efficacy concerning teacher and fellow attitudes in presenting technology

TABLE I
Partner Teacher Comfort Level with Communication about Technology and Engineering

Comfort Level Statement (Measured on a 5-point Likert Scale)	Pre-Institute		Post-Institute	
	Mean	SD	Mean	SD
I am certain I can present information about sensor technology in ways that my students will understand.*	3.77	1.24	4.62	0.51
I am certain I can present information about engineering in ways that my students will understand.*	3.62	1.19	4.62	0.51
I am comfortable talking about ideas to incorporate sensor technology into the classroom with other teachers.*	4.00	1.08	4.69	0.48

*Statistically significant differences defined by Wilcoxon signed-rank tests in sample population of 13 INSIGHT partner teachers.

TABLE II
Participant Comfort Level in Helping Students Achieve Proficiency with Science and Technology Standards

Comfort Level Statement (measured on a 4-point Likert-like scale)	Pre-Institute		Post-Institute	
	Mean	SD	Mean	SD
Identify appropriate problems or opportunities for technological design.*	2.62	0.67	3.24	0.70
Propose a design and identify constraints reflected by that design.*	2.71	0.64	3.38	0.67
Compare designs and choose between alternative solutions.*	2.76	0.62	3.43	0.68
Implement a chosen design.*	2.81	0.75	3.38	0.74
Evaluate that design solution and its consequences.*	2.81	0.75	3.38	0.67
Evaluate that design solution and its consequences.*	2.86	0.65	3.29	0.64

*Statistically significant differences defined by Wilcoxon signed-rank tests with N=21 teachers and fellows.

and engineering in the classroom, and helping students gain profieciency in these subjects, as "...there is substantial evidence to suggest that, teachers' beliefs in their capacity to work effectively with technology are a significant factor in determining patterns of classroom computer use"[9]. For both teachers and fellows, clear patterns of increased confidence and comfort with these areas emerged from analysing the pre- and post-institute responses. These results can be seen in Tables I and II above.

V. Conclusion

The INSIGHT GK-12 Program has been effective in integrating sensor technologies and computing science principles into diverse K-12 classrooms, and has garnered positive feedback from all of its participants. Coupling the intensive training of the summer institute with an ongoing partnership between a teacher and a fellow has proved to be a very productive and valuable strategy. Staggering new entrants (teachers and fellows) into the program has also been an important strategy, as doing so ensures that every new cohort of teachers and fellows train side-by-side with a group of returning veterans from the previous year. This also helps to encourage out-of-the-box thinking, as the previous cohort has already tackled the often-challenging task of identifying ways in which sensors can be used in unusual settings, like physical education classes. This can in turn lead to fresh thinking from the new participants. The result is an active and imaginative community of practice, committed to integrating sensor technologies and computing science fundamentals into everyday classroom practice.

Acknowledgment

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Integration of Sensors and Electrical Engineering into Secondary Geometry Curriculum

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***Abstract*— Several studies have reported on the potential benefits of integrating engineering education in K-12 curricula. Such benefits include: (i) an improved student learning and achievements in mathematics and science, (ii) an increased awareness of engineering and what engineers do, and (iii) an interest in pursuing engineering as a career. To help realize these benefits, the goals of the University of Texas-Pan American Research Experiences for Teachers in Emerging and Novel Engineering Technologies (RET-ENET) program are to: (i) engage math and science teachers in engineering research during the summer for the period of six weeks, and (ii) support the recruited teachers to translate their engineering research experiences into hands-on engineering-inspired curricula that they implement in their classrooms during the academic year. Using specific examples from the 2012 RET-ENET program, this paper discusses the activities conducted by a team of teachers who worked on a radar imaging research project and the process that led to the development of hands-on geometry lessons inspired by the research experience. The observation of the implementation of the lessons in the teachers' classrooms and the results of student assessments showed that the engineering-inspired hands-on lessons engaged students and increased their interest in learning the geometry concepts.**

Keywords— Research experience for Teachers; K-12 Geometry; Engineering content in science and mathematics instruction; Hands-on learning.

I. Introduction

New data published in the 2012 National Survey of Science and Mathematics Education report sheds new light into the serious challenges that the United States faces in its efforts to increase student achievement in math and science [1]. Out of the nearly 7,800 teachers surveyed, only one-third of middle school math teachers have a degree in mathematics or math education. The survey also shows that a large number of teachers do not feel well prepared to plan instructions that meet the needs of students at varying levels of math and science understanding. Teachers who are not well prepared are usually not comfortable with teaching challenging math or science concepts. When teachers are not comfortable with teaching a challenging content, they tend to teach the content superficially or avoid teaching the content [2]. A study has shown that teachers' discomfort and lack of confidence in teaching math concepts have a negative impact on student learning and perception of math [3].

Due to the strong link between engineering, math and science, several initiatives have been taken to introduce engineering content in K-12 math and science curriculum. The motivation behind these initiatives is twofold: (i) make a connection between math and science concepts to real-world applications to engage students and motivate them to learn math and science concepts, and (ii) promote pathways for students to be part of post-secondary STEM degree programs. There are two main approaches for infusing engineering in K-12 math and science curriculum. In the first approach, engineering is treated as a unique discipline and engineering curriculum is often offered as pre-packaged courses [4, 5]. The second approach calls for employing engineering as a tool for teaching math and science contents - that is engineering is embedded in math and science curriculum [6]. Both approaches have their merits. While there is an ongoing effort in the nation to increase K-12 math and science teachers' content knowledge, it is important to recognize that teachers can potentially become more confident to teach challenging concepts and know how to relate them to real-world engineering applications if they participate in a professional development program that gives them the opportunity to experience engineering.

To address the above discussed issues, The University of Texas-Pan American (UTPA) and several school districts in the region have formed a partnership to provide a professional development program for teachers to experience engineering research and translate the research to relevant hands-on math and science curriculum that meets state standards. This professional development program – Research Experiences for Teachers in Emerging and Novel

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Engineering Technologies (RET-ENET) – was established in 2011 and hosted at UTPA. The first cohort of twelve middle and high school math and science teachers completed the RET-ENET program in the summer of 2012.

There is a number of papers that present the summer activities of other RET programs. However, there is a lack of published work that focuses on the various challenges that teachers face when they are asked to translate their engineering research experiences into relevant math and science curricula. Using specific examples from the 2012 UTPA RET-ENET professional development program, this paper discusses the main challenges associated with the task of translating research experiences into hands-on engineering-inspired activities that are appropriate to the subjects and grade levels the teachers teach, and that can be seamlessly integrated into the curriculum. Due to space limitation, this paper considers the activities of one single team of teachers who worked on a radar imaging research project and who, in collaboration with engineering faculty, re-designed their traditional geometry lessons to include hands-on activities that are relatable to the engineering research conducted during the summer program.

II. Overview of the RET-ENET Program and Research Questions

The RET-ENET program engages middle and high school math and science teachers in authentic engineering research experiences during a six-week summer program. Twelve middle and high school math and science teachers were selected to participate in the 2012 summer professional development program. Four engineering research projects were offered and teachers worked in trios on each project under the mentorship of an engineering faculty. The engineering research projects were in the areas of (i) nanotechnology, (ii) radar imaging, (iv) renewable energy, and (v) wireless communications. The summer program included several professional development seminars and workshops to provide the necessary tools and knowledge for teachers to conduct the assigned research projects and to help guide them to translate their research experiences into classroom activities.

This paper presents the research and curriculum activities of the team of teachers who worked on the radar imaging research project. The program research questions are:

- What roles does an active participation in authentic engineering research have on teachers' understanding of engineering and their adoption of new pedagogy?

- What influence does the mode of hands-on instruction by RET-ENET teacher participants have on their students' learning and interest in science, math, and engineering?

III. Teacher Engineering Research Activity

A team of three teachers, who teach mathematics and geometry subjects at middle and high schools in the Rio Grande Valley (RGV), worked on inverse synthetic aperture radar (ISAR) imaging [7-9]. None of three teachers has had an engineering background. They were introduced for the first time to radar imaging and were given a research task that consisted in analyzing the performance of an ISAR signature simulator by processing radar images of a three-dimensional model of a Boeing 727 and comparing them to real ISAR images of the same aircraft.

The teachers spent the first two weeks of the summer program reading background materials on ISAR imaging. A workshop was offered by the University library staff to help the teachers learn how to conduct electronic searches of technical articles. A workshop on the basics of the MATLAB software [10] was also offered by the RET-ENET management team as part of the summer professional development program activities. Teacher teams were asked to submit weekly progress reports. A weekly meeting with the program management team was held to promote discussions between all four research teams. The purpose of the weekly research meeting is three-fold: (i) teachers learn about research activities conducted by other teams, (ii) project management team monitors progress made by the teachers, and (iii) questions are answered and concerns by teachers are addressed by the program management team.

To understand the scope of the ISAR signature simulator, the radar imaging team began the research activity by generating radar images of three dimensional models of basic figures such as cubes, cylinders, and triangular prisms. The team used the basic models to start the testing the simulation software. This initial activity helped the teachers gain a better understanding of various components of the ISAR signature simulation software. The ISAR images created by such simple shapes were easy to analyze. After the teachers have felt more comfortable with the research process, they then moved to construct a model of the Boeing 727 using Blender - a 3D computer graphics software program [11]. At the end of the six-week summer program, the teachers succeeded in evaluating the quality of the ISAR signature simulator's images of the aircraft model. They completed a research report and prepared a research poster that was presented to other teachers, students, faculty, and school administrators at the end of the summer symposium held at the University.

IV. Resulting Lessons

A. Translating Research into Relevant Lesson Activities

An important component of the RET-ENT summer program engaged teachers in exploring and designing hands-on activity lessons for their math and science classrooms. Before the teachers started the summer program, neither the project management team nor the teachers had determined which of the exiting lesson plans should be redesigned and used with their students during the following academic year. On the first day of the summer program, teachers, however, were asked to identify some important concepts that their students either find difficult to understand or show no interest in learning. As teachers progressed in their research, they were asked to identify one or two important elements from their research experiences that can be linked to the concepts they teach in their classrooms. Weekly lesson development sessions were held to guide the teachers in the development of their lessons. The development of hands-on lesson plans was an iterative process. The first step of the process was to formulate an engineering connection to the math and science concepts. During the early lesson development sessions, teachers discussed their research experiences and shared ideas for lessons with other program participants and the project management team. As the summer progressed, teachers designed hands-on activities for their lessons that they discussed with their colleagues and the project management team. Throughout the lesson development sessions, inputs from teachers, engineering and education faculty were instrumental in formulating the engineering connections and shaping up the engineering-inspired hands-on lesson plans. Supplies were acquired for teachers to experiment with the various design components of their new hands-on lessons.

B. Making An Engineering Connection

To help in the design of the hands-on activities, teachers were guided to formulate concrete engineering connections to the science and mathematics concepts being taught in their lessons. More specifically, teachers had to draw from their research experiences some real-world engineering applications that can show how engineers apply the science and mathematics concepts to design new systems and solve problems. As the summer progressed, teachers became more knowledgeable about the engineering research problems they were working on and were able to improve the formulation of the engineering connections to their lessons.

After some discussions between the engineering faculty and teachers, it was found that the radar imaging problem can be related to at least three geometry concepts taught to middle and high school level classrooms. The three geometry concepts were: (i) The Pythagorean Theorem, (ii) Trigonometric Functions (SOHCAHTOA concept), and (ii) Similar Triangles.

The formulated engineering connection is stated as follows:

Math, Science, and Engineering play an indisputable role in the creation of modern measuring devices. Without some of these devices, it would be extremely difficult or even impossible to measure distances due to bad weather, hostile territories, or remoteness of location. Examples of such devices include Synthetic Aperture Radars (SAR) that are developed by Electrical Engineers. SAR technology has provided terrain structural information to geologists for mineral exploration, reconnaissance and targeting information for military operations, and oil spill boundaries on water to environmentalists. SAR systems use radio waves to create images of flying or stationary targets. These radio waves are transmitted and received by an antenna. The antenna generates the waves and sends them towards the target. Once the waves hit the target, they bounce back towards the antenna. In order to obtain clearer images, engineers must find slant range (distance from the radar to target and ground range (horizontal or ground distance from radar to target). Sometimes distances cannot be measured directly. Therefore, engineers use mathematics to find these distances. However, some trigonometric ratios and equations can only be used with right triangles. Fortunately, the radar antenna, the target, and a point of reference on the ground form a right triangle (Fig. 1).

For each lesson, the engineering connection is tailored as follows:

- *Pythagorean Theorem: Engineers use the geometric concepts of the Pythagorean Theorem to calculate distances in any right triangle model.*
- *Trigonometric Functions: Engineers use trigonometry to calculate unknown distances by using angles and known sides of a triangle.*
- *Similar Triangles: Attributes of similar figures can be used to create a scale model of the radar and target scenario. Ratios and proportions of corresponding sides can be used to test the proportionality of a scale model and to calculate distances.*

C. Hands-On Activities

Teachers often teach geometry in a procedural fashion and rarely make connections to real world applications. With input from the project management team, the teachers decided to consider an experimental set-up similar to a real-world radar system. In this setup, an infrared (IR) range sensor module is used to emulate the radar system. The IR range sensor can be used to determine distance measurements from voltage readings. A toy airplane or an airplane modeled out of clay could be used to emulate the target. To include a partial design component into the lessons, students are given the opportunity to build their own sensor modules. Each student group is given a kit (Fig.2) and instructions to build and IR-based sensor "radar" system prototype shown in Fig. 3. Students are then engaged in calibrating the sensor by collecting different measurements of distance between the sensor module and a wall and the corresponding voltage readings taken from a multi-meter (Fig. 4).

The current hands-on activities provide a new strategy to teach the geometry concepts by making them more interesting and engaging for students. Because of the formulated engineering connection between the geometry concepts and the real-world application, students see themselves playing the role of engineers to solve a problem. Teachers feel confident about the subject because they can speak from experience. This fact motivates students to learn the concepts.

D. Classroom Challenges and Learning Objectives

The classroom challenges are intended to make students feel they are "engineers". They are challenged to solve an "engineering" problem. The classroom challenge and learning objectives for each lesson are given next. The learning objectives include learning outcomes related to technology - resulting from the incorporation of the hands-on activities into the lessons.

1) Pythagorean Theorem (Grade Level: 8)

a) Classroom Challenge: Pretend you are an engineer working with NASA aviation. Under time and funding constrains, NASA has asked you to construct, calibrate, and evaluate their lastest Radar system design. The functional prototype, radar calibration results in graphical and tabular form, and distance evaluation results are due in four days!

b) Learning Objectives:At the end of the activity, students will be able to:

- Demonstrate a basic understanding of a Synthetic Aperture Radar system
- Formulate a tabular and graphical model that describes the relationship between variables
- Use the Pythagorean Theorem to calculate sides of a right triangle

2) Trigonometric Functions (Grade Level: 10):

a) Classroom Challenge: A hostile nation is preparing to launch a nuclear missile test in the coming days. We must obtain satellite images to confirm or deny this unauthorized activity before any other actions are taken. Your team is equipped with an MQ-9 Reaper, an unmanned aerial vehicle, capable of flying as high as 50,000 feet but only operational at 25,000 feet. Your UAV must fly by the hostile nation's presumed nuclear site and obtain radar images without being detected. At each station, the specifications and limitations of your UAV will be provided for you. Furthermore, the hostile nation's presumed nuclear site has been known to have a radar monitoring system. The specifications of their radar system have also been provided for you at each station. You must make the necessary measurements to figure out if your UAV will be detected by the hostile nation's radar system.

*b) Learning Objectives:*At the end of the activity, students will be able to:

- Use right triangle trigonometry to calculate unknown distances
- Use right triangle trigonometry to calculate unknown angles
- Use sensors to measure distances
- Convert voltage measurements to distance measurements
- Describe how to find unknown distances and/or angles using trigonometry.

3) Similar Triangles (Grade Level: 7)

a) Classroom Challenge: "Imagine you are an army soldier that monitors radars in a military base. You are asked to present how radar imaging is done to a group of people. Your audience is not familiar with radar imaging. You decide to use a model to help your audience better understand your presentation. Your model must be similar to the one shown in the presentation. How can a model help you present this concept?You know the angle formed by the ground range and the airplane's altitude is 90 degrees and the angle formed by the ground range and slant range is 37 degrees. How can you find the measure of the third angle in your triangle? How can you make a realistic model of the scenario? How can similarity help you construct a proportional model to make it realistic?

b) Learning Objectives:At the end of the activity, students will be able to:

- Use critical attributes of similar figures to determine if two figures are similar or not.
- Find the measure of an angle in a triangle when given the measure of the other two angles.
- Learn how technology is used to measure angles and distances.
- Connect their current learning to real-world applications in radar imaging.

E. Lesson Implementations in Teachers' Classrooms

The hands-on lesson on the Pythagorean Theorem was implemented in Memorial High School (McAllen ISD, Texas) in Fall 2012. The hands-on lesson on Similar Figures was implemented in Alonzo De Leon Middle School (McAllen ISD, Texas) in Fall 2012. The lesson on Trigonometric Functions was implemented in Jimmy Carter Early College High School (La Joya ISD, Texas) in Spring 2013.

The implementation of each lesson took four days. During the classroom implementation, students showed excitement to construct the sensor modules and learn how to use a multi-meter to measure voltage. Students used their sensors, multi-meter and TI-84 graphing calculators to measure the distance from the radar to the airplane and record it in their worksheets. Students then measured the distance using their measuring tape to compare the accuracy of their readings to that provided by the sensor. Students answered questions provided in the worksheets developed for the lesson. Students then participated in a gallery walk to view and learn about the other students' models. On the last day, students took a test to assess their learning of the taught geometry concepts and radar imaging. All students met the passing standard on the test; the passing standard on the test was 70%.

V. CONCLUSION

This paper describes the research activities of a team of math teachers recruited by the research experiences for teachers in engineering program hosted at The University of Texas-Pan American. The paper also discusses the adopted process that helped translating the gained research experience into engineering-inspired hands-on geometry lessons appropriate for middle and high school students. These activities not only engage students and increase their interest in the subject, as seen from classroom observations and assessment results, but also increase teachers' confidence to teach challenging concepts and relate them to real-world applications.

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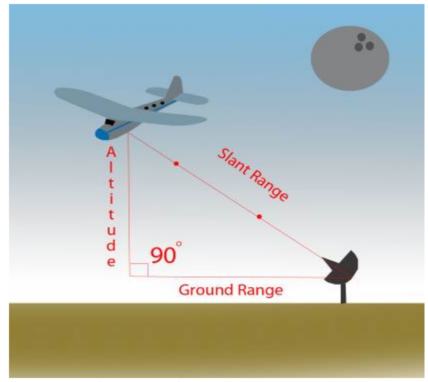

Fig. 1. Radar system geometry

Fig. 2. A "radar" system unit kit is prepared for each group of students. The kit contains a battery holder, three AA batteries, a Sharp IR sensor, two alligator clips, two screws, two hex nuts, and two wire connectors.

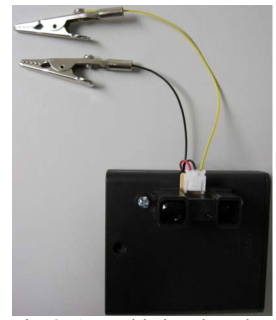

Fig. 3. Assembled IR-based sensor "Radar" system prototype.

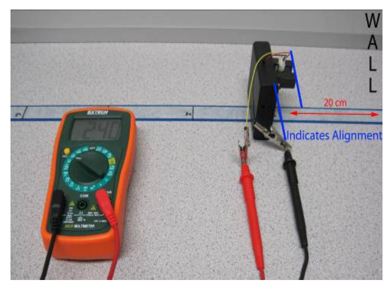

Fig. 4. IR-based sensor "radar" sensor calibration set-up.

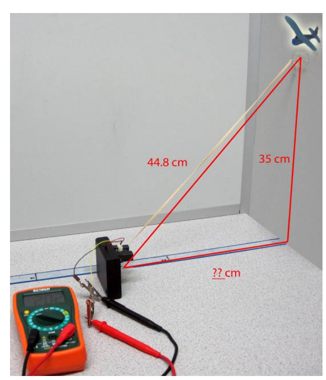

Fig. 5. Indoor "radar" system evaluation with unknown ground distance, height of 35cm, and hypotenuse of 44.8cm (used in the Pythagorean Theorem lesson).

This IS child's play

Creating a "playground" (computer network testbed) for high school students to learn, practice, and compete in cyber defense competitions

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Abstract— The IT-Adventures program is designed to increase high school students' interest in information technology (IT) as a career. It allows them to learn about IT in non-threatening, extracurricular IT-Club activities using inquiry-based learning. The IT-Clubs have four tracks from which students can select to study: cyber defense, game design programming, robotics, and multimedia. This paper focuses on the cyber defense venue and the need for students to have equal access to computing equipment on which to learn about computer operating systems, networking, and information security prior to competing in a cyber defense competition (CDC) at the end of the academic year. The creation of a remotely located and managed "playground" provides uniform access to equipment across schools. This paper shares our knowledge and experience in creating the "playground".

Keywords—high school outreach, inquiry-based learning, cyber defense competition, information assurance.

I. Introduction

IT-Adventures is a highly successful high school outreach program run by Iowa State University (ISU) dedicated to increasing interest in and awareness of information technology (IT). The program, which is in its seventh year, has four tracks from which students can choose to study: cyber defense, game design programming, robotics, and multimedia [1]. This paper focuses on the cyber defense venue and the need for students to have equal access to computing equipment on which to learn about computer operating systems, networking, and information security.

As part of the IT-Adventures program, an IT-Club is created at the high school that runs as a year-long, after-school, extra-curricular activity. The inquiry-based approach [2-4] of the IT-Club is a successful method to increase student understanding of information assurance and computer/network security in a non-threatening, non-graded environment. The capstone event for students who participate is a two-day cyber defense competition (CDC) on the ISU campus.

In past years, physical access to hardware and operating systems for the students to practice with has been provided two ways. In the early years, computer hardware was donated to the program from corporations. The systems were refurbished and reshipped to the high schools to setup. This was not a scalable process. Therefore, in more recent years, the high schools were told to ask for donations of old equipment from companies geographically close to them. While this reduced the refurbishing and shipping requirements on the outreach program staff, it created inequities in what the students had at each school.

To solve this problem, the authors of this paper created a "playground" that is available to the students enrolled in the IT-Club in the fall of the year. This allows uniform access to equipment. Each IT-Club is given remote access to a network in which they can experiment; building different operating systems and installing different network services. The high school students spend the entire year remotely working in their assigned network space. Then, one month prior to the competition, the "playground" is wiped clean and the high school students can setup their competition networks for the CDC.

II. Outreach Program Background

IT-Adventures specifically targets high school students who previously have not exhibited an interest in studying IT. There are already programs available in IT-related areas such as the Lego First Tech Challenge and the Cyber Patriot Games where students who have IT knowledge can gain more knowledge. Those students and their programs are comparable to varsity athletes competing in a varsity sport. The IT-Adventures program is modeled after an intramural sport. Every student can have the opportunity to explore IT and to learn from it, not just the ones who are already good at it. This widening exposure to IT for high school students is especially important since computer-related courses are nearly non-existent in high schools across the U.S. [5].

As part of their IT-Club activities, the high school students are given access to learning materials, as well as a set of questions to explore. When the students choose to participate in the cyber defense venue, their "problem" is to compete in a state-wide CDC in the spring [1, 6-8]. The details of a CDC are discussed in Section III. Although we generally average 100 students in the cyber defense venue per year, in April 2009 the largest CDC ever hosted in any division, (collegiate or high school, on our campus or other campuses), occurred as part of the IT-Adventures program with 36 teams and 174 high school students competing.

The "playground" was developed with the support of a Department of Justice grant. The IT-Adventures program is supported by Iowa State University Department of Electrical and Computer Engineering and the Information Assurance Center.

III. PLAYGROUND CONFIGURATION

IT-Club members have remote access to the "playground" beginning in the fall of each academic year. For a majority of the year the students can use the "playground" to explore, learn, and play in a safe and controlled environment. However, during the month preceding the CDC, the "playground" becomes a competition environment. This design allows ISU to actively support the learning modules and labs because the hardware configuration is known and readily accessible by the university student workers and project staff. Additional information about the technical staff who support the "playground" is provided in Section IV.

The "playground" is built around a set of servers running ESXi 5.1. In its current configuration, there are five ESXi servers, however, the "playground" is highly configurable and could exist in other configurations depending upon equipment and number of student teams. Each of the current five ESXi servers is shown in Fig. 1 as a box composed of red dotted lines. The largest red dotted line box in the drawing depicts the ESXi server which houses the Internet-Scale Event and Attack Generation Environment (ISEAGE – pronounced ice-age) testbed, the air gap proxy, the remote desktop protocol server, and the ISO image datastore.

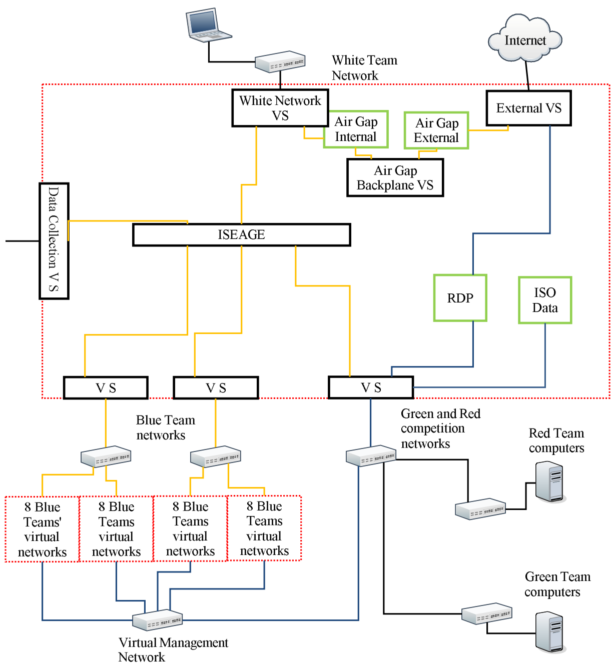

Figure 1. Playground Diagram

This ESXi server has one network interface card (NIC) connected to the Internet which allows two connections to the outside world through a virtual switch labeled external virtual switch (external VS). The first connection out of the external VS is for a remote desktop protocol (RDP) server that the high school students use to remotely connect into "playground" environment. They use the RDP server to get connected to their virtual networks through the virtual management network. In Fig. 1 the lines that connect the high school students from the external VS into the RDP server and then through to their virtual networks are blue. The high school student networks have each been pre-configured with one virtual switch in the virtual management network to allow them to start their virtual network configuration. A printed document which illustrates the remote access procedure to log into and use the "playground" was created for the high school students to reduce questions about access.

Each of four physical servers (red dotted line boxes in the bottom left of Fig. 1) have been configured in ESXi to host eight different IT-Clubs' virtual networks. With their own virtual network space they are allowed to build and configure machines in any manner using any public domain or Microsoft-based operating. Operating systems are installed through ISO images stored in the central ISO datastore, also shown in Fig. 1 connected with a blue line. Although the students use the RDP server and the virtual management network for installing servers and operating systems in their virtual networks, the machines they build and configure use the IP address space in the ISEAGE network which is discussed below. These connections are shown in yellow in Fig. 1.

The other connection to the external VS is for the air gap proxy which secures the ISEAGE network traffic that the high school students' networks generate. The set of two servers that provide the air gap is shown in the top right corner of Fig. 1. The server labeled Air Gap Internal is the only egress point for traffic leaving the ISEAGE testbed. It allows web and ftp traffic to pass out of the high school students' networks, but restricts all other traffic. By using this configuration, students are allowed to connect to the Internet to download patches or search for additional information about configuration problems, but other traffic is prevented from escaping. This provides an isolated network environment in which the student networks can run. It was constructed to avoid the inevitable misconfiguration or unwanted attacks on the real world network. The server labeled Air Gap Internal also provides the domain name service (DNS) for the high school teams' virtual networks which allows them to appear to each other to be part of the Internet.

The core of the ISEAGE testbed is a routable IP network that supports the traffic to and from the high school students' virtual networks. Because of ISEAGE's internal programming, it provides IP address space for each high school group's virtual network and allows them to experience running a network as if it were actually sitting on the Internet. ISEAGE allows to traffic appear as if it has routed through the Internet, although it stays within the ISEAGE environment. ISEAGE is unlike conventional testbeds where each router represented by either a real router or a software router running on a computer. ISEAGE supports the concept of an internal cloud network where the cloud represents a cluster of routers. If an external computer performed a traceroute it would see a number of hops between itself and server as if there were real routers between it and the server. The TTL field in the IP header would also indicate the traffic traversed multiple routers. Again, this allows the students to see traffic as if they were separated from each others' virtual network via the Internet rather than routing traffic through a single server.

Upon further examination of Fig. 1, there are additional networks that have not yet been discussed. These remaining networks are not necessary for the year-long inquiry. They are built into the “playground” to be used during the CDC event. In a CDC there are four teams of people needing network connectivity: Blue, Green, Red, and White.

The Blue Teams are the high school student teams who setup and defend their network from attackers. They also participate in numerous activities (called anomalies) throughout the competition requesting changes to their network. The team who administers these anomalies is called the Green Team.

The group who tests each student team’s network for vulnerabilities and plays the role of attackers in the competition consists is called the Red Team. They actively engage in network scanning, penetration testing and exploitation of vulnerabilities.

To win a competition, the student teams earn points based upon service uptime, usability, security, and reporting. The judges record the points earned during the completion and are called the White Team.

Fig. 1 shows that there is a virtual switch for the Green and Red teams to connect into the ISEAGE testbed to test the high school student teams’ networks for usability, as well as vulnerabilities. There is also a virtual switch to connect the White Team to monitor and score the competition.

The final connection into the ISEAGE testbed is labeled Data Collection in Fig. 1. This allows the authors to collect the traffic generated during setup, as well as during the competition for further analysis.

IV. Technical Support for Playground

Technical support for the “playground” requires both paid and unpaid undergraduate students at ISU. The primary technical support for the “playground” is provided by the undergraduate student staff members of the Information Assurance Center. They configure and maintain all the ESXi equipment, the ISEAGE network, and the support systems such as remote access and ISO images under the direction of the authors of this paper. In addition to these paid student workers, ISU also has a student organization called the Information Assurance Student Group (IASG). Volunteers from IASG, along with paid Information Assurance staff, provide the remote setup support for each of the high school IT-Clubs, as well as write the rules for the CDC and staff the actual two-day event. Remote setup support is staffed approximately 20-30 hours per week, mainly in the evening.

V. Future Work

Creating a “playground” allowed uniform access to equipment for all IT-Clubs and allowed high school students to spend the entire year remotely working in their assigned network space. This approach, while demanding additional technical support staffing on the part of the IT-Adventures program, was far superior to the ad hoc approach taken to supplying physical hardware for students in past years. The technical support staff was able to more efficiently and effectively answer questions for the high school students and the students did not have the technical road blocks of antiquated computer equipment getting in the way of learning.

The “playground” is fully implemented, but the updated learning modules to replace existing modules are still under development. The expectation is to have these new learning modules in place by Fall 2013. While there has been on-going assessment of the IT-Adventures program throughout the life of the program, additional assessment tools still must be put in place to evaluate the effectiveness of the new learning modules and the “playground”. This work begins also in Fall 2013.

In future implementations, the “playground” will include a set of vulnerable machines with which the students could learn about conducting penetration testing on their own systems. The closed environment in which the student networks exist allow the students to run tools against these systems to find the vulnerabilities and then to use tools to exploit what they have found without any traffic traversing a real world network.

Finally, while this paper focuses on the use of the “playground” in a high school setting, the “playground” can be used to support educational activities at the community college and university levels as well. We have had one community college in Iowa recreate a version of the “playground” to support their own post-secondary classroom activities. Other colleges and universities have also expressed interest in an implementation of the “playground”.

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A Curricular Framework for Critical Infrastructure Protection Education for Engineering, Technology and Computing Majors

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***Abstract*—The 16 critical infrastructure sectors identified by the US Department of Homeland Security employ many engineering, technology and computing graduates who increasingly face critical infrastructure protection (CIP) issues. However, most undergraduate curricula in these disciplines do not incorporate CIP in any meaningful way. This paper proposes a flexible curricular framework for integrating CIP into undergraduate education via self-contained inter-disciplinary CIP course modules; a course module is a distinct curricular unit such as a lab or teaching component for use by an instructor in existing courses without requiring any course or program modifications. The proposed course modules cover physical, human, and cyber aspects of CIP. The framework is designed for use in multiple disciplines, and the modules are designed for presentation at different levels of the undergraduate experience, with subsequent modules building on those presented earlier. This approach is intended to prepare students for careers solving problems in design, implementation, and maintenance of robust, sustainable infrastructure assets.**

Keywords— critical infrastructure protection; course modules; homeland security

I. INTRODUCTION

Critical infrastructure refers to systems and assets so vital to any country that their incapacity or destruction would result in a debilitating impact on security, the economy, national public health or safety [1].

The US Department of Homeland Security has identified 16 critical infrastructure sectors that include such functions as transportation, energy, healthcare, food and agriculture, water, financial services, emergency management, and defense, critical manufacturing and commercial facilities. Many of these sectors, such as the electric grid, fuel delivery systems, and water purification and delivery plants, are supported through the Internet, or cyber resources.,. The flexibility and advantages of cyber resources is generally recognized, but they come with a high cost: the constant threat of interruption, theft, manipulation, and destruction.

Many engineering, technology and computing graduates already work in critical sectors. Given the urgency and the necessity for critical infrastructure protection, it is not difficult to make a compelling case that these graduates will thus be facing an increasing set of critical infrastructure protection issues in their careers. While the Department of Homeland Security has prepared informational materials on these sectors and some instructional units are available for graduate students [2], undergraduate curricula do not address CIP in any meaningful way. Further, much of the available materials focus on the physical and human element of vulnerability, and not the cyber element. It is this cyber (virtual) element that is most inextricably linked to the resiliency of the system, as the real issue is not whether the system is rendered inoperable, but rather how quickly it can be restored to operability. Therefore, the less resilient the system, the greater the relative impact. Since cyber systems connect and control much of our infrastructure and resources, their resiliency is fundamental to a safe, secure and functional society.

This paper describes a curricular framework for integrating critical infrastructure protection (CIP) concepts across engineering, technology and computing. In addition, to allow this material to be reused across multiple diverse student groups, the integration is accomplished by using a set of interdisciplinary course modules. In this context, a course module is viewed as a distinct curricular unit such as a lab or teaching component, which can be used by an instructor in an existing course typically without any course or program modification approvals. These modules can be expanded as needed to prepare students for careers in problem solving, design, implementation and maintenance of robust and sustainable infrastructure assets.

II. MOTIVATING THE CURRICULAR FRAMEWORK DESIGN

How do we protect current and future resources critical to our nation's health, security and economy? If such systems are breached or compromised, how can we ensure they will be resilient, and be able to go back on-line in a minimum amount of time? Our examination of the major issues in protecting critical infrastructure indicated the emergence of three driving forces, as discussed below.

- **Reliance on complex systems.** The increased reliance on complex systems, coupled with high multivariate and unpredictable risk from natural and intentional sources is a major factor. Events such as the September 11 attacks, the Virginia earthquake, and several major hurricanes (for example, Katrina, Irene or Sandy) exposed vulnerabilities in many critical systems that

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modern society depends on each day. Several critical infrastructures were designed for operation in a manual or analog mode and now have been retrofitted to be managed digitally through cyber based systems [3]. Future engineers, technologists, and managers need to understand how design and implementation can exacerbate vulnerability or increase resiliency. Additionally, while there is a tendency to view risk in terms of large densely populated urban centers, the reality is that these critical systems govern operations in wide cascading networks. Significant risk is thus not confined to our biggest cities. Thus, an outage in a large city where critical servers are located may cause serious disruptions in dependent smaller areas.

- **Societal changes in computing.** The rapid growth in mobile computing devices such as smartphones and tablets and the widespread adoption of cloud computing has made cyber security a concern for everyone. Moreover, issues of cyber security and the impacts of security breaches span multiple CIP sectors [4].
- **Need for a CIP-aware populace and workforce.** Employees who understand the socio-technical issues and risks faced by our modern society are in demand in both public and private sectors [5], especially given that most of the nation's critical infrastructure is privately owned [6]. Students who are exposed to CIP concepts along their educational path will graduate with necessary skills and knowledge to address risk and resiliency issues in critical infrastructure systems.

These three major issues provided the motivation for integrating CIP across several courses and disciplines, using "drop in" modules to serve as supplemental materials for vertical integration into an array of multidisciplinary courses across all years of undergraduate study. Students thus encounter relevant CIP concepts several times at increasing depth as they progress through their degree programs.

III. COURSE MODULES

This effort focused on modules, herein defined as a lab or teaching component. Modules were designed so they could be used by an instructor in an existing course without requiring formal curricular changes or approval.

The foundation of the approach is a set of self-contained instructional modules that can be "dropped into" relevant classes. The modules cover physical, human, and cyber aspects of CIP in appropriate detail, from introductory material to deeper, more technical concepts. These self-contained elements can be used in many different ways. Some examples of module usage are given below.

- **To replace obsolete or outdated material.** Computer science or engineering classes need frequent updates to keep pace with technological advances. These modules are an excellent way to replace outmoded topics with a contemporary, pressing problem of system security.
- **To enhance and strengthen existing material.** Some course topics touch on infrastructure concepts, e.g., discussions on privacy, hacking, or hardware issues such as loading. Modules would augment this material by linking theoretical concepts with the real-world systems whose security, safety, and resilience are made more or less vulnerable through software and hardware design.
- **To supplement a course with new material.** In this scenario, modules introduce a new topic for the course. Note that supplementing a course with a new module could mean other topics would be shortened or, if obsolete, dropped altogether.
- **To function as homework assignments or labs.** Because these modules are meant to be stand-alone units, including both content and assessments, they can be used as homework or supplemental assignments, and designed specifically for this purpose.

A. Curricular Goals

Although there are 16 Critical Infrastructure and Key Resource (CI/KR) sectors as defined by DHS, there are fewer pervasive themes we identified across all sectors. Hart and Ramsay [7] define a five-part framework based on policy, networks, level of hazard, level of protection and system design. Each component included physical, human and cyber (virtual) elements.

Our instructional team developed the following learning outcomes based on the objectives defined by Hart and Ramsay [7] in their CIP course guide:

- **Learning Outcome 1.** Understand national strategies and policies on CIP and Key Resources – CI/KR
- **Learning Outcome 2.** Identify key components of a complex system
- **Learning Outcome 3.** Describe the hazards present in the critical components of a complex system
- **Learning Outcome 4.** Assess the level of protection and resiliency for the components of a complex system
- **Learning Outcome 5.** Learn system design concepts to achieve the desired protection and resiliency.

B. A Sample Course Module

For illustration, we selected one of our course modules that can be used in multiple courses offered at different learning levels. Other modules being developed include level-appropriate material and exercises to provide students experience with concepts at multiple levels of detail. These modules are based on the requirements outlined in the DHS National Infrastructure Protection Plan [8].

Module: Introduction to Critical Infrastructure Protection

This course module will introduce students to basic concepts underlying critical infrastructure; its relationship to emergency management and planning; and why protecting the infrastructure is important for personal, community and national security cover topics. Students will learn that critical infrastructure/key resources encompass those physical entities and processes that make our communities function effectively. The module will also show how critical resources of energy supply, water/wastewater, transportation, telecom, emergency services/medical, facilities and finance depend upon computing, engineering and technology and our national interests are protected by securing these sectors, and demonstrate how computing, engineering and technology both support this infrastructure and provide tools of protection.

Suggested target courses for this module include introductory engineering, technology, and computing courses on networking, telecommunications, civil engineering technology, and computing security.

CIP Learning Outcomes: 1, 2

IV. Assessment and Evaluation

To ensure the course modules are effective, each module has a set of concrete achievable outcomes that will be assessed and evaluated. Evaluation data will be used for both formative and summative purposes: (1) to improve the assessment instruments and instructional modules as they are pilot tested and revised, and (2) to provide evidence that this approach enables learning at all levels. Our assessment will answer the following:

- **How easily and effectively are modules integrated into existing curricula?** Feedback from design teams and adopting instructors will evaluate module usefulness, ease of use, time to introduce the topic, and appropriateness of indicated module prerequisites.
- **How effective are the modules for students?** Student assessment will be measured through student feedback and learning gain.
- **How effectively are students in different disciplines learning the intended outcomes of each module?** Using direct assessment techniques, we will examine achievement between different discipline groups (computing, technology, and engineering majors).
- **Are the modules appropriate for each educational level?** Instructor interviews will reveal student perceptions of module delivery, value, and content.
- **To which extent is each CIP learning outcome attained?** Direct assessment measures will be collected for each module, and evaluated by CIP outcome.

Evaluation data will be used to improve the assessment instruments and instructional modules as they are deployed. For the purposes of evaluation, each module is an object of study. Both direct and indirect methods will be used to measure each outcome. Direct assessment occurs through criterion-referenced tests that measure whether students have learned the variety of intended outcomes. Indirect measures include student perception surveys and individual interviews to measure student perception of their own learning.

V. Conclusions

Recognizing that our graduates may work in business sectors facing infrastructure protection issues, a cross-disciplinary team of faculty developed a strategy to ensure that students were exposed to critical CIP issues. This effort started with course modules to introduce necessary concepts and theoretical backgrounds, and was extended to build a framework of self-contained instructional modules. The framework is intended to prepare students for careers in solving problems and issues in design, implementation, and maintenance of robust, sustainable infrastructure assets.

While these course modules fill a curricular gap, students will want, and industry will need, deeper knowledge and skills. We plan to design an interdisciplinary degree program in CIP that prepares students for careers in industry, public service, and academia. We are also exploring partnerships with local and regional governments to offer CIP instruction to emergency managers and public officials.

VI. Current Status

At present, several of the modules have been designed while others are currently under development or further revision later in 2013.

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Simulating Industry:

An Innovative Software Engineering Capstone Design Course

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***Abstract*—Universities are required to produce graduates with good technical knowledge and 'employability skills' such as communication, team work, problem-solving, initiative and enterprise, planning, organizing and self-management. The capstone software development course described in this paper addresses this need. The course design contains three significant innovations: running the course for two cohorts of students in combination; requiring students to be team members in 3rd year and team leaders in their 4th (final) year; and providing assessment and incentives for individuals to pursue quality work in a group-work environment. The course design enables the creation of a simulated industrial context, the benefits of which go well beyond the usual, well-documented benefits of group project work. In order to deliver a successful outcome, students must combine academic theory and practical knowledge whilst overcoming the day-to-day challenges that face project teams. Course design enables the blending of university-based project work and work-integrated learning in an innovative context to better prepare students for participating in, and leading, multi-disciplinary teams on graduation. Outcomes have been compellingly positive for all stakeholders – students, faculty and industry partners.**

Keywords—Software Engineering, Capstone Design Course, Work-Integrated Learning, Group Project, Industry-Based Project, Peer Assessment, Peer Assisted Learning, Internship, Course Design, Curriculum

I. INTRODUCTION

Increasingly employers and society more generally are requiring universities to produce graduates with appropriate 'employability skills' such as communication, team work, problem-solving, initiative and enterprise, planning and organizing, and self-management [1]. To achieve these outcomes, universities and other tertiary institutions frequently use capstone design group project courses to help students develop these important skills.

In the early years of their engineering degree, students learn in a largely theoretical fashion. Although some institutions use approaches such as team work and problem based learning (PBL) from the first year, practice of theoretical learning is frequently limited to artificial assignments or small-scale group projects and problems which fail to demonstrate adequately the true value of important engineering activities. More frequently, however, students work individually without the opportunity to develop the team working skills along with professional skills.

Group project courses require students to work in teams and to undertake medium-sized projects, sometimes for real-world clients from outside the university environment. This enables students to take part in all aspects of the engineering process. Working in teams exposes students to the issues and problems associated with communication and team productivity. Both practice and the literature (for example [2]-[7]) suggests that project courses are highly effective in preparing students to face the real-world, as well as for consolidating learning.

Ensuring satisfactory outcomes for all stakeholders – academics (student learning, confidence in assessment); students (learning, grades, fun) and clients (product, intellectual assets) – can be a difficult task as all three have widely divergent requirements for success. Success for one may not necessarily mean success for another. Additionally, fairly assessing individual student contribution can be an even more difficult and time-consuming task [8].

The group project courses described here are a significant capstone of the software engineering degree at the Australian National University (ANU). Students participate as team members in one project in their 3rd year and as team leaders in another project in their 4th (final) year. For two consecutive semesters, small teams of five or six students, with 4th year team leaders and 3rd year team members, work with industry partners to develop solutions to contemporary, real-world problems. Student teams are closely supported throughout by experienced, industry-based mentors alongside their industry clients and faculty. Academic assessment is achieved principally through the mechanism of three gateway reviews staged through the project.

This design, combined with the assessment scheme, has allowed us to simulate an industrial context. As well as team work skills and experience, students gain practical knowledge of current industry practice which goes well beyond the technical knowledge in their other university subjects. They use software tools, programing languages and project management approaches which are prevalent in industry but not always taught at university. Students learn about the iterative nature of software development and regularly discover that a single approach does not suit all stages of their project – and thus learn through experience the value of adaptability.

Each year, course designers and coordinators work closely with industry partners to offer students a wide selection of projects which range from pure computer science and software engineering research, through developing proof of concept software to the more traditional implementation of e-Commerce and mobile applications. Software developed by students is regularly incorporated into the code base of our industry partners. Student projects win industry awards and the course itself won an Australian Council of Engineering Deans Education Excellence award.

The capstone design course described in this paper has been carefully designed to achieve the overall goal of "*help[ing] students develop leadership skills and become an effective member of a team which makes and implements appropriate engineering decisions related to the development of software systems that deliver measurable value to clients*" [9]. Each year the effectiveness of the course is assessed qualitatively, based on feedback received from students, clients, mentors and faculty.

II. Course Design

At the ANU, Bachelor of Software Engineering (BSEng) students undertake two capstone design courses – one in 3rd year and another in their 4th (final) year while Bachelor of Information Technology (BIT) students undertake a capstone design course in their 3rd (final) year. Students work on real-world problems for real-world industry partners for two consecutive semesters.

The innovation of combining the 3rd and 4th year courses into one, while at the same time working with industry partners, has enabled the creation of a simulated industrial context which provides benefits over and above the usual, well documented benefits obtained from undertaking group project work. Teams consist of five to six students: four or five 3rd year students (both BSEng and BIT) led by one or two 4th year (BSEng) students. Faculty plays the role of senior management in a notional consulting company. Within the simulation, it is assumed that the company (as represented by faculty) successfully tendered for a number of projects for which it has subsequently recruited teams. The role of the company's senior project manager is played by team mentors – who have industry and project experience. Mentors work closely with teams, especially the 4th year team leaders. Teams all work with an industry partner or university client.

Course design incorporates peer assisted learning (PAL) [3] which has been shown to be a powerful method for leveraging learning beyond the direct efforts of the teacher. To be effective, however, it requires situations that motivate the more experienced students to assist the less experienced. Combining 3rd and 4th year students on one team facilitates PAL directly, as the 4th year students have previously completed the course, and have an incentive through their shared project marks to improve their juniors' performance. PAL, lectures and structured reflection homework provide students with opportunities to share the experience of their peers' projects, increase their learning over and above their own design and implementation experiences, and to develop a community of practice [10], [11].

Since assessment is the key to student learning, the best way to change that learning is to change the assessment scheme [12]-[15]. Accordingly, the assessment scheme has been continuously refined to help us better meet the learning outcomes of the course. As the course design has developed, we have moved progressively from focusing assessment efforts on the quality of deliverables to concentrating on process and team work. The key to success in this aspect of the design was the introduction in 2008 of formal peer assessment and in 2009 project reviews in association with a holistic view of the quality of deliverables.

By design, the assessment scheme places responsibility on students to control their projects: to determine scope, schedule and deliverables. In consultation with their project's industry client, students are also responsible for establishing their own systems and software development lifecycle and project management environment. Student teams are closely supported throughout by experienced, industry-based mentors alongside their industry clients and faculty. At three key points through the project, students, industry partners, mentors and academics participate in 'gateway reviews' which examine a team's performance and project progress to provide guidance and assurance that they can progress successfully to the next stage of the project. The gateway review process also provides the principal mechanism for academic assessment.

A significant student and faculty concern related to group work is the existence of non-productive group behavior such as social loafing and free riding [16] where students who do not complete tasks as responsibly as their peers, nonetheless attain the same mark as their more responsible peers [17], [5], [18]. To overcome such problems and to improve learning, course design uses peer assessment of team colleagues to generate differential individual marks from team marks. Mentors and faculty provide feedback and mentoring to individual students and teams to help them learn from their peers' assessment and to improve team performance. Mentors also assist team leaders to use this data to mentor and develop their team members.

Clients treat students as a team of junior consultants, frequently inducting them into their organization. Clients often require that student teams comply with company processes and procedures related to how they run projects within their organization. Reminiscent of industry governance procedures, the gateway reviews involve representatives of all stakeholder groups – clients, faculty, mentors and all members of the team. As well as providing the mechanism for academic assessment the gateway review process provides meaningful feedback and guidance to the team to help them deliver real – tangible – value to clients.

Further detail related to course design can be found in two earlier papers by Johns-Boast & Flint [19], [20].

III. Significance to Engineering Education Practice

Through deliberate and intentional learning opportunities, linked with appropriate and careful assessment, our students obtain the benefits of work-integrated learning [21], [22] without either extending the length of their study or missing out on exposure to valuable content in other courses because these have been sacrificed to provide space in the curriculum for participation in internship programs for credit.

In addition to the usual and well documented benefits from undertaking group project work (for example, [23], [4], [24], [6], [25]), the industrial simulation we have created helps students fuse theory with practice and thus improves students' ability to transfer knowledge from the academic environment to the work-place and vice-versa [21], [22]. The course introduces students to the professional skills required of a competent engineer: leadership, management, communication with both peers and supervisors and teamwork in particular, as well as ethical and other responsibilities.

Unlike internships, sandwich courses and work placements where students work with a single company and frequently a single area of that company for periods of time often no longer than a semester, our students work for eight to nine months each year with different organizations and clients on different projects. Consequently their exposure to different work places, cultures, project types and teams provides them with a much wider experience than a single industrial placement would normally offer. In addition, through the greater autonomy, responsibility and decision making required of students participating in the course, our students are offered greater opportunity to develop leadership capacity than generally happens in traditional work placements and internships.

Project gateway reviews require students to defend their decisions as well as encouraging them to try things and to take risks that would not be possible in traditional internships and work placements. In consultation with their clients, students are responsible for all aspects of the management of their project. They frequently select and use a broad range of tools for project tracking, issue management, continuous integration, code review, configuration management and version control, and adopt approaches widespread in industry which they don't learn at university.

By removing many constraints from the assessment scheme and handing over complete control of their projects to students, and increasing the focus on reflection, self and peer assessment, and critical thinking, we have encouraged the development of autonomous learning [26]. Peer assessment of contribution to the team's work achieves a fair and equitable allocation of marks that adequately reflects both individual knowledge and contribution [27], [17], [5]. More importantly in terms of student learning, however, peer assessment also helps students understand and develop key skills related to team work and performance review as well as enabling 4th year students to develop mentoring skills as they work with team mentors to develop and mentor the 3rd year members of their team.

From anonymous student feedback collected since 2010, it is apparent that students value the challenges and opportunities the course provides; saying for example, that the course provides "*opportunities to learn things that aren't part of a pre-existing and highly structured course - to do something semi-original*" and that they enjoy "*the challenge ... to get something designed and built based upon what the client wants, and it gives you a great feeling of satisfaction and pride to know that you built something from scratch*".

Feedback from industry partners is consistently positive. Our partners indicate they see the projects as an "*extremely valuable pedagogical tool*" and "*an innovative educational program that is extremely beneficial for all involved*". Of real benefit from the point of view of student learning is that industry partners assert that "*the tasks that we provide for the students are not artificial or 'make-work' in any way*".

Moreover, our industry partners like that the course "*allows students to engage with industry early*", that they get to "*look over*" the students prior to employing them, and that it provides them with an opportunity "*to give back to the ANU*" as well as providing "*a means for us to corporately contribute to producing more highly skilled and capable engineering graduates. This in turn will be for the betterment of the profession and ultimately for the betterment of society as a whole*".

Faculty have also benefitted from the relationships created with industry: we have recently had a Researcher-in-Business [28] grant which grew from the organization's engagement with the academic through provision of a student project. A side benefit to the School is that by combining 3rd and 4th year classes we achieve a more efficient use of academic time and effort in class contact, project selection and management, at no extra cost in assessment.

A. Demonstrated effectiveness

The assessment scheme is designed to support the principal goal of the course: *to help students develop leadership skills and become an effective member of a team which makes and implements appropriate engineering decisions related to the development of software systems that deliver measurable value to clients* [9]. Feedback gathered since 2010 shows that all stakeholders are pleased with the outcomes delivered by the assessment scheme, especially the project review process and its ability to help students deliver real value to clients and to gain valuable experience.

Anonymous student evaluations show that students generally like the assessment scheme and understand the value of the review process and its rich formative feedback, saying for example that the "*project reviews work well because they force you to process the feedback being given and act on it (at least more than other forms of assessment I've seen). You often don't see the feedback from exams, and I often dismiss the feedback from normal assessments because it's a specific situation. But with the projects, there's a direct link between acting on the feedback and future progress and outcomes*". Students also comment that they "*really like the reviews ... [as] they were a great chance to show how our process was working (or not)*". Additionally, the review process develops students' ability to critically assess their own work as it requires them to take "*a step back from the inner workings of the project, [which] gives us an objective view of our project's progress rather than our highly subjective one*".

Students similarly note that they "*like the idea of reflections and peer assessment. It is good way to give feedback and reflect on the working of a team*" as well as liking the unstructured nature of the assessment scheme. While students acknowledge the nature of the work required by the course, they comment that despite sometimes encountering "*a lot of stress caused by the project ... it was definitely worth it*".

Feedback from our industry partners indicates that they are impressed both with the operation of the course and the quality of the students. One partner has noted that "*the course has obviously taught them [the students] about the practical components of working in the real world because the project team managers have worked well in liaising between their group and the company sponsoring the project. We asked the team to produce a mobile application ... and the team has delivered, despite many challenges being thrown at them and many unexpected working and technical obstacles appearing along the way*"; another notes that students "*experience of all the complexities ... of real world engineering in a relatively benign and supportive environment*".

The quality of the course is also demonstrated by external measures: a number of student projects have won awards at regional and national levels from the Australian Information Industry Association (AIIA) and the Australian Computer Society (ACS) and in 2012 the course itself received a "Highly Commended" award from the Australian Council of Engineering Deans (ACED) for Engineering Education Excellence.

B. Benefits to industry

Since 2004, 353 students have graduated from the program and 65 external/industry projects with 46 organisations and 26 university projects have been completed. Depending on enrolments, we run up to 13 different projects per year. Over 75% of industry partners have been start-up companies, individuals developing a proof of concept prior to formal start-up, small to medium enterprises (SME) and non-profit organisations. Based on the number of hours it is suggested that each student should spend on their project (10-12 hours per teaching week, i.e. 26 weeks), estimated hours of industry partner involvement and including overheads for mentors and faculty, we estimate that the value of each project is around $150,000. It can be argued therefore, that through the medium of these student projects the ANU provides $1 million software development assistance each year, mainly to start-ups and small and medium (SME).

When identifying benefits gained from their participation, industry partners have noted that the student projects "*generally result in the production of 'very nice to have' capability that we would probably not otherwise have been able to introduce ... [and] provide a small but worthwhile addition to the overall operational capability of the software engineering group during the course of the year*" [29]. One regular industry partner obtains a secondary benefit from participation because "*the student projects also provide opportunities for junior software engineers [in the company] ... to participate in the projects as clients and client project managers. This is an educational and career enhancing experience for those engineers".*

C. User acceptance and take up

Although the course is compulsory for many students, recently there has been increasing enrolment from students for whom it is an elective option. Furthermore, since 2010 over 83% of students who submitted responses, rated the course "Enjoyed and learned a lot" or "Enjoyed and learned something". Students' feedback includes comments that it "*was a really great course. It was practical, enjoyable and interesting (I hope all courses were like this course). The course was organised very well. It's hard to find a thing that should be changed with this course*". Furthermore, depending upon the year in which the data was collected, between 73% and 91% of students who responded said that they would recommend the course to other students.

Students value highly the freedom that the course assessment provides saying, for example, "*I liked organising things for myself and working things out by myself. I liked not having something due every 2 weeks and how there were few well-defined deliverables*". They also appreciate the efforts of the mentors and course faculty who "*spent a lot time and effort in teaching us, also really appreciate for giving us so much valuable feedbacks on our project, coz I really gain a lot in it*". Students who provide feedback generally reflect it is "*all in all, very good course*" and "*is one of my favourite courses I've done at uni*" as well as observing that "*it seems like lecturers have been tinkering with this course for years. But it's good how it is now. Don't change anything*".

Contrary to our experience when we began offering industry-based group project courses in 2002, we now have more projects put forward each year than we have student teams to undertake them. Many of our industry partners are repeat clients; half a dozen of whom have undertaken three or more projects since 2009. They like that "*it is possible to get a good outcome that can be used ... [and that it] lets me stay connected with the latest trends*" as well as stating that they "*intend to continue ... involvement into the foreseeable future*". Industry partners' involvement with the course is "*a very positive one from the point of view of the ... project team and the wider company*". A first time client said "*we had no idea on how the setup worked but the teaching staff were fantastic in making sure we were well prepared in knowing how to earn the right to welcome a project team to the company as well as how best to engage with their students, many of whom the staff work with personally ... It has been so much of a success, we want to come back for more next year. The staff have been supportive and their students superb*".

D. Difficulty and complexity

Increasingly, universities are required to produce graduates with appropriate 'employability skills' such as communication, team work, problem-solving, initiative and enterprise, planning and organisation, and self-management [1]. Frequently this is achieved by requiring students to undertake a 'sandwich course', work placement or internship. Although the benefits of a well-designed work placement course have been well documented, the literature indicates that such courses are rare [20]. We contend that the design of the ANU software engineering group project course both provides the benefits of more traditional work-integrated learning programs while overcoming many of the associated problems, as our course design provides greater control over learning outcomes than is usually possible in more traditional work-integrated learning programs. Additionally, both practice and the literature suggest group projects are also highly effective in preparing students to face the real-world and for consolidating learning [22].

Also well documented in the literature are the difficulties of providing students with both a beneficial and enjoyable group learning and team work experience [5]. To help overcome these, the course introduces students to the concepts of personality and the influence it can have on individual communication and work styles; to the stages of team development and how to move quickly and successfully through those stages to become a self-managing, highly performing team; and to the roles necessary within a team for a team to achieve success. Through the introduction of formal peer assessment the course has helped students learn about and deal with "couch potatoes" and "freeloaders" within teams [5]. These steps have helped make the whole experience a more enjoyable and productive process for students.

Developing an assessment scheme which successfully provides equitable grading of students undertaking a variety of projects, which range from the more straight forward information system implementations to highly complex and conceptually difficult research-based projects has not been an easy task. Making this task even more complex was the combination of the 3rd and 4th year courses into a single course. The combination of the project review process, which focusses on process rather than output, and peer assessment of team contribution has enabled the ANU course to achieve success. Inclusion within the assessment scheme of significant individual and team reflection ensures that students become aware of what they are learning, thus helping them develop an understanding of how this learning is applicable to future projects and in the work-place.

Another difficulty encountered is helping many students move from 'assignment mode' where work is done in short intensive bursts at the last minute to the more continuous effort required of project work. Associated with this is the difficulty of convincing students to share their work with their peers, team mentor and sometimes even their client prior to it being 'perfect' as it would be if they were submitting an assignment for assessment. This problem has been largely overcome by encouraging teams to work closely with their mentors and through the use of team repositories regulated by version control software.

IV. CONTINUOUS MONITORING AND EVALUATION

A variety of different strategies can be used to measure teaching effectiveness [30]. The effectiveness of this course has been measured qualitatively using student ratings (both formal and informal), industry partner feedback, self-evaluation, as part of Engineers Australia (EA) accreditation review of the BSEng, and through external awards won by students and the course itself.

Alongside a formal university-wide course evaluation process, students are encouraged to provide anonymous open-ended feedback at the end of the course using the Moodle learning management system (LMS). In addition to this feedback, students are encouraged to provide constructive criticism and feedback at any point during the course. At the start of each year, students are made aware of the changes that have been made in response to feedback received from the previous year's cohort.

At the end of each course, the course faculty and mentors hold a Post Implementation Review (PIR) and evaluate how well we have met the principal goal of the course: *that we will help students develop leadership skills and become an effective member of a team which makes and implements appropriate engineering decisions related to the development of software systems that deliver measurable value to clients* [9]. This goal has not changed since 2004; and neither have course outcomes: that 4th year students *will demonstrate a high level of professional judgement and application of software engineering best practice, as demonstrated through the identification, development, use and evaluation of appropriate processes and artefacts required to provide real value to the client*; while 3rd year students *will demonstrate technical competence in all aspects of the software development life cycle* [9].

The course is assessed using the concepts of constructive alignment [31] and Tyler's [32] notion that the specification of behavioural change suggests learning activities which lead to increased familiarity with the associated content. This means the PIR focuses on refining the assessment scheme to help the course better meet its learning outcomes. Input to the PIR comes from the anonymous feedback obtained through the LMS, grades, team performance based on mentors' observations, indirect feedback obtained through peer assessment and students' reflective homework, as well as feedback from clients. PIR evaluation has led to both major and minor changes to the assessment scheme. The more significant changes are discussed in the following paragraphs.

Initial course design had students responsible for developing a schedule of deliverables, some of which were mandated, and receiving only formative feedback throughout the year, with summative feedback received at the end of the project. Additionally 3rd and 4th year students had different assessment schemes. All students were required to undertake a three-hour, written examination at the conclusion of the course. The first significant change to the assessment scheme was made in 2006: summative assessment was introduced at regular points through the project, required artefacts were no longer mandated and a common assessment scheme for all students was introduced. While both 3rd and 4th year students were still required to undertake formal examination, 4th year students participated in an oral exam.

Teams had been experiencing difficulty adhering to their own deadlines for production of artefacts and deliverables. Mandating artefacts seemed to lead students to consider them to be something orthogonal to project completion, something that they were required to do for assessment purposes, but not to ensure a greater chance of project success which led to what we called the 'two project syndrome' where some teams produced one set of artefacts for the client and another for course faculty. Separate assessment schemes for 3rd and 4th year students led students to focus attention on what they perceived they were required to do to maximise their marks rather than working as productive team members and ensuring the project provided value to clients. Introduction of an oral exam for 4th year students was in response to academic concern that a final examination, especially a written examination, was not an appropriate assessment method given the goals of the course and the very different projects that students undertook. The oral examination allowed academics to determine more precisely what 4th year students did and didn't understand about conducting a software development project. The positive outcomes from the oral exam led to the introduction of the gateway review process in 2009 in place of examinations for all students.

The two most significant changes which have helped us meet learning outcomes and which we believe set our courses apart are the use of peer assessment – introduced in 2008 – and the project review process – introduced in 2009. Not only has peer assessment helped overcome many of the problems associated with group work [5] faculty have greater confidence in the validity of individual grades. More importantly, however, learning what it means to objectively assess another's contribution is a crucial part in the development of management and leadership skills. Another benefit flowing from the introduction of the project review process is the uncoupling of the academic requirements of the course from the conduct of the project.

The introduction of peer assessment as a method of deriving individual marks for team work has not only improved student enjoyment but appears to have enabled us to improve our ability to differentiate between students. Typically marks for group work cluster closely around a higher mean [33]. While student marks vary from year to year, since the introduction of peer assessment in 2008 the standard deviation from the mean of student marks has increased from 7.74 to 9.94, indicating a wider spread of marks and demonstrating the increased ability of faculty to differentiate between students.

During the most recent BSEng accreditation review carried out by Engineers Australia in 2010, the software engineering group project courses were acknowledged as enabling our students to develop strong professional skills while providing them with an opportunity for rich experiential and cooperative learning. The quality of the projects and the student teams has been externally assessed through participation in competitions run by the Australian Computer Society (ACS) and the Australian Information Industry Association (AIIA) where a number of teams have won awards at both regional and national levels. In 2012 the course itself received a "Highly Commended" award from the Australian Council of Engineering Deans (ACED) for Engineering Education Excellence.

We have not carried out a formal evaluation through survey of graduates and employers in an attempt to ascertain whether the course has made a qualitative difference to the 'employability skills' of students graduating from our programs. One of the significant problems we face with such an evaluation is the small student cohort, averaging 45 students graduating each year, many of whom move, including overseas, to accept employment. Each year, however, we collect input and feedback from our industry partners as part of the PIR conducted at the conclusion of each course. Their feedback, while not specific to the development of 'employability skills', includes statements such as "*the ANU is our primary source of junior software engineers*" and that they "*like employing ANU software engineers*" which could indicate that there is a limited source of graduates or that ANU graduates in particular are sought after, though whether that is because of this course or not we could not tell. Furthermore, the feedback indicates that our industry partners believe the course helps make our students employable as it provides "*students with an experience of all the complexities and difficulties (and rewards!) of real world engineerin*g" and that it helps students gain experience of the "*practical components of working in the real world because the project team managers have worked well in liaising between their group and the company sponsoring the project.*"

V. Conclusion

The innovative course design and assessment scheme described in this paper, result in high quality outcomes for all stakeholders – students, faculty, industry partners and the institution. We believe the ANU course design is unique: it does not appear to have been documented in engineering education elsewhere, nor are we aware of it having been used by other institutions.

The course design – combining two cohorts into one; requiring students to participate first as team members and then as team leaders; working with industry partners on real-world problems; and providing teams with mentors who have significant industrial experience – and the assessment scheme – gateway reviews to assess process and team performance, and peer assessment of contribution to generate differentiated individual marks – has enabled us to create an effective industrial simulation. The simulation provides students with opportunities and benefits that far outweigh the more usual group project capstone design courses. Students combine academic theory and practical knowledge to enable them to over-come the day-to-day challenges faced by multi-disciplinary teams; they use tools and practices prevalent in industry but frequently not taught in university; and they develop professional and team working skills. Moreover, the simulation enables our students to obtain the benefits from participating in work-integrated learning without either extending the length of study or missing out on valuable content because other courses have been sacrificed to provide space for participation in internship programs for academic credit.

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Using a threaded framework to enable practical activities in Operating Systems courses

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Abstract—**Teaching Operating Systems (OS) is a rather hard task, since being an OS designer is not a desired goal for most students and the subject demands a large amount of knowledge over system's details. To reduce the difficulty many courses are planned with laboratory practices, differing in how the practices are designed. Some try to implement next-to-real kernels, others use simulators, and even others use synthetic kernels. In this paper an approach based on synthetic kernels is described. It uses thread programming in order to establish control over the operating system components. This approach allows the kernel to grow following the materials presented in the course. It has been successfully applied in two different courses at our University, the first one being a basic OS course and the second one an upper level course. Results from these applications are presented.**

Keywords*—*Kernel implementation, Operating systems design courses, Operating systems laboratory, thread programming

I. Introduction

One of the hardest subjects to be taught in computer science is the design of operating systems. Besides the existence of several textbooks covering the subject, [1], [2], [3], among other successful texts, learning these concepts involve knowledge in data structures, computer architecture and networking. Although learning these contents may be left to earlier prerequisite courses, it is not desirable to leave the OS course too late in the curriculum, which demands that part of that knowledge has to be brought inside the course. The consequence is that lots of material have to be covered, and understood by students, in order to have a complete view of the technologies used to implement an operating system.

To alleviate this situation most of the courses include laboratory practices. Since the subject is quite complex, different approaches have been suggested to tackle these practices. The most relevant are:

- **Kernel implementation**, where students have to implement an actual version of an OS kernel;
- **Simulators**, where students simply simulate the operation of kernel's components;
- **Component implementation**, where students implement certain components of a kernel, but do not connect them.

Each of these approaches have pros and cons, such as allowing in-depth knowledge of the system but demanding too much effort for the kernel implementation. One way to reduce the effort is to use real kernels and organize practices that are performed over these kernels, modifying or reimplementing some portions of it. One of such kernels is Minix [3], whose implementation has more than 27,000 lines. It is easy to imagine that such large code is hard to understand in a short period of time, even if only small parts of it are addressed.

Differently from the conventional approaches, the one proposed here involves the implementation of specific components, which are compounded through a kernel emulation framework based on threads. This allows for an incremental approach towards a complete synthetic kernel while maintaining a functional system along the way. Since the implementation can be incremental, the knowledge necessary is also incremental, enabling the offer of an OS course as early as in the Sophomore year.

In the following pages one finds the description of this approach, followed by how it is deployed in two different courses offered to computer science majors. Results from these courses are presented, followed by a discussion about similar approaches. Conclusions from this experiment finalize the text.

II. Threaded Components of an OS

As previously stated, the practices intended to better understand the OS functionality are based in the implementation of its components through threads. In this section a full description about how these threads are implemented and how they are compounded in order to emulate an operating system is provided.

A. Compounding threaded components

A synthetic OS is created as a multithreaded system. This means that each of its components will be a separate thread, which is started in the occurrence of certain events in the system. This approach enables the implementation of most of the services provided by the OS as an independent component, that can be executed without the implementation of the remaining system.

Figure 1 shows the main structure used for the synthetic kernel. As one can see, the program has an infinite loop containing a function (control_unit) that returns the event that must be managed in each loop. Its output defines which thread must be started, that is, which OS component will act in that cycle. Each component is implemented by a single thread, in order to allow effective concurrency among them. Events that

```
OS_Kernel {
    Boot_init();
    while (true) {
        op = control_unit();
        switch (op) {
            case 0 : start thread A;  break;
            case 1 : start thread B;  break;
                    .
                    .
                    .
            case n : start thread N;  break;
        }
        update_status();
    }
}
```

Fig. 1. Framework for an Operating System synthetic kernel

incurr in the execution of specific threads may include calls to semaphore primitives, I/O requests, process creation, page faults, quantum-time interruptions, etc.

After starting a thread the kernel proceeds updating the system status, what includes presenting the actions to the user. This is performed by the update_status function. This function has also to schedule the next process to the CPU, based in what was the triggered event and the previous status of the system. It must be noted that the scheduler, although part of the process management, is not treated as a thread, since it has to provide a result before any other event can occur.

With this framework the instructor and students get a fully functional system, even if only few components are implemented. The parts that must be implemented are the two external functions in the framework (control_unit and update_status), the process table structures, and the desired OS components. The control_unit may be implemented through simple specifications, such as a random generator or as an input interface. The update_status can be implemented as an interface to show the system's status and eventual manipulations over the process table. It is possible for the instructor to either provide both functions in order to guarantee a customization over the kernel's inputs and outputs or request their implementation from students.

All OS components can be specified and implemented independently. They are synchronized through the access to the process table, which provides the necessary data structures to manipulate the running synthetic processes. The interactions between components are performed by calls to specific threads.

The main advantage of this approach is that the instructor can pick only the components that he/she thinks that are more important, reducing the amount of implementation needed. Another advantage is that the amount of details in each component can also be controlled by the instructor. This way students can get a hands-on practice over important components of a OS, without the burden of knowing complex details about hardware or even understanding a huge amount of code written by someone else.

B. *Creating specific threaded components*

One should have noticed that the external functions and the process table are vital parts of this approach. However, their discussion will be left to the next section, where the application of this approach in two different courses is described. Here, we are concerned only with the specification of threaded components, since they are the core of the students work even if they have to implement the whole framework.

As said before, the instructor can choose which OS components will be implemented. Surely, some components are essential, such as the process management control, but each functionality can be implemented, and verified, independently. In order to enable such scheme each thread has to be modeled as an independent piece, that access the shared process table. Therefore, each thread has to:

- Access the process table in a mutual-exclusion approach;
- Perform the necessary process table manipulation, such as blocking or releasing a process;
- Call, when necessary, the process scheduler or other OS threads.

These requisites are easily achievable. This happens because the amount of interactions between threads can be increased incrementally, starting with very simple components before proceeding to more complex ones. However, even operations much more complex such as managing virtual memory, can be easily implemented with a careful design of interactions between memory management and disk and processes management components.

III. Application of the Threaded Kernel in Specific Courses

The threaded approach just presented has been applied in two different courses offered to Computer Science majors. The first course, in which this approach has been applied since 2007, is an introductory Computer Systems course titled Foundations of Computer Systems which covers operating systems and computers networks in a single course [4]. The second course, in which the application occurred since 2009, is an advanced course titled Operating Systems Design, which is mandatory only for students following the Computer Systems track inside their major[1]. The application of this approach, including examples for each course, will be described in separated sections.

A. *Threads in the Foundations of Computer Systems course*

This is a mandatory course for students pursuing the computer science major. It is intended for students in their 4th semester in the university with knowledge in data structures and digital circuits. Since it is also an introductory course, covering a quite large amount of subjects, there is not much time available for laboratory practices. The syllabus covers these major topics:

[1]The Computer Science major is split into four tracks after sophomore year (Computer Systems, Information Systems, Digital Control and Automation, and Scientific Computing), and students have to chose one of them to get a degree [5].

1) Overview of parallel and distributed systems to establish the interactions between OS and computer networks;
2) Operating systems management components, including an introduction to concurrent programming;
3) Computer networks protocol (RM-OSI and a brief overview of TCP-IP);

The flow goes back and forth from OS to networks contents in order to show their relationships. A thorough description of this course, in its original format, can be found in [4].

The fact that it is mandatory and cover many topics is the main motivation to use an incremental approach for practices such as the one presented here. Since there is not much time available, only few components are actually implemented here. Our choice usually falls into implementing the process management, including the dispatcher, and the disk I/O management.

As a side note, assignments approaching computer networks include isolated tasks, such as the implementation of a sliding-window protocol emulation, the spanning-tree algorithm, and the ARP protocol among others.

It is possible to ensure a challenging task each year, even asking for the same components, if the algorithms for dispatching and disk scheduling are different every year. Changing these algorithms implies in modifications on how processes are managed or interact, avoiding that the practices could become repetitive. For example, in the most recent offer of this course students had to implement a priority-based dispatcher, which demands that information about the processes priority have to be stored in the process table. Dispatchers implemented in previous years included round-robin, SRTF (Shortest-Remaining Time First), and an I/O bounded priority algorithm.

Each practice (implementation) is evaluated accordingly to three rubrics: program correctness, code comments, and output interface. The first two are quite obvious and do not demand further description. The output interface is judged considering the amount of organized data is provided about the "execution" of processes in the multithreaded operating system being emulated, that is, the interface has to provide clear data to follow the program execution and check its correctness. Therefore, a graphical interface is not required and Figure 2 shows an output of a student program, during emulation.

Although the text in that figure is in Portuguese, some remarks can be drawn from it. First, it provides a system's clock in its top line, followed by a message that tells which randomly generated event will be treated (the conclusion of an I/O operation in this case), and how to react to it (doing nothing in this case since there was no process waiting for I/O)[2]. Then, it presents a process table, with information about all processes executing, where the five columns indicate the process identification (NP), status (Estado), CPU time already used (TE), number of I/O operations performed (IO), and the process priority (Pr). Therefore, it presents enough data to check the system execution, step-by-step.

[2]It should be noted that this specific situation occurred because the random generator does not check which events are feasible at any given time, what is not a correctness problem.

```
TEMPO DA CPU: 11

MENSAGENS DA THREAD ioFinish:
HOUVE UMA CHAMADA PARA FINALIZACAO DE IO.
NO ENTANTO, NAO HA PROCESSO BLOQUEADO NO BCP.
LOGO, NAO PODE HAVER DESBLOQUEIO.

:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
::::::           DADOS SOBRE O BCP                    ::::::
:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
:: NP    Estado               TE      IO      Pr          ::
:: 1     ::::ATIVO::::        2       1       3           ::
::                                                        ::
:: LEGENDA:                                               ::
:: NP: NUMERO DO PROCESSO                                 ::
:: TE: TEMPO DE EXECUCAO                                  ::
:: IO: NUMERO DE ENTRADAS E SAIDAS                        ::
:: Pr: PRIORIDADE DO PROCESSO                             ::
:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
```

Fig. 2. Output produced during the execution of a student implementation

```
ID      PRIORIDADE      STATUS
6       3               Execução
7       3               Pronto
9       3               Pronto
8       1               Bloqueado
10      2               Bloqueado

Endereço de Memória     Trilha  Bloco   ID      ProcessoStatus  Requisição
        4987            156     27      10      Esperando E/S   Leitura
        2686            84      30      10      Esperando E/S   Leitura
        860             27      28      10      Esperando E/S   Leitura
        1810            57      18      8       Esperando E/S   Escrita
        3055            96      15      8       Esperando E/S   Leitura
        1944            61      24      8       Esperando E/S   Leitura
        1596            50      28      8       Esperando E/S   Leitura
        3386            106     26      0       Executando E/S  Leitura
```

Fig. 3. Output produced during the execution of a second practice implementation, now including disk access requests

Figure 3 presents the interface from a different student, showing the execution of the same system, but now including the management of requests for disk access using the scan algorithm. In this interface the student presents a list of processes "running" in the system, in a tabular format containing the process ID, its priority and status (considering three possible states for a process, that is, it can be allocated to the CPU - "Execução", in the ready queue - "Pronto", or blocked - "Bloqueado"). After this it shows the list of disk I/O requests, showing the memory and disk locations, the process that requested the operation, operation status and type (input or output).

Each assignment has to be finished in a period lasting from 15 to 20 days and is executed by pairs of students. The first assignment usually takes more time since students have to implement not only the process manager but also several utility components. They also have to get acquainted with thread programming in the C language.

Since its first application, this approach for lab practices has improved the understanding of operating system concepts. Students get better prepared for written evaluations and the failure rate decreased by a large margin. Statistical data available shows that the failure rate was reduced threefold (from around 30% to 10% for classes were this approach was used).

Tables I and II show the results from a survey applied for the most recent class, which concluded in December 2012. From a total of 15 pairs of students we received answers from 10 pairs (66.67% of the total), using Google Docs forms.

TABLE I. SURVEY RESULTS ABOUT DIFFICULTY OF DESIGN PRACTICES IN THE FOUNDATIONS COURSE (% OF RESPONDENTS)

	Very hard	Hard	Median	Easy
Overall difficulty	10	30	45	15
First assignment (process management)	30	70	0	0
Second assignment (I/O management)	0	80	20	0
Average of the other assignments (computer network protocols)	0	25	40	35

TABLE II. SURVEY RESULTS ABOUT USEFULNESS OF DESIGN PRACTICES IN THE FOUNDATIONS COURSE (% OF RESPONDENTS)

	Very useful	Useful	Somewhat useful	Not useful
Overall usefulness	40	30	30	0
First assignment usefulness	40	30	20	10
Second assignment usefulness	40	30	30	0
Other assignments usefulness (computer network protocols)	35	25	30	10

From table I we can see that students had more trouble with the assignments related to OS, which confirms the notion that this is a difficult subject. It must also be noted that they felt more comfortable with the second assignment, when they already knew the framework of the emulated kernel.

Although not presented in this table, some other aspects collected from the survey must be listed here. In the first assignment students revealed that their major difficulties were related to thread programming and the understanding about what had to be implemented. In the second assignment, their difficulties were related to the I/O mechanisms and the relationship between the kernel components. Another complaint was related to the specification of the assignments, which some students had trouble in identifying the actions that their systems had to perform.

From table II it is possible to notice that students have the feeling that they learned better by implementing the components that were required in the practices. It is also possible to identify that they felt that the OS practices were a little more useful (70% of respondents) than the computer network practices (60%). It is important to notice also that this feeling could be verified in the students' grades, which improved reasonably from classes where there was no laboratory assignments.

B. Threads in the Operating Systems Design course

The same approach has been applied in a more advanced course, which is taken only by students that are in the Computer Systems track. This means that the classes are smaller and that more material can be covered in the practices. This course can be divided in two disjoint parts:

1) A theoretical view of distributed operating systems and distributed systems, including synchronization algorithms, fault tolerance and replication;
2) A design view of conventional (single processor, multiuser, multitask) operating systems, based in the threaded kernel introduced in the previous course.

```
 Processo | Quantum   | Estado
-------- Maior Prioridade --------
 03       |       | EXECUTANDO
 04       |       | PRONTO
 05       |       | PRONTO
 06       |       | PRONTO
 07       |       | PRONTO
 08       |       | PRONTO
 09       |       | PRONTO
 10       |       | PRONTO
 11       |       | PRONTO
 12       |       | PRONTO
--------- Menor Prioridade ---------
 NULL
---------- Bloqueados ----------
 01       |       | BLOQUEADO
 02       |       | BLOQUEADO
  Page fault! (pid:3)
```

Fig. 4. Snapshot of an OS emulation running memory management components

Since students enrolled here have already took the Foundations of Computer Systems course, they know in advance the structure of the threaded kernel used in the practices. This makes easier to develop each component further. Therefore, the design practices involve more components with a higher degree of interaction between them. As an example, Figure 4 presents a snapshot of executing processes with management of page misses and virtual memory, which are functions usually not implemented in the first course. In this figure we can see in the last line a message saying that the process with "pid=3" caused a page fault. In the top part of the figure this process appears as running (EXECUTANDO), and the fault will move it to the blocked processes list (Bloqueados), that contained processes 1 and 2, just before the fault.

It is also possible to see in Figure 4 that processes are organized in a two-level queue scheduler. Each queue has a different priority ("Maior Prioridade" and "Menor Prioridade") defined by the frequency of I/O requests. For that practice it was defined that when a process requested for an I/O operation it should be moved to the lower priority queue, remaining there until it executed continuously without I/O requests for 5,000 time units.

To facilitate experimentation and to allow a better understanding of the whole kernel, in this course the control_unit() function is implemented as a reader of synthetic programs. These programs use a simple syntax to map execution events in regular programs. The control_unit() function uses a "process control block - PCB" where each process has a pointer to a file containing the synthetic program. It emulates its execution by reading one line and applying the correspondent action in each function activation, until the end of the file.

Figure 5 shows a short example of a synthetic program. In its header (first five lines) we find the program's name, file identifier, original priority, file size, and a list of semaphores used by the program. After that comes the synthetic code, where the instructions "read x" and "write x" are disk access requests for the track x, "exec y" means CPU processing during y time units, "V(z)" and "P(z)" are calls to operations over semaphore z. Other synthetic instructions may include I/O operations to specific devices, e.g. printers or monitors, and process creation through fork.

```
sint1
1
1
32
s t

exec 4000
read 20
exec 500
read 30
exec 5000
P(s)
exec 200
P(t)
exec 10000
write 20
V(t)
V(s)
exec 2500
```

Fig. 5. Example of a synthetic program ran by the threaded kernel

With the synthetic commands we can represent a large amount of events that occur in a conventional system. The threads for each OS component can be specified including more complex functions, such as manipulating virtual memory, page tables and so on, as indicated by the example in figure 4. Additionally, since synthetic programs comprise what could be hundreds of bytes in a single command, page manipulation is made by establishing that each page can accommodate k synthetic commands, and that the memory has N pages available to the processes. This allows the implementation of paging mechanisms, including the treatment of page faults and address translation.

The use of synthetic programs make it easier to simulate the OS operations. Students can concentrate in them, instead of how interruptions and system calls could be generated. Although this approach could make easier the practices in the first course, we do not use synthetic programs there in order to ensure a better understanding of the hardware operation. We believe that this is important because most of the students will not take the OS Design course, having only that opportunity to be in contact with such issues. Therefore, making they work extra on managing interrupts and syscalls is a valuable effort.

We do not have a quantitative evaluation about the application of this approach in the OS Design course. However, we have qualitative insights from students that took this course in previous years, and they do not differ from those provided by the surveys applied in the Foundations of Computer Systems course. This should not be surprising since students in the advanced course are a subset of students that took the first course.

IV. Related work

As previously stated, the practices in operating system courses follow three different approaches. Here we will further discuss only the approaches based in simulation and component implementation, while a broader and more detailed review can be found in [6].

An approach based in component implementation is presented by Laadan, Nieh and Viennot [7], where they use the Linux kernel as a testbed for modifications in specific components, such as system calls or the scheduler. This is actually a continuing effort on previous works from the same group. Their approach demands, however, a large knowledge about Linux implementation.

In other direction we find the work from Robbins [8], where students can practice disk scheduling algorithms in a simulator built with this purpose. Although it is very useful for this topic, it does not address other important aspects of an OS and also do not demand any implementation from students, being simply a help for the understanding of the algorithms.

Nachos [9], is a traditional simulator used as a teaching operating system, replaced by Pintos [10]. Pintos is a full machine simulator and students are required to implement/modify small parts of it. Although several components can be targeted it is hard to understand the whole OS operation from these parts.

Finally, we have PennOS [11], where a user-level OS is simulated through the use of the *user context* library in order to enable low-level implementation of OS mechanisms without the need of special access to hardware instructions. This demands a strong knowledge about this library and low-level programming, as indicated by students reviews.

V. Conclusions

In this paper we described a multithreaded approach for laboratory practices in Operating Systems courses. This approach has been applied into two different courses taken by computer science major students, using different levels of components.

From the reports given by students, including answers to the survey applied in the intermediate level course, we can conclude that the use of threaded components allowed for:

- A better understanding of the concepts involved with the implementation and operation of an operating system;
- An improvement in the average grades in both courses in about 10%, with the rate of students failing to pass the first course dropping from an average of 30% from 1998 to 2006 to an average of 18% since then;
- A reduction in the number of students avoiding the Computer Systems track, associated with an increase in the number of students doing their graduation papers in topics related to distributed computing, from 4-6 students per year to 8-10 students nowadays.

Besides the success achieved, there are some aspects that still can be improved, such as:

- Establishment of different command architectures for the language used in synthetic programs, which would allow for their use even for a very small set of OS components;
- Creation of a common framework between the simulated components and user interface, reducing the number of components that have to be implemented by students;

- Improvement in the specification of all assignments, especially the first assignment in the Foundations course, since it is in that moment that the whole framework is defined.

Concluding, our final remark is that this approach for OS practices can be very useful, since it provides a deeper understanding about key components of an OS at the same time it does not require a large knowledge about the kernel or even programming details.

Acknowledgment

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Bug of the Day: Reinforcing the Importance of Testing

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***Abstract*—Software engineering students typically dislike testing. In part this is due to the simplicity of the programming and design exercises in introductory computing courses - the payoff for thorough testing is not apparent. In addition, testing can be seen as tangential to what really matters: developing and documenting a design addressing the requirements, and constructing a system in conforming to the design.**

Such dismissive attitudes do not accord well with the realities of commercial software development. The cost of fixing, repairing and redistributing a flawed product can dwarf that of development.

The Software Engineering Department at the Rochester Institute of Technology (RIT) teaches (and requires) basic testing as part of its foundation courses in the first two years. In addition, it offers an upper division course on testing, giving an in-depth treatment of best-practice tools, techniques and processes. Recently we've incorporated a "Bug of the Day," which serves to broaden student awareness of the cost of software flaws. Class discussions focus on the cost of the bug, its root causes, and how it might have been discovered and repaired prior to product release.

Keywords—Software Testing, Software Engineering Education, Quality Assurance

I. Introduction

Creating software that is on time and within budget is difficult; identifying, locating and repairing bugs only adds to the difficulty. Defective software not only significantly increases the development time and cost of a system, if released, it can have catastrophic effects - up to and including death [1].

Students generally view software testing as a bland, unexciting and insignificant task [2, 3]. They feel that creating applications is fun, but reviewing the quality of an application is boring. Software testing may appear to be a time consuming, uneventful activity requiring long hours of work with few results. Furthermore, testing is not typically part of a students grade and there is a self fulfilling aspect to the view that testing is unimportant [4]. Finally, the current educational mindset is building, not breaking software [5].

By way of contrast, professional software engineers must balance software quality against product delivery on time and within budget, and testing typically accounts for over 50% of a software product's cost. Though most universities host one or more computing programs, few focus on issues related to developing high-quality, low-defect software. Testing, to the extent it is covered at all, is rarely an object of sustained focus. In particular, only a handful of programs offer a course devoted solely to software testing [6-8].

For curricula taking testing seriously, it is necessary to teach students contemporary principles, processes and practices. In addition, students need the opportunity to put what they learn into practice, using testing techniques and tools at all levels, from the individual unit to the system as a whole. However, such education is insufficient if students do not gain a deeper appreciation of the significance of testing. One way to address this concern is to incorporate material on significant software failures as part of formal coursework; at RIT we call this "The Bug of the Day" (BotD).

Prior to class, students read material describing a real world software bug and its impacts. Each class begins with a discussion of that day's bug, with the instructor serving mainly to start the discussion and keep it on track. During this time students are asked to reflect on the problem, its root causes, and how it might have been prevented. The goal is to ingrain a respect for the importance of software quality and the role of testing in any quality assurance process.

The remainder of this paper comprises five sections. Section 2 discusses the course context, including objectives supported by BotD. Section 3 describes the BotD activity in further detail, including some of the examples, guiding principles for BotD selection, some examples used in class, and associated discussion topics. Section 4 presents student feedback 4, while section 5 surveys related works. The final section summarizes our use of BotD.

II. THE TESTING COURSE CONEXT

The undergraduate software engineering program at RIT has offered an upper division software testing course since 1998. The sole prerequisite is a second year course, Introduction to Software Engineering; which introduces basic unit and functional testing in the context of a term-long, multi-iteration team project. In addition, the graduation requirement of a full year of co-operative education means most enrolled students have additional testing experience via their co-op jobs.

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The course primarily serves to introduce principles and practices at the core of a disciplined testing process, and to give students experience applying contemporary testing tools and techniques. Much of this applied activity takes place in the context of a term-long testing project. With instructor guidance, teams of 4-5 students each select an open source software project, define test plans based on the available documentation and review of the code, and execute several testing iterations. At the end of the term, each group makes a presentation of their findings along with a detailed bug report. Teams are encouraged to forward their findings to the project development team.

A second objective is instilling both a sense of the importance of testing and the associated skeptical mindset that serves testers well. It is here that BotD, described in the next section, is most significant. The course meets twice a week for 110 minutes over the span of the 10-week quarter. Most class sessions have three components: a BotD discussion, a formal presentation related to testing, and a time slot devoted to a lab activity.

III. BUG OF THE DAY

A significant component of being a software engineer is how to create software that is high quality. Understanding the proper testing procedures and technologies is paramount for producing high quality software. Reviewing and understanding past instances of where defects occurred in software is beneficial for students for several reasons. Comprehending these past events and the reasoning behind them will allow students to gain experiences and knowledge which they may use when they encounter similar situations in their future careers. Additionally, these prior events will provide a real world context for the students and help to both foster their interest in software testing and reaffirm the course topics being discussed. For this reason, we created the BotD activity.

A. BUGS TO A SOFTWARE ENGINEER

System faults cause significant aggravation to end users, may lead to overall system failures and have led to billions of dollars in lost revenue [9]. Many of these defects may have been eliminated through the use of software testing [10]. Software bugs occur for a variety of reasons. Some of which include simple developer coding errors, incorrect specification understanding or incorrect requirements [11]. One of the primary goals of a software engineer is to create applications that are as defect free as possible [12, 13].

The BotD activity was a way for us to demonstrate the importance of software testing to future software engineers. Additional goals were to expose students to various testing and defect prevention techniques, to get them thinking about ways to resolve issues should they encounter a similar situation in industry and to foster student interest in the topic.

Each BotD activity was comprised of several aspects. These included a brief description of the bug, its effects and resolution taken.

B. GUIDING PRINCIPLES

The BotD examples were initially selected before the Fall term. Based upon student feedback and requests, the selected cases have been modified in the two course offerings that utilized this activity. When selecting a BotD example, several guiding principles were used. All cases should be relevant, simple and have good discussion points.

Relevant: A BotD example should represent a situation which the students could possibly face in industry. This serves two primary functions. The first is that the discussed scenario will help to educate students to instances which they are likely to encounter. Additionally, students will likely recognize these as relevant cases and thus be more inclined to both pay more attention to the bug and contribute more to the subsequent class discussion in a meaningful manner.

The instructor may strive to maintain relevance for the examples by ensuring that the discussed bugs are reasonably recent and if code is discussed make sure that it is in a language that a significant portion of the students understand. Student feedback indicated that they enjoyed discussing bugs which were fairly recent and had a technical context which they reasonably understood.

Simple: The discussed BotD should be reasonably understandable in only a brief period of time. While a student is not expected to comprehend every minute detail of the bug, they should be able to firmly understand the major points in only a five minute reading. We have found that the best examples are approximately 500 to 1000 words in length. However, this number should be shortened if the case encompases technical details.

Every student taking the course will not be at the same technical level. Some students will be far more experienced in various technologies and programming languages than others. We kept this in mind when selecting examples. The goal of the BotD activity was not to acclimate students with new technologies. The purpose is ensure that students actively think and discuss the reasons for the bug and how it could have been avoided. An overly technical or complicated example would detract from this goal.

Discussion Points: When selecting BotD examples, we strove to select cases which would have interesting and clear talking points. Some of the primary discussion points were the root cause of the error, how it could have been avoided, how its root cause could have been more quickly discovered and what would the student's recommendations be to the software group in order to avoid such instances in the future.

Instances which had reasonably clear solutions were often avoided. Examples with several possible remedies were frequently chosen since they would typically lead to a classwide, student led, informal debate over what the proper solution to the situation would be. This type of active thinking was a primary objective of the BotD activity. In the course feedback, several students indicated that while they typically do not speak up in most classes, they found themselves regularly contributing to these BotD discussions.

C. EXAMPLE #1: MARS CLIMATE ORBITER

The Mars Climate Orbiter was launched in December 1998 and was intended to collect data for approximately two earth years and serve as a relay station for five years. The cost for this NASA project was approximately $327 million. In the Fall of 1999, the orbiter reached Mars and needed to decelerate. Precise speeds and events that needed to occur were calculated in advance. After the first burn to slow the orbiter down, contact could not be reestablished and the orbiter was presumed lost [14].

A NASA analysis of the failure determined the root cause to be due to a confusion in units. A development group assumed the units of measurement to be in pounds, while the other in Newtons. One Newton is worth approximately .2248 pounds force. This miscalculation caused the orbiter to take a different trajectory than planned, one which was 170 km closer to Mars than intended. This caused the orbiter to likely burn in the upper martian atmosphere [15].

The notion that such an error could occur is often surprising to students. How could such an expensive NASA project fall prey to such a simple failure? This serves several important lessons to students. First of all, no software cases are too simple to test. Even the most basic situations are capable of leading to massive and catastrophic system failures. Additionally, if such a simple error can thwart such an expensive NASA project, then it can happen to any undertaking. Finally, in the realm of general software engineering, this case serves to solidify the importance of team communication.

Other than basic team communication, at least three other tests could have helped to avoid this bug. The first is a code review by a somewhat science-knowledgeable individual. Someone reasonably familiar with the difference between pounds and Newtons would have likely discovered this issue reasonably easily. A second possible test would be if the developed code was checked against an expected model of how the code should function or even a mock object. Finally, proper unit testing would have likely found this error at the code level.

D. EXAMPLE #2: GOOGLE MALWARE SNAFU

In early 2009, a human error at Google caused all websites to be briefly identified as possibly malicious. For a short period of time, all searches resulted in the warning “This site may be harmful to your computer”. Google soon stated that the issue was caused by “human error” when a developer designated “/” as a site that was attempting to install malware on a user’s computer. Google’s malware detection system understood this to mean that all sites on the internet were possibly malicious. Fortunately for Google, they were able to quickly roll back the update so the duration of the problem was only about 40 minutes [16].

There are several discussion points from this issue. The first is that even though this was a very minor syntax glitch, it had wide ranging ramifications and affected a significant number of internet users. This helps drive home the notion that nothing is too small to test for. If something can go wrong, it should be accounted for. Another topic of conversation is how this issue could have been avoided. While a simple response could be for the developers to ensure that they don’t make such a mistake, this is not reasonable to expect in all situations. The matter of putting a system in place to reasonably avoid an instance like this in the future is not a simple solution with a straightforward answer. Situations like this that make students think outside the box not only keep them interested in the course, but help them to come up with a wide range of possible solutions for a particular problem.

IV. STUDENT FEEDBACK

The students made their opinions clear that they both enjoyed the activity and extensively learned from it as well. At the conclusion of the course offered in the winter of 2012-2013, students were asked to anonymously fill out a survey regarding the BotD activity, the results of which are shown in Table 1. Out of 32 students who responded, all of them stated that they enjoyed the activity. 84% of the students stated that they learned a significant amount from the activity while half stated that it was their favorite part of class. Students indicated that they enjoyed the real world nature of the issues being discussed along with the impacts that software bugs may have on applications. Students also stated their enjoyment of the lighthearted nature of the activity and how the discussion was done in an informal, non-graded fashion. This made the students more at ease during this classwide exchange. Students also stated they enjoyed more recent bugs as opposed to software issues that had occurred a relatively long time ago. One interesting portion of received feedback is that a significant number of students inversely stated that either too little or too much time was devoted to the activity.

TABLE I. STUDENT COURSE EVALUATION DATA

Did you enjoy it?	**Did you learn from it?**	**Favorite Part of Class?**
32/32 (100%)	27/32 (84%)	16/32 (50%)

Following are representative samples of written feedback we have received:

The activity connected software testing concepts to reality. Discussions are fun. Became aware of some high-risk problems like handling time.

I enjoyed reading about different bugs in the real world and how how companies responded to them.

It provided us with concrete examples of how what we were studying applied in the real world, helped to demonstrate the importance of thoroughly and effectively testing applications at all levels and all stages of development, and *also showed how often proper testing is not fully done in the real world.*

A primary goal for the activity was to put student's at ease, encourage them to ask questions, make mistakes and come up with alternative solutions. A desire was to have the students want to learn, not force them to learn. This was accomplished by allowing the students to propose their own bug examples and have the students provide input on the type of issues they would like to analyze. The instructor also acted as a moderator for the discussion and created a conducive environment for a student led discussion. Students have provided substantial feedback that they enjoyed the fact that this activity was not graded, thus allowing for a more easy going, friendly and non-judgmental environment. This notion is well exemplified by the following student feedback:

The fact that there was no quiz on it and that we were able to take a break from lecture. Its nice change of pace from all the rest of the classes where you can just read something over for the first time, discuss it, learn from it, and not have to worry about being graded.

I liked being able to actively get involved in discussion and exploring different reasoning and solutions.

V. RELATED WORK

We are not aware of any existing courses which use an activity related to our "Bug of the Day" exercise. A similar activity is conducted in an Engineering Secure Software class at RIT with positive results [5]. In the context of software testing, there are numerous institutions which offer courses pertaining to software testing. While many of them have activities that discuss current software techniques and technologies, none of them are known to actively discuss real world cases in such a manner on a routine basis [6, 7, 17].

There are numerous other works which purport the need for a further emphasis on software testing and quality in the student curricula [3, 4, 18, 19]. In order to foster student interest in software testing, Preston examines the use of real world projects in information technology education. Using real world projects help in motivating students in addition to providing a more real world experience for the students [20]. Harrison [21] discusses teaching software testing from two perspectives, one being the developer and the other as the software tester. The main benefit of this is approach is that students witness the importance of testing from both viewpoints and they learn to apply testing techniques from both perspectives. Goldwater [22] discusses several fun ways to incorporate software testing into a curriculum. In his example, student projects are evaluated against a common test set in a competitive fashion.

VI. SUMMARY

Future software engineers need to understand the importance of testing in developing high-quality software, as well as the principles and practices that are the foundation of a successful testing regime. In addition to standard material on testing techniques, our course incorporates a Bug of the Day activity to reinforce the cost of letting defects seep into production software. The time devoted to in-class discussion serves to sharpen student appreciation of the need for testing, and to give them the opportunity to see how appropriate testing can be critical to system success. Students generally appreciate the inclusion of these discussions. Indeed, based on preliminary discussions of this technique, at least one colleague at another university plans to incorporate BotD in their testing course. We encourage others to consider this approach in the courses they teach.

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Didactic and Interdisciplinary Experiences in a Software Engineering Course

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Abstract - **Didactic experiences are very important in a Software Engineering course. We think they help to achieve at least six objectives of the course: to identify fundamental concepts of software engineering, to recognize software life cycles, models and methodologies of software development, to perform analysis of software products requirements, to design and develop a software product, to use the methodical processes of a real-world project, and to implement solutions following specific methodologies. In this paper we will show our didactic experiences in the Software Engineering Processes course. We developed a sequence of learning activities and their application (extracted from real requirements of clients and users) in different contexts such as environmental, medical and social, which results in higher levels of learning, interdisciplinary exercises and practices close to what students will face in their professional lives.**

Index Terms **-** Software Engineering, Didactic Experiences, Learning Activities, Interdisciplinary.

I. INTRODUCTION

Didactic experiences are lived events intended to teach a lesson. They are very important in a software engineering course since they help to achieve at least six objectives of the course (based on the ACM/IEEE-CS Computer Science Curricula): to identify fundamental concepts of software engineering, to recognize software life cycles and models and methodologies of software development, to perform analysis of software products requirements, to design and develop a software product, to use the methodical processes of a project, and to implement solutions following specific methodologies.

In our Software Engineering Processes course we use real-world projects as a strategy to achieve the objectives, that is, we use didactic experiences where students must build a real product needed by real clients and/or users. This strategy is not new (the reader may refer to [1, 2, 3] to see other works about this strategy), however we realize that if we combine it with other learning and interdisciplinary activities we are about to describe in this document, we maximize not only the achievement of the objectives but communication skills in interdisciplinary environments and the understanding of how computer science can contribute in different contexts of society.

Using projects as a strategy for teaching is typical in the Problem-based learning methodology (PBL). PBL has the construction of knowledge (ideas and notions) as a fundamental axis. It builds new knowledge from previous one, by planning, implementing and assessing real world projects. Some of the main characteristics of the projects of this kind of learning are [4, 5, 6, 7]: they focus on students; they are well-defined; they are related to the environment and the culture; their specific aims are related to curricula standards; results can be exposed to final users; they connect academics to non-academic (i.e. productive sector) areas; experts can provide feedback and assessment; students can think about results; and the assessment is real and periodical (portfolios, partial deliveries, papers, etc.).

This kind of learning strategy has been used (and adapted) successfully in Software Engineering courses the latter years. In [4] authors "extended the concept of integrated project based learning by focusing on the design and development of a real word project that can be utilized as a real solution". On the other hand, in [5] authors "proposed to adapt the PBL methodology that is especially designed to be integrated into software engineering classroom in order to promote collaborative learning environment". Finally, in [6] "a new learning methodology mapping the roles and phases considered in PBL methods into the roles, iterations and phases considered in the 'y' process, called yPBL" is proposed.

This document is organized as follows: section II describes the course and its objectives, where learning experiences were applied; section III presents a description of each one of the activities that we develop in the course; in section IV we show the strategies articulating these activities in order to achieve the proposed objectives; sections V, VI and VII detail the way we select the projects, how we assess the learning activities and which were the appreciations, difficulties and successes of students; finally in section VIII we provide some concluding remarks.

II. Course Description

The following didactic experiences were put into practice in the Software Engineering Process course [8]. This course was designed for middlers (we have a five year program) of Computer Science at the Pontificia Universidad Javeriana in Cali, Colombia. It is part of the fundamental core of the program, and its classes are scheduled in two 16-week sessions each semester. In this course we study processes involved in software development, we introduce different development methodologies and their application according to a context, and we encourage our students to apply the concepts and techniques learned in the course using real-world projects as an axis. In Table 1 we present the objectives of the course.

TABLE 1. OBJECTIVES OF THE COURSE

OBJECTIVE	TOPIC TO WORK
To identify the main concepts of software engineering.	· Software features and qualities. · The purpose of software engineering and its difference with computer science. · Software processes and models associated to them. · Models in the software development process.
To recognize software life cycles, development process models and software development methodologies.	· Software life cycles. · Models of software development processes. · Software development methodologies. · Advantages and disadvantages according to the context where it will be applied. · Application of an agile software development methodology to a small project.
To gather, analyze and model requirements of a medium-scale software product.	· Phases in the requirements engineering process. · Characteristics that requirements must have in a software project. · Functional and non-functional requirements in software development projects. · Software Requirements Specification Document (SRS) based on established standards. · UML diagrams to model software product requirements.
To design a medium-scale software product.	· Techniques and models in the software design process. · Software design documents based on established standards. · UML diagrams to model the application design and operation. · Design alternatives related to architecture, structure and interfaces of a software product.
To develop, validate and test a medium-scale software product.	· Good practices in software development processes. · Software verification and validation processes. · Formal methods in software development. · Construction and integration of software components according to established specifications and designs. · Evaluation and validation of software solutions according to established specifications.
To use processes of analysis, design, development, validation and maintenance of a real software project.	· Implementation of a software solution following a specific methodology from the requirements gathering to the validation of the developed product.

Learning activities have been implemented in this course since the first semester of 2011, however in each new class the methodology is adjusted and new elements or didactic situations are incorporated in order to improve the students' learning process. The experiences showed in this document include all the strategies and methodologies implemented in semester 2012-2.

III. Learning Activities

In order to achieve the objectives of the course and to accomplish the expected learning process, we proposed a sequence of activities related to each other. These activities let students to learn the theoretical background of software engineering, to apply that background into specific contexts, and to acquire the knowledge through academic reading and writing activities. The following are the activities proposed.

A. Project Fulfillment

The course uses the project-based learning approach [9, 10], focusing on ***real-world project***s of software development. This means that real clients/users of the product to develop exist and they need the product. Additionally, for the project we search topics that allow students to interact with other disciplines and that promote holistic education. Recent projects have been:

- Information system of the basin of the Pance River (Environmental, Social, Academic). 2011-1
- Information system to organize medical histories (Medical, Academic). 2011-2
- Information system to train and learn how to fill medical histories (Medical, Academic). 2012-1
- Information system for controlling social responsibility projects. (Social). 2012-2

For the topic of the projects, we give priority to those that allow students to have contact with their environment from a social, environmental or human point of view. For the project development we apply the *Rational Unified Process (RUP)* [11] software development methodology, which let us work sequentially and in a rigorous way each one of the build phases of the application.

Since we want students to know the use of agile software development methodologies [12] (topic covered on the first classes of the course) we also propose a mini-project to be developed in approximately 4 weeks. The objective of this mini-project is "to develop a small web application using the agile software development methodology (*eXtreme Programming* [13] or *Scrum* [14])". With the mini-project we expect students to apply the principles of this kind of methodology in a real small project. Recent mini-projects proposed were:

- A web page for a (amateur) coin and bills collector (Numismatics). 2012-1
- A web system called "Grandmother Recipes". 2012-2

B. Reading and Writing for Learning

In different moments of the course we use different learning strategies associated to reading and writing [15, 16]. These strategies are related to the topics of course. The following are the activities implemented:

- For reading we developed guides orienting students to analyze a particular text with a clear objective. The document is discussed in class and associated with contents of the course.

- With writing we seek students to systematize the application of software development methodologies (associating their own experiences), to deal with the use of a format and language of their own discipline, and to motivate to write their own experiences in software development for a wide public (not just the professor). To apply this strategy we developed a guide to write papers.

C. Use of ICT (Information and Communication Technology)

As a support to the course, to the topics and to student's discussions about the main project development, we have been used some tools related to ICT. The activities have been:

- Use of a learning management system (LMS) [17] to share with students the material worked in class, the proposed activities and extra support material.
- Use of a forum [18] aiming at sharing information and experiences associated to the development of the main project, at solving questions and problems from a collaborative point of view, at clarifying requirements of the software to develop, and at discussing different technical alternatives in the developing stages in order to obtain different ways to a determinate solution.

D. Theoretical Support

Finally, all the above activities have a theoretical support [19, 20] to be taught. Hence we use:

- Lectures to expose the main concepts of topics. Slides are available via the LMS. They show the theoretical concepts studied in the course.
- Individual expositions that are assigned to each student. The objectives of these expositions are to delve in a topic, to write a paper where the student presents his/her analysis of the topic, and to improve his/her oral skills. These activities come with support by the professor, giving the student feedback and extension of the knowledge.

IV. Strategies to Articulate and Develop the Learning Activities

We use the strategy of presenting the theoretical concepts and their application in real cases of software development to articulate the contents and the learning activities. Having real clients/users in projects along with important characteristics such as interdisciplinary, social responsibility and environment knowledge make students face situations they will face in their professional life, which allow the learning process to go beyond the very theoretical concepts.

The following is the description of some tasks we give to students. We believe these tasks contribute to achieve the learning objectives.

- **Presentation and study of theoretical concepts related to software development projects**. This course introduces the software development processes (requirements gathering, analysis, design, development, tests and implementation). Each one of them is studied during the semester. The theoretical part is giving by means of lectures supported by slides that are available via the LMS. It is also provided by readings and expositions students must do with help from the professor.

  With these activities we accomplish the learning objectives concerning the theoretical part and we settle the foundations to achieve all the other objectives by applying the concepts in real-world projects.

- **Fulfillment of a mini-project in order to apply the concept of agile software development methodology**. During the first 4 weeks we discuss the generalities of software life cycles and the agile software development methodology. The professor presents a global vision of the methodology, two students present the two main agile methodologies, and bibliographic material is posted in the LMS. We propose an agile software development project in which teams of students must apply the principles of one of the methodologies. Finally, we make students to write a technical paper about the experiences in the fulfillment of the mini-project, following a particular format. This activity allows students to systematize the acquired knowledge in the application of software development methodologies with their own experiences.

  As professors we help in the development of the mini-project and the writing of the results. We schedule time weekly to meet students. We think these activities help to accomplish all learning objectives from the point of view of a particular methodology that have a different style to the traditional. Additionally, they have another impacts such as improve of the reading skills, writing of technical documents and relation with interdisciplinary groups.

- **Fulfillment of a project of software development in a real scenario**. Once the mini-project is finished, we being the study of each one of the software development processes using a rigorous methodology (RUP), for which we propose the development of a project with the following characteristics:

  - The development of useful software (not just an academic exercise). We seek to resolve an existing real problem. For the semester 2012-2 the social responsibility office at the university needed an information system for managing social responsibility projects. Since this was a real-world project, it faced students to the benefits and difficulties of interact with users and clients, to

requirements gathering and to experience the application of concepts, techniques and methodologies in a software development project.
- The topic of the project intends students to be integrated in a multidisciplinary environment. They have to modify their technical language to an appropriated one in order to talk with users and clients of the project. In addition, in an intention of promoting holistic education we also seek for a topic related to social and environmental areas.
- We select a medium-scale software development project. This allows students to apply a more rigorous methodology and to work each one of the phases of the software development process the minute it is studied in class.

To ensure that students present their advances and experiences, we propose partial deliveries of the project, each one covering one or two phases of the software development. These partial deliveries are guided by document and software standards, and they have to be presented in an oral presentation to the whole class. The presentation always opens a debate and allows feedback by classmates and the professor. We also use a forum where students may share their experiences or post questions that can be resolved by another student or the professor. Finally, weekly we discuss the project (or mini-project at the beginning of the course) in a schedule especially reserved for this matter.

We believe these tasks allow accomplishing all learning objectives from a rigorous methodology point of view, that is, a point of view where each learning objective is achieved by applying the concepts taught in class in a particular phase of the software development. Likewise, these activities also help to accomplish other learning processes such as following standards, writing technical documents, relationships in interdisciplinary groups and knowledge of social and/or environmental issues in the region.

V. PROJECT SELECTION AND INTERACTION WITH CLIENTS/USERS

Finding "clients" needing some software development is an easy task. The strategy is to search and interview project managers or heads of academic areas within the topic interests of the current class. In the interviews we detect some particular needs, we define the scope of the project and we design a general guide of the project.

At the beginning of the academic semester, the client (and in most of cases future users of the system) makes a presentation of the area and his/her needs for a software development. In this first encounter information is very general and normally the difference between the language of the client and the language of students does not allow a wide comprehension of the requirements of the system. However, after a research about the work and the context related to the project, and the continuous meetings with clients and users, students acquire the ability of understanding the language from other disciplines and the ability of expressing their ideas in a non-technical way or at least in a way understandable for every people involved in the project.

Meetings, communications and other interactions with clients/users are coordinated directly by students, and supervised (and redirected if necessary) by the professor.

VI. ASSESSMENT METHODS

In this course we use different assessment strategies and tools: midterms and finals exams to assess the application of learned concepts; technical writings; the capacity of following of software development standards and methodologies; and the development of software products with some characteristics and qualities. In addition, we associate the assessment of the learning objectives to the ABET (Accreditation Board for Engineering and Technology) accreditation process, which we are implementing in the Computer Science program.

In the ABET accreditation process [21, 22], the learning activities must contribute to some abilities or student outcomes named from A to K, each one with a different weight depending on the course. The students outcomes for computer science are [23]: (A) An ability to apply knowledge of computing and mathematics appropriate to the discipline; (B) An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution; (C) An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs; (D) An ability to function effectively on teams to accomplish a common goal; (E) An understanding of professional, ethical, legal, security and social issues and responsibilities; (F) An ability to communicate effectively with a range of audiences; (G) An ability to analyze the local and global impact of computing on individuals, organizations, and society; (H) Recognition of the need for and an ability to engage in continuing professional development; (I) An ability to use current techniques, skills, and tools necessary for computing practice; (J) An ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modeling and design of computer-based systems in a way that demonstrates comprehension of the tradeoffs involved in design choices; (K) An ability to apply design and development principles in the construction of software systems of varying complexity.

According to what we established for the course of Software Engineering Processes in the ABET accreditation process, it contributes to 8 of the 11 student outcomes. Table 2 presents the assessment instruments, the weight of each one of them and their relation with the student outcomes this course contributes to.

TABLE 2. ASSESSMENT INSTRUMENTS

ASSESSMENT INSTRUMENT	%	A	B	C	D	F	I	J	K
Homeworks and quizzes	10%	36%	26%	20%		12%		6%	
Oral presentation	5%	75%				25%			
Mini-project	10%		20%	17%	15%	9%	12%		27%
Midterm	20%	25%	45%			15%			15%
Final	20%	15%		60%		10%			15%
Project:									
First phase (requirements)	10%		60%		8%		15%		17%
Second phase (design)	10%			44%	8%		15%	33%	
Third phase (development)	15%				8%	10%	30%		52%

Each one of the instruments we use are designed to contribute to some of the student outcomes (e.g. 25% of the midterm contributes to (A) the ability to apply knowledge of computing and mathematics appropriate to the discipline, 45% to (B) the ability to analyze a problem, and identify and define the computing requirements appropriate to its solution, 15% to (F) the ability to communicate effectively with a range of audiences, and 15% to (K) the ability to apply design and development principles in the construction of software systems of varying complexity). The purpose of the assessment strategies is to verify the scope of the learning activities or expected abilities in every moment of the course.

VII. STUDENT'S APPRECIATIONS, DIFFICULTIES AND ACHIEVEMENTS

At the end of the course we make a survey with students in which we quantify (1 – 5) the fulfillment of each one of the student outcomes. Table 3 shows the result of the survey.

TABLE 3. SURVEY OF CONTRIBUTION TO THE STUDENT OUTCOMES

STUDENT OUTCOMES	A	B	C	D	E	F	G	H	I	J	K
Response Average	4.6	4.8	4.6	4.4		4.4			4.4	4.1	4.7

As the reader can see, student appreciations about the contribution of the course to student outcomes are high.

It is important to remark that the student outcomes most valued were (B) the ability to analyze a problem, and identify and define the computing requirements appropriate to its solution and (K) the ability to apply design and development principles in the construction of software systems of varying complexity. These outcomes are directly associated to developing projects, relationships with clients/users and the application of a methodology depending on the context and the complexity.

Definitely, the most difficulties students manifest are not associated to technical aspects but to the relation with clients/users (requirements understanding, scheduling of meetings, negotiations about scope, etc.) and the ability of handling documentation and standards. Once students understand what they have to do and how to follow the methodology, results are obtained quickly. Notwithstanding, at the end of the course students overcome all these and they learn valuable knowledge.

On the other hand, another difficulty to solve is the time limit to complete the software development (that is, to get to the implementation), and the academic effect (grading) of the work. For the client the highest expectation is in the product, but for the student is in the grade. We overcome this problem by proposing to conclude the project in an elective course of advanced software engineering.

VIII. CONCLUDING REMARKS

In the Software Engineering Processes course we developed a sequence of learning activities related each other. We try students to apply in real-world projects the theoretical concepts taught in class, to acquire significant experiences, and to use writing as an element to systematize their knowledge using a discipline proper language.

The integration of different activities seeking a greater and better learning such as: project-based learning, use of reading and writing as a support for learning, application of theoretical concepts from different points of view and use of ICTs, allow students to better understand the topics of the class, to experiment the result of the application in a real situation, to write the result in a proper language, and to associate the results to the environment and the context.

When students face a software development problem with real clients and users and, in top of that, from other disciplines, they found themselves in situations that we can hardly teach in a classroom. Students must adjust their technical language to interchange ideas with members of the team project, to use modeling language (e.g. UML) to express their designs, to "negotiate" with users and clients in the definition of requirements and give them different techniques to accomplish the expected objectives.

Experiences, difficulties and successes in the development of a project are discussed in class and compared to theoretical concepts. We observe how the applications of those theoretical concepts have some meaning depending on the context. Likewise, the discussion about the project development and the production of written documents allow noticing that student learning are high and their experiences are very close to what they will face in their professional lives.

This course also attains, as an additional value in the formation, that students get to know their environment from a more social, environmental and human perspective, and how from the computer science area of knowledge they can participate in any of those perspectives.

Finally, the results in all phases of the course and the opinion of the students about the experiences and acquired knowledge allow to conclude that the Software Engineering Processes course attain, by means of their learning activities, the proposed objectives.

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Self-affirmation and Success in Undergraduate Computer Science

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***Abstract*—This paper reports on the category of "self-affirmation", one of the key abstracted categories identified in a qualitative study that sought to examine the factors that influence student perception of success in undergraduate Computer Science. Self-affirmation is the process whereby an individual focuses on important and positive aspects of their life with the aim of affirming their sense of self-worth and value. This positive self-regard makes individuals more accepting of negative feedback.**

The grounded theory approach employed in this substantive study provides a unique insight into the students' perspective of the key factors that influences their perceived success. Self-affirmation processes emerged as a key element of this theory and merit inclusion in future efforts to support and scaffold freshman learning in computer science.

I. Introduction

The challenges of student recruitment, retention and continued attainment in Computer Science at the undergraduate level have been of concern to faculty members and University authorities for many decades [7], [21], [8], [44], [4]. Despite much effort in this regard, these issues still remains a source of much discussion and debate in the literature [13], [29], [37], [2].

Freshman students are usually experiencing University life for the first time and may experience a period of adjustment where they develop an appropriate sense of their own responsibility for, and ownership of, their learning [20]. Students of Computer Science face additional challenges as there is often very little continuity between the subjects studied in the final years of their second level education and those encountered during the freshman years of an undergraduate degree program [17]. Moreover, many freshman students have little or no experience of the style of logical thinking that is required for courses in areas such as computer programming, computer networking and hardware systems.

We report on a key factor of a substantive qualitative study [18] that explored the prior experiences that freshman undergraduate students believe help them succeed and we identify elements of self affirmation that were common to those who perceived themselves to be successful. All participants had English as a first language and had followed the traditional entry route to University directly from second level education.

Self-affirmation [35] refers to the processes by which an individual seeks to make sense of their own actions and of the world around them. These processes are usually considered as a defensive mechanism as they may be invoked in response to the typical setbacks and negative events of daily life. For example, a student may seek to rationalise poor academic performance by deciding that they have no aptitude for the subject in question or they may accept their poor performance and use it as a motivation for change. Alternatively, an individual who has experienced adversity and become discouraged may actively seek out positive life experiences to help them counteract negative sentiment.

In this paper we explore the self-affirmation processes that influence and shape participant attitudes towards their studies, which in turn influences achievement and success. Self-affirmation varied along a continuum from strongly positive to strongly negative. Participants experienced positive feelings when they were successful in completing a computer related task or when their skill and ability was praised by academics and tutors. Each participant's belief in their own ability was affirmed as a result of these interactions. At the negative end of the continuum, participants described the influence of negative feedback as being discouraging, leading them to become anxious and worried about their decision to study computer science.

II. Background

A. *Predicting Success at the Freshman Level*

The ability to predict an individual's potential for succeeding [44] has been seen as a key factor to improving retention on Computer Science and Technology based degree programs. A wide range of factors have been considered in the effort to determine predictors of success – these factors include age, gender, mathematical ability, second level performance, previous computer experience, computer anxiety, computer attitude and computer self-efficacy [32], [15], [24], [3].

The majority of this work has been in the quantitative domain where a numerical scale is used to rate the students ability or performance, with some form of statistical analysis (e.g. factor analysis or principal component analysis) then performed to determine the most significant factors influencing success.

Many students experiencing difficulties during their first year at university cite the challenges encountered while learning to program as one of the major causes of their problems. Indeed many engineering and computer science students claim

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to “hate programming” and feel unable to grasp even the most basic skills [41]. Students who struggle with programming courses either fail and drop out of the course, or manage to continue but assiduously avoid future programming projects and ultimately choose a career that does not involve programming [33]. Psychological studies of programming date back over thirty years [30], [45], but appear to have had little impact on the culture of learning in a programming class. Indeed, the literature indicates that today’s students have little or no confidence in their programming abilities [37], [2]. One of the challenges for those in computing education is to design effective learning environments which result in a significant improvement in students’ attitude to, and attainment in, programming.

Many have viewed this as key to overall success on computer science and technology based degree programs and so have concentrated their efforts on predicting student success around introductory programming courses (e.g. [14], [44], [5]). This is often identified as the CS1 problem. Indeed, computer programming is a key element of the computing curriculum [40] published jointly by the ACM and the IEEE Computer Society. This curriculum provides recommendations for the structure and content of undergraduate programs in computer science and is often used by higher level educational institutions to shape the design and content of their degree programs.

B. *Self-Affirmation*

Self-affirmation theory has its roots in an exploration of dissonance processes e.g. in the dilemma faced by someone who continues to smoke cigarettes despite the over-whelming evidence linking smoking to lung cancer. Steele [35] argued that in order to reduce the impact of such a dissonance the individual need only engage in some affirmation of general self-integrity, even when that affirmation bears no relationship to the dilemma or inconsistency being faced.

Self-affirmation theory argues that those who can maintain a positive global sense of self-worth will be less threatened by conflict or insecurity in a single domain of their life. If an individual’s sense of global self-worth is temporarily bolstered then they have been shown to be more willing to tolerate threats, setbacks and negative events [9]. Self-affirmation can take place when an individual reflects on important aspects of their life that are distinct from the threatening domain or when the individual engages in activities that highlight perceived positive values or attributes that are different from the discommoding domain.

Sources of self-affirmation include social roles (e.g. being a student), values (e.g. religion), group identity (e.g. gender), central beliefs (e.g. political ideology), goals (e.g. economic success), and relationships (e.g. family, friends). Most self-affirmation occurs at a sub-conscious level, in that individuals are unaware that they are employing self-affirmation strategies as a means of coping with adversity.

Individuals strive to maintain a positive view of themselves despite the challenges and setbacks they encounter in everyday life. For example, in an effort to maintain a positive view of themselves students may attribute poor examination performance to external factors beyond their control, such as examiner bias. Coping strategies of this type can be detrimental if they stem from inaccurate views of reality that prevent an individual from developing an awareness of their personal shortcomings and deficiencies. Self affirmation is the strategy whereby one draws on one’s global sense of self-worth in order to be more accepting of life’s setbacks and threats to one’s sense of self-worth and value in the world.

In studies that explore the effect of self-affirmation individuals typically engage in activities that affirm their sense of self-worth and value prior to engaging with set tasks. These self-affirmation activities can seem rather artificial and contrived e.g. participants may be asked to list traits that were central to their essential being and self-worth; from these they then pick the trait they consider the most important and finally they write a short essay about a time they successfully demonstrated that trait [9], [16].

Despite the artificial nature of the self-affirmation activities detailed above, many studies have shown that such activities increase the participant’s self-affirmation and make them more receptive to negative feedback and criticism. For example, self-affirmation has been identified as a successful method for mitigating the effect of stereotype threat. Stereotype threat occurs when an individual experiences concern or anxiety about how their performance can confirm negative stereotypes about their social group [36]. For example, gender related math attitudes can play a significant role in undermining the interest and performance of girls and women in science, technology, engineering and math (STEM) domains [12]. Even those with positive attitudes towards the domain can be at risk of stereotype threat [28].

It has been shown that women perform more poorly on a challenging mathematics test when it is described as diagnostic of their abilities, as compared to how they perform on the same test when it is described as non-diagnostic, i.e. performance decreased in the presence of a stereotype threat [25]. However when the same test is administered to those who have taken part in self-affirmation activities prior to the test, then their performance is at a similar level to those in the non-diagnostic group. These self-affirmation activities focused on affirming a valued attribute other than mathematics. Similar results have been observed in tests conducted with college level physics students [26].

In this work we explore the category of “self-affirmation” identified in a qualitative study of factors that influence student success. These activities differ from those in traditional self-affirmation studies as they are not artificial or contrived, but rather are drawn from the real-life experiences of the participants.

III. Grounded Theory

The findings in this paper form part of a much broader qualitative study of the students’ perspective of the experiences that influence success at the undergraduate level [18]. This substantive qualitative study was carried out over a number of years and was conducted using the Grounded Theory methodology [10], [11], [38]. This methodology provides detailed systematic guidelines, analytic procedures and research strategies for the conduct of qualitative data analysis that lead to theory development.

Grounded theory requires the researcher to carry out the analysis of the data on a number of levels. Strauss's three-state approach to analysis was adopted [38]. This involves open, axial and selective coding [39]. Open coding requires the researcher to identify, name, categorize and describe any phenomena found within the text. These codes are then reviewed with the aim of grouping those with a common theme together into higher order entities, called concepts [1].

Concepts are then further analysed with the aim of gathering together those with a similar focus into more abstract groups, called categories. The process of relating categories to each other is known as axial coding. The researcher then identifies the similarities and differences that exist between the categories through a process of constant comparison.

As the researcher identifies central categories and the relationships that exist between them and their sub-categories, the focus is usually on the causal relationship between them [6]. When gathering more data will not yield further insights a point of theoretical saturation has been reached [22]. Finally, selective coding is the process of determining the central phenomenon to which all other categories can be related. Strauss and Corbin [39] view this as the central narrative or storyline which links the categories and their relationships.

An important element of any qualitative study is the trustworthiness of the results obtained. The authors each have over a decade of experience as faculty members in Computer Science and they are both active researchers in the field of Computer Science Education. Like many in this field this is not their only sphere of research activity, as they are both research active in the field of computer science. They are not only practiced in the conduct of studies involving grounded theory [19], but have also carried out qualitative investigations in the phenomenographic research tradition [34]. Their familiarity with the conduct of qualitative research and with the domain under investigation i.e. computer science, means that they are familiar with the context and environment of the study. This background provides them with the theoretical sensitivity needed to analyse the data gathered for this work.

When using the Grounded Theory methodology the theory emerges from the constant comparative techniques employed. The results obtained are corroborated and confirmed by member checking, while triangulation with the quantitative studies in the literature also strengthens the trustworthiness of the findings.

IV. Data Collection and Analysis

The grounded theory methodology is not prescriptive when it comes to data collection, indeed the researcher is encouraged to gather data from multiple sources using a wide variety of methods as this helps ensure the trustworthiness of the results obtained.

While the bulk of the data used in this study was collected through the interviewing of participants, data was also obtained from focus groups. The sample was homogeneous, as all participants were engaged in pursing the same degree program (Computer Science). In total 22 participants were interviewed, while a further 10 engaged in focus group discussions. This is a relatively large sample for a qualitative study of this nature, where samples of 15 to 20 participants are common. All interviews and focus groups meetings were recorded and subsequently this data was transcribed prior to analysis. The study was carried out in accordance with the University's ethical policies and all data was dealt with according to the relevant data protection policies.

The interview approach adopted was that described by Lofland as a "directed conversation"' [23], where the interviewer directs the conversation depending on a number of factors including the participant's current physiological state, the rapport between the researcher and the participant, the researcher's awareness of the interview process, the researcher's theoretical perspective and the topic under consideration. It is important that the researcher should not be overly-directive as this may reduce the richness and quality of the data collected.

Patton defines a focus group as "an interview with a small group of people on a specific topic" [27]. The nature of a focus group is such that the number of questions that can be asked is significantly lower than in an individual interview setting. Hence, in this work focus groups were used to seek confirmation of emerging categories or theory.

V. Evidence of Self-Affirmation

In this study self-affirmation processes are shown to influence and shape participant attitudes towards their studies, which in turn influence student perceptions of their achievement and success. Over three-quarters of those who participated in the study engaged in self-affirmation and felt that it was one of the factors that contributed to their perceived success. Self-affirmation varied along a continuum from strongly positive to strongly negative. Participants experienced positive feelings when they were successful in completing a computer related task or when their skill and ability was praised by their teachers. Many indicated that they returned to recollections of these activities and their previous successes when they found other aspects of their studies challenging.

In a qualitative study quotations are used to illustrate phenomena observed across multiple participants. Taken individually each quotation could be considered as merely anecdotal, however it is more appropriate to view each quotation as one example drawn from a much larger collection of similar observations from within the collected data. Representative quotations from the dataset are provided to illustrate each of the observed phenomenon.

The section begins with a series of quotations that illustrate some of the many, subtly different, self-affirmation processes that the participants found to be effective in helping them to succeed in their undergraduate studies. The focus of this section then shifts to negative self-affirmation, where participants describe situations in which they felt threatened and uncertain about their studies or where they did not engage in self-affirmation. Taken collectively these observations form qualitative evidence for the inclusion of self-affirmation as one of the key categories that students perceive influence their success.

One participant first commented on their positive experiences when writing computer programs:

> **Participant A:** "Writing computer programs can be really satisfying. When you are doing it and it works, you get a lot of satisfaction. It's really worthwhile and you want to do it again because it makes you feel like you've achieved something."

they then drew on these experiences to boost their ego when struggling with other aspects of their studies:

> **Participant A:** ".... so when I get stuck in electrotech, I often go back to programming because I know I can do it."

This is an example of self-affirmation where the student draws on a positive experience in a different, distinct area of computer science to affirm their sense of self and their ability.

Another student commented on how they drew on positive feedback they had received in the past to help them when they found their studies challenging:

> **Participant B:** "I was doing some stuff on the computer and my teacher was really impressed, so that made me realise I was quite good at this. Then if I'm not able to understand the problem then I know it's because it is difficult and not because I'm not any good at it. That seems to make it easier."

This student is taking responsibility for their studies and not blaming others. They accept that they may run into challenging problems during their studies. This is self-affirming behaviour as the student does not question their own ability when faced with a problem that they find difficult.

Another student engages in self-affirmation by drawing on positive feedback they have received on their work:

> **Participant C:** "When I do well on assignments then I feel really happy because I know I've got it right. So I know that I can do assignments and that I will do well on the course. It makes me feel good about myself."

This student bolsters their sense of self-worth by dwelling on the happiness they have experienced in the past.

Others talked about engaging in self-affirming activities when they find themselves struggling with their studies. The following student described how they liked to take time out to use social media when their studies were proving to be particularly challenging:

> **Participant D:** "I like to go and do something completely different... I might check on my friends pages or update my profile. Then I can go back to the problem with a clear head. It is best to take a break and then go back. I don't give up."

This participant is not only only illustrating how they engage in positive self-affirmation, they are also indicating their persistence and strong sense of self-efficacy.

Another participant talked about how personal relationships were a source of self-affirmation for them. They explained how time spent with their school friends and family helped them to take a more positive approach to their studies. This student lived close to the University during the week, but returned to their home town every weekend.

> **Participant E:** "It is a struggle to get through the week. I find I get very down because I can't keep up. However, I go home each weekend and I meet my friends on a Friday night. It is amazing how much better I feel afterwards and how much I can get done on a Saturday. It's like I suddenly can understand things when I go home."

While participant E actively sought out meetings with others as a means of self-affirmation, another participant dealt with negative feelings in relation to their studies by consciously thinking about the things that they value, reminding themselves about past academic or personal success.

> **Participant F:** "I did well in school. I was good at English and History, as well as Maths. I know I can do well. However, there are so many different things involved in programming that it just threw me completely. It was very tough. I thought it was just me, but then I realised I'm not the only one. We are all trying our best."

This student is drawing on his past academic success to help them move from a negative perspective of the value of their work to a more accurate view of reality where they acknowledge that while the subject is challenging, they are trying their best.

At the negative end of the continuum, participants described the influence of negative feedback from their teachers and peers. In relation to their university studies one of the participants rationalised their poor grades as follows:

> **Participant G:** "It's embarrassing when you don't get things and wh of this before and I don't want the others to see what mark I got, because then they'll know that I don't understand it."

This participant is feeling threatened and admits to fears of how they will be perceived by other students in their cohort . They engage in defensive mechanisms by attributing the source of their failure to the fact that they not met the subject before. This is unlikely to capture the full picture, as most students in the group are in a similar position. This participant has not engaged in self-affirmation and is unlikely to be able to learn from their mistakes as they are unwilling to reflect upon all possible reasons for their lack of success.

Another participant described their reaction to negative feedback from a demonstrator:

> **Participant H:** "The demonstrators aren't the best. One of them is very sarcastic and he always makes me feel like I know nothing. He doesn't seem to know how to get down to your level. He don't explain things and they say you should know it from your notes. I always feel very stupid afterwards."

This participant is indicating how they are left with negative thoughts and beliefs about their ability after laboratory classes. Unlike some of the participants quoted above, this student does not seem able to counter these feelings by recourse to self-affirmation.

One participant expressed how they started to doubt their decision to study computer science when they tried to learn how to program on their own:

> **Participant I:** "I tried to teach myself how to program last summer. I found it really tough and I was really worried that I'd be bad at it and that I'd chosen the wrong course."

This student's sense of their aptitude for the domain has been eroded by their inability to learn how to program on their own. They lack confidence in their ability to program and seem unable to place this single setback into a wider context e.g. this may be the student's first attempt at independent self-study and they may not yet realise that computer science is not just about learning to program.

These negative self-affirmation influences are not only linked to the participants experience on their own; some reported how comments by others caused them to worry:

> **Participant J:** "My parents didn't really want me to study computer science. They didn't think I'd be good at it, so I was a bit worried at first."

This student's defensive bias is drawn from the value they place on the advice received from their parents. This is not surprising as the most persuasive domain of self-affirmation is personal relationships [31].

In the following quotation the participant explains how they rationalised their concerns about doing well in mathematics:

> **Participant K:** "In school I used to feel annoyed when I didn't do well. I don't think he was a very good teacher and I wasn't the only one who didn't like him; though some of the others got A1's. It was quite hard to focus to be honest. I knew I had to get a C in honours maths. That was really my main concern for the whole of sixth year, well for fifth year as well. I didn't think I'd get it. I was really, really concerned about it."

This participant is acting in a defensive manner, devaluing the ability of their teacher even though they admit that others in their class group had got very high grades. In order to make feel better the student places the blame on an external factor, in this case the teacher, so that they do not have to address any influential internal factors such as their preparation for the examination and the effort they put in throughout the year.

Self-affirmation is a well-established theory, however it is often used within the classroom in rather contrived, artifical ways. The representative quotations above provide real-world examples of how computer science students attitudes towards their studies are influenced by their engagement in self-affirmation. Educators seeking to help students who are feeling uncertain or discouraged can draw on these more practical self-affirmation techniques to help counteract their students' negative attitudes and beliefs.

VI. Conclusion

It is natural for people to wish to protect their personal sense of their self-worth and ability, for example, students are likely to become defensive when faced with evidence of negative academic performance. This can lead them to seek to place the blame on external factors e.g. examiner impartiality, rather than internal factors e.g. their own skill. This may give them a biased world view and restrict their ability to learn from their mistakes. Self-affirmation theory explains how a person's innate defensive mechanisms can be overcome when they affirm alternate sources of self-worth [35].

The effect of self-affirmation has been verified in rather contrived experiments where participants engage in self-affirmation by writing short essays about values that are important to them [9], [16]. More recently, studies have confirmed that people engage in self-affirmation in the creation of their social media profiles [42], [43].

This paper has explored self-affirmation from a different perspective; providing real-world evidence of self-affirmation in action, both at a conscious and sub-conscious level. In this study the participants' descriptions of how they engaged in a wide variety of forms of self-affirmation to help them overcome academic challenges and setbacks led to the emergence of self-affirmation as one of the key categories in the emergent grounded theory of learner perceptions of successful engagement in undergraduate computer science [18].

This paper is unique in its exploration of real-life engagement in self-affirmation and how this influences student perceptions of their own success. Consequently self-affirmation should form part of all future efforts to support and scaffold learning in computer science.

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Deciding to Stay: The Intersection of Sex and Race/Ethnicity

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***Abstract*— While much of prior research has focused on understanding the reasons students leave engineering, and therefore talk to those students who switched out of an engineering major, this study contributes the new perspective of students who seriously considered leaving but ultimately decided to stay in their engineering major. The qualitative analysis suggests that about one-third of students seriously considered leaving engineering but ultimately decided to stay. The reasons students decided to stay in engineering fell into eight main categories, with the most common reasons being the rewards that will come with an engineering degree; enjoyment of engineering; or an aversion to quitting or desire to prove that you can do it. Differences in rationales were discovered between males and females, between different race/ethnicity groups and at the intersection of sex and race/ethnicity.**

Keywords—retention; engineering; diversity

I. Introduction

Diversifying the engineering field continues to be a struggle. Improving the representation of engineering students from historically underrepresented race/ethnicity, sex, class, disability, groups etc., should yield greater diversity of thought in the field as a whole. Recent research has indicated that more diverse work teams produce better outcomes and are better problem solvers than teams of high ability that do not consider a diversity of perspectives [1-4]. As written by Professor Scott E. Page, "If people think alike then no matter how smart they are, they most likely will get stuck at the same locally optimal solutions. Finding new and better solutions, innovating, requires thinking differently. That's why diversity powers innovation" [5]. Increasing diversity in engineering as well as science, technology, and mathematics fields would drive technical innovation and improve U.S. chances to remain competitive.

Understanding the experiences of racial and ethnic minorities in engineering has been difficult because there are relatively few people from underrepresented groups in engineering. And as society becomes more diverse and multi-racial, we need to re-conceptualize prior ways of thinking about racial and ethnic identities. For example, only a little over a decade ago on the 2000 Census, the US Government finally began collecting and examining race/ethnicity with a multi-cultural perspective by allowing US Census respondents to indicate more than one race or ethnicity on the form.

One theoretical perspective suggests that people who share a common culture are part of a status group. Different status groups generally have different levels of status in the social order and different values and traditions [6,7]. Diverse undergraduate students in engineering may identify with multiple status groups. The context of student interactions and the context of engineering itself may result in certain aspects of student identities becoming temporarily more salient than others. An understanding of how status group values can impact the reasons students stay in engineering provides a new perspective to the field.

Research shows that undergraduate students regularly change their majors, and engineering students, in particular, often consider leaving the major for a different one. The reasons why students consider leaving but nevertheless decide to stay are relevant to understanding what can be done to keep students who are already in engineering. This paper will examine the following research questions:

- To what extent did students report that they considered leaving?
- For what reasons did students remain in their engineering major?
- Are certain factors more important for students from certain racial/ethnic and/or gender groups?

This exploratory analysis helps us understand what experiences and/or how status group values might result in students deciding to stay in engineering, enabling schools to focus on what works. This paper concentrates specifically on sex and race/ethnicity status groups. The research results from this qualitative analysis will ultimately contribute to the creation of a more inclusive engineering education environment for women and men of all races and ethnicities.

II. Background

A. How Status Groups Inform Our Understanding

When examining the experiences of students with different identities, an understanding of the role of status groups can help. Status groups are a unit of analysis used to denote groups of people who share a common culture, or a sense of status equality based on participation in the common culture [6,7]. Note, however, that status groups can be fluid and change based on circumstances [6].

According to Weber, status groups can come from differences in life situation due to positional power, in addition to other situations [7]. In engineering, it could be argued that men, in general, and White and Asian/Asian American men in particular, are the status group in control of engineering education. Status groups continually struggle for advantage, and the dominant groups' values become the de facto culture that non-dominant groups struggle against. This theoretical perspective suggests that students from non-dominant status groups (such as women, underrepresented minorities, students with disabilities, etc.) will experience the dominant status culture in different ways, and that students' perceptions of their experiences will be shaped by their own status culture values.

B. *Why Students Stay or Leave*

Much research in engineering education has focused on why students leave the field.

Student academic performance, particularly in freshman and sophomore gatekeeping courses, plays a key role in student persistence in engineering programs, particularly for students who experience difficulties in these classes [8-13]. Academic and social integration of college students has been found to contribute to student retention [14-17]. Formal and informal aspects of social life, including co-curricular activities and other personal interactions on campus, as well as formal and informal aspects of academic life, such as faculty-student learning interactions in and out of class, respectively influence social and academic integration [16-18].

Students who switch out of engineering majors tend to have less confidence in their study habits, enjoy studying engineering less than those who stay, and are less likely to believe that graduating with an engineering degree will guarantee them a career [8]. They express concerns about the kinds of work that will be available to them in engineering and the lifestyles of those careers [13]. The more confident students are that they will find engineering work satisfying and aligned with their interests and values, the greater their intentions to remain in engineering beyond graduation [19]. Many minority students, in particular, report strong feelings of obligation to serve and repay their communities for support received [13].

Ethnic minority students may face additional challenges, such as differences in ethnic/cultural values and socialization, internalization of negative stereotypes, ethnic isolation and perceptions of racism, and/or inadequate program support [13,20-22]. Many students of color face specific challenges as a result of being underrepresented minorities in engineering undergraduate programs. They may also lack peers, faculty role models and mentors [13,23].

Existing literature regarding student persistence in undergraduate engineering programs does not offer a lot of insight into the experiences of underrepresented groups, especially ethnic minority men and women.

III. Research Methods

This qualitative inquiry, which is part of a larger mixed methods research project funded by the Alfred P. Sloan Foundation, known as the Project to Assess Climate in Engineering (PACE), focuses on making sense of the realities and experiences of undergraduate engineering students using an interpretive perspective [24]. Qualitative interview approaches have been successful in elucidating the perspectives of STEM students from underrepresented groups [25-27].

A. *Sample*

In 2008 and 2009, currently enrolled engineering students 18 years of age or older were invited to participate in one-on-one interviews based on a stratified random sample. This project analyzed interviews with 116 undergraduate engineering students (63 women, 53 men, and 34 men and women from underrepresented race/ethnic groups.) An appropriate qualitative study sample size is one that sufficiently answers the research question(s) [28]. The analytic sample for this paper includes the 41 students who shared that they had seriously considered leaving engineering. Of the 41 students, 22 were women and 19 were men. In terms of ethnic breakdown, the number of students who self-identified as members of underrepresented groups ranged from two to eight, and those who identified as White made up the majority of participants. Students also represented various engineering program stages including first through fifth year. See Table I.

The students come from 13 US universities, ranging in size from 1,904 to 50,995 students, with an average enrollment of 24,682 students. Seventy percent are public universities, sixty-two percent are designated "very high research activity" under the Carnegie Classification, and eight percent are Minority-Serving Institutions.

B. *Procedures*

Semi-structured one-on-one interviews were conducted with participants to gain an understanding of student experiences in their own words, allowing the researchers and participants to engage in conversations with purpose (Merriam, 1998). These were conducted and audio-recorded at each participating institution by trained PACE research team members and consultants. Questions on the interview protocol that were useful in this analysis included: Have you ever considered leaving engineering? When? Why? What changed your mind? What motivates you to continue in engineering?

TABLE I. STUDY PARTICIPANTS

Race/Ethnicity	**Demographics**		
	Men	***Women***	***Yr. in School***
African American/Black	1	3	1^{st}(1), 3^{rd}(3)
American Indian	2	0	2^{nd}(1), 4^{th}(1)
Asian/Asian American	3	2	1^{st}(1), 3^{rd}(1), 4^{th}(3)
Asian Indian	1	2	1^{st}(1), 2^{nd}(1), 5^{th}(1)
Hispanic/Latino	3	5	1^{st}(3), 2^{nd}(2), 3^{rd}(2), 4^{th}(1)
White	9	10	1^{st}(1), 2nd(5), 3rd(1)), 4th(9), 5^{th}(3)

This work was made possible by a grant from the Alfred P. Sloan Foundation.

C. Analysis

Data analysis, using NVivo 9 qualitative data analysis software, utilized a combination of both open and focused coding methods [29]. Research questions provided a lens for the notation of ideas and themes, as well as for code generation [29]. This led to organizing and grouping data by theme and relationship to other data, moving from general to specific themes and vice versa, in order to understand the phenomenon being studied [30]. Throughout the process, we looked for patterns, themes, and regularities, along with contrasts, paradoxes and irregularities. Data displays were enlisted for organizing and exploring the data [30,31]. Analytic memo writing was used during the analytic process to help interrogate, systematically explore, and make sense of the data [30].

IV. FINDINGS

This section moves from general result descriptions to increasing disaggregation of the results by sex and race/ethnicity in order to provide context for the more specific findings. The findings described below are organized into four main sections: overall results (trends for all students who seriously considered leaving, but decided to stay), differences by sex, and by race/ethnicity, and intersections of sex and race/ethnicity. While percentages are used to indicate trends in the data, keep in mind that the percentages are based on relatively small numbers.

A. Overall Results

Of the total 116 currently enrolled engineering undergraduate students interviewed for the larger PACE study, 41 (35%) indicated that they seriously considered leaving engineering. A total of 36% of the men and 35% of the women had seriously considered leaving, which demonstrates very little gender difference within our qualitative sample. However, greater differences were seen among racial/ethnic groups. In order of ascending prevalence, the percentage of each group to seriously consider leaving is: 31% of Whites, 36% of African American/Blacks, 38% of Asians/Asian Americans, 40% of Hispanics/Latinos, 50% of Asian Indians, and 66% of American Indians.

Students were motivated to continue in their engineering programs for multiple reasons, including: the rewards of an engineering degree [Rewards of Degree], enjoyment and/or interest in engineering [Enjoyment of Engineering], aversion to quitting or proving they can do it [Aversion to Quitting/Prove Can Do It], adjusting and realizing it gets better [Adjusting/It Gets Better], the support and encouragement of friends and family[Friends/Family], alternative options were less or not at all appealing [Alternative Options Less Appealing], and co-op and/or internship experiences [Co-op/Internship Experience]. In total, 90% of participants described two or more reasons for staying and 39% described three or more reasons. This results in a multifaceted understanding of student reasons. See Table II.

TABLE II. REASONS FOR STAYING IN ENGINEERING, BY SEX

Reasons	Prevalence of Reasons		
	Total (out of 41)	***Women (out of 22)***	***Men (out of 19)***
Rewards of Degree	31 (76%)	19 (86%)	12 (63%)
Enjoyment of Engineering	18 (44%)	8 (36%)	10 (53%)
Aversion to Quitting/ Prove Can Do It	14 (34%)	9 (41%)	5 (26%)
Came This Far/Too Late to Turn Back	12 (29%)	7 (32%)	5 (26%)
Adjusting/It Gets Better	10 (24%)	6 (27%)	4 (21%)
Friends/Family	8 (20%)	6 (27%)	3 (16%)
Alternative Options Less Appealing	7 (17%)	6 (27%)	1 (5%)
Co-op/Internship Experience	5 (12%)	4 (18%)	1 (5%)

The most common reason for staying in engineering (indicated by 76% of participants) was that an engineering degree had a lot to offer students [Rewards of Degree], including helping students realize their career goals, contribute something important to society, prepare for many different careers, as well as provide good job prospects, job security, salary, and a sense of pride.

The second most common reason for staying in engineering (indicated by 44% of participants) was the enjoyment of and interest in engineering [Enjoyment of Engineering]. Students described deriving gratification from solving puzzles, fixing things, working with materials, applying science and math, and learning new material. These students see engineering as a field one could never get bored in, given the many interesting possibilities. The third most common motivator expressed by students (34% of participants) was an aversion to quitting or a desire to prove they could make it through engineering and earn a degree [Aversion to Quitting/Prove can do it]. This points to a more negative rationale for making the decision to stay in engineering.

B. Differences by Sex

When the responses are examined by sex, the most common motivator is still Rewards of Degree for both men (63%) and women (86%). However, women were more likely to indicate this than men (Table II). Men also described motivation to stay in engineering due to Enjoyment of Engineering (53%), as this Hispanic/Latino man explains: *Despite the difficulty of a lot of my classes, I actually enjoy it. I enjoy learning, doing it, actually performing and seeing it. What makes me also is as an engineer I can be a more impact to society. One of my biggest goals is to help make change…I really want to be an influence for good in the world, so that is why I want to be an engineer.* A total of 58% of all men indicated one of these two factors; the other reasons for staying were much less frequently indicated among men.

Women provided a more multifaceted view of the reasons they stay in engineering, with the least common reason (Co-op/Internship Experience) still expressed by 18%. This White woman's comment offers an example:

Freshman year, I think I almost left five times, but each time the new major I thought of, I didn't really want either. [I] kept thinking I'd change my mind, but there's nothing else I wanted more than engineering, [so] I just kept staying in it…And then once I got a job in engineering too, like an internship, I ended up liking that a lot. I don't really like the classes in school very much, but I did like the internship…So it [was] like, well if I get through classes, I can find a job that I really like in engineering, so I might as well stick through these torturous classes and everything and then I might really enjoy what I'm doing afterwards, so it makes it worth it. [What motivates me to continue in engineering] I guess [is] just to get through it. I'll graduate in less than a year, so it's just like you just do the homework and do the classes and just finish it and then you'll graduate and move on. I mean, it's not that bad sometimes, but also it's bad. I do really like the kids though, so that really helps. Makes it fun.

Unlike the men, women's second most frequently indicated reason for staying in engineering was Aversion to Quitting/ Prove Can Do It (41%). The majority of women (55%) described three to five motivators for staying in engineering, 45% provided two reasons, and no women had fewer than two reasons. On the other hand, 21% of men indicated three to four motivations for staying and another 21% talked about only one reason for staying, while no men offered more than four reasons.

C. Differences by Race/Ethnicity

Looking at distinctions by ethnicity, Rewards of Degree still stands out as the most common factor motivating students to stay in engineering for most groups. Exceptions include American Indian students, who indicated Enjoyment of Engineering with similar frequency to Rewards of Degree. Asian Indian students expressed Aversion to Quitting/Prove Can Do It just as commonly as they indicated Rewards of Degree. Different from all other groups, Asian/Asian American students' most common response (60%) was Alternative Options Less Appealing. See Table III.

Additional distinctions emerge when we look beyond the most common motivators. For example, the second most common reason expressed by African American/Black students (3 out of 4) was Came This Far/Too Late to Turn Back. Whereas half of Hispanic/Latino students' indicated both Enjoyment of Engineering and Aversion to Quitting/Prove Can Do It, second in prevalence to Rewards of Degree. The second most common reason for Asian/Asian American students (indicated by 40%) reflects one of the most common reasons for other groups, Rewards of Degree. In the case of White students, 10 out of 19 discussed Enjoyment of Engineering, making this their second most common response.

TABLE III. REASONS FOR STAYING IN ENGINEERING, BY RACE/ETHNICITY

Reasons	**Prevalence of Reasons**					
	African American/ Black (out of 4)	***American Indian (out of 2)***	***Asian/ Asian American (out of 5)***	***Asian Indian (out of 3)***	***Hispanic/ Latino (out of 8)***	***White (out of 19)***
Rewards of Degree	100%	100%	40%	67%	88%	74%
Enjoyment of Engineering	0%	100%	20%	33%	50%	53%
Aversion to Quitting/ Prove Can Do It	0%	50%	20%	67%	50%	32%
Came This Far/Too Late to Turn Back	75%	50%	20%	33%	25%	21%
Adjusting/It Gets Better	50%	0%	0%	0%	25%	32%
Friends/ Family	25%	0%	20%	0%	25%	26%
Alternative Options Less Appealing	0%	0%	60%	0%	0%	21%
Co-op/ Internship Experience	0%	0%	20%	0%	0%	21%

D. Intersections of Sex and Race/Ethnicity

Looking at how ethnicity and sex intersect sheds light on some additional distinctions among students. In addition to Rewards of Degree, all three African American/Black women indicated Came This Far/Too Late to Turn Back, which led them to decide they may as well finish their engineering programs. In contrast, in addition to Rewards of Degree, the one African American/Black man reported that Adjusting/It Gets Better played a key role in his decision to stay:

I guess I wasn't so ready for the level of work, so it took a while to get adjusted. That's been probably the only issues -- like believing that I can actually do this stuff…I guess after my first semester; after my initial shock of -- seeing college is not too bad. I picked up the studying, so I kind of knew what I had to do to get good grades. [I] felt a little more confident…You always hear that engineers make more money coming out of college; they're more likely to get jobs. So, I figure if you're going to go to school for four years you might as well make the best out of it [because] I know in the long run I have a whole life ahead of me, so that makes all the big difference

The second most common reasons given by Hispanic/Latina women as to what motivates them to continue in engineering remained the same as the whole group -- Enjoyment of Engineering and Aversion to Quitting/Prove Can Do It. The third most common motivators for Hispanic/Latina women were: Came This Far/Too Late to Turn Back and Friends/Family. In contrast, Hispanic/Latino men's second most common reasons were spread evenly across three reasons: Enjoyment of Engineering, Aversion to Quitting/Prove Can Do It, and Adjusting/It Gets Better.

Responses from Asian/Asian American women were distinct from Asian/Asian American men in that their most common response reflected the overall group [Alternative Options Less Appealing], while men's responses were spread evenly across multiple responses. For example, this Asian/Asian American woman described her motivation this way: *Well, I can't really think of what else I would want to do. So, that was probably a factor. I do feel accomplished when I do well in a class or feel like I'm learning. So, at least I'm learning. Because I've taken just general, like literature or science arts classes, LSA classes and it's just a lot more boring. I'd rather be doing engineering.*

Finally, White student responses also differed by sex. Both Rewards of Degree and Enjoyment of Engineering were expressed by the same number of White men. While White women's second most common response reflected that of women overall [Aversion to Quitting/Prove Can Do It], the next most common responses varied. In this case, the third most common responses expressed by White women were: Alternative Options Less Appealing, Enjoyment of Engineering, Adjusting/It Gets Better, and Co-op/Internship Experience as reasons for staying in engineering. Following closely behind is being motivated by Friends/Family. Interestingly, only one White woman mentioned Came This Far/Too Late to Turn Back as a reason for staying.

Very few distinctions were found among Asian Indian students when we examined the disaggregated trends by sex and race/ethnicity.

V. Conclusion

This qualitative analysis expands current research on retention and attrition, and the results ultimately can contribute to the creation of a more inclusive engineering education environment for women and men of all races and ethnicities. While much of prior research has focused on understanding the reasons students leave engineering, and therefore talk to those students who switched out of an engineering major, this study contributes the new perspective of students who seriously considered leaving but who ultimately decided to stay in their engineering major. This presents important information for institutions offering engineering degrees that can help them better serve and retain a diverse population of undergraduates.

The data indicated that of the total 116 currently enrolled engineering undergraduate students interviewed for the larger PACE study, 41 (35%) had seriously considered leaving engineering. While distinctions between gender groups were negligible, notable is the high prevalence for considering leaving among certain ethnic groups. However, all forty-one students expressed determination to complete their degree, identifying various reasons for staying. Eight different themes emerged from the analysis of students' reasons for staying in engineering despite having seriously considered leaving Institutions could benefit from considering how to address these various factors to contribute to increased retention, by emphasizing and reiterating the rewards of an engineering degree, providing support for students to learn about what is involved in pursuing an engineering degree and adjusting accordingly.

While Rewards of Degree stood out as the most common motivator overall, certain factors were more salient and certain patterns emerged for students from particular gender and/or racial/ethnic groups. For example, more men (53%) than women (36%) indicated that Enjoyment of Engineering motivated them to continue (second most common response from men); whereas more women (41%) than men (26%) reported Aversion to Quitting/Prove Can Do It (second most common response from women) as a reason to stay. As members of the dominant status culture, men may not feel the same need to prove themselves that women do, accounting for the difference examined above. In some ways, since men lack the daily struggle against the dominant culture, they can stay for reasons such as the love of engineering work, rather than a more negative orientation such as an aversion to quitting or desire to prove oneself. This signifies that until there is a massive culture shift in engineering overall, as well as within specific engineering departments, women will likely continue to express less intrinsic motivation for staying in engineering.

Women also conveyed a more multifaceted view of the reasons they stay in engineering, with the majority describing three to five motivators for staying. Not even a quarter of men, on the other hand, indicated three to four reasons for staying, and no men mentioned more than four reasons, implying a more straightforward process for making the decision to stay in engineering. Could it be that the more barriers a status group has to overcome, the more complex their stories become about why they stayed in engineering? For women, there are many more barriers to staying in engineering, resulting in complex descriptions of what kept them in the major. This speaks to the need for institutions to examine the various barriers that may be facing women at their particular schools and develop means for addressing and reducing them to better support women.

The Aversion to Quitting/Prove Can Do It theme illustrates how contrasting viewpoints could potentially result in differential workforce outcomes. Some of the reasons in this category tended toward a more negative-orientation, such as students not wanting to be a 'quitter', being raised to finish what they started, and not wanting to 'fail' at something. Others indicated more of a survivor instinct, like realizing that getting through this meant they could get through anything, wanting to prove that women could be engineers, or expressing a desire to challenge oneself. While the latter indicates more of an aspiration to continue in the field and pursue the goal of becoming an engineer, despite the barriers, the former could portend that a student may actually leave the field after graduation and not pursue an engineering career. This illuminates how seemingly minor distinctions in student perspectives could potentially result in very different outcomes. If institutions could identify students likely to graduate yet not likely to pursue an engineering career, they could then create interventions specific to the needs of these students. This could result in a wider range of individuals pursuing engineering careers, which could positively impact the field overall.

Student rationales for staying differed quite a bit by race/ethnicity and some distinctions become even more pronounced when looking at how race/ethnicity and sex intersect. For example, African American/Black women and men's second most common motivators both reflect some level of struggle, yet there is a somewhat different orientation towards this struggle for women than for men. African American/Black women indicated Came This Far/Too Late to Turn Back. This reason, which for all three female African American/Black engineers was combined with Rewards of Degree as motivation to stay, implies a somewhat negative or unhappy experience yet a strong 'eyes on the prize' orientation. The one African American/Black man also indicated an orientation toward the 'prize' of Rewards of Degree; however, his stance toward his experience was framed more positively in that he talked about Adjusting/It Gets Better.

Much like with women in general, this could signify that African American/Black women face additional barriers compared to African American/Black men, and as such have a harder time adjusting and feeling like things get better. Conducting additional research focused specifically on African American/Black women, or both African American/Black women and men, could help unpack this phenomenon to not only determine what additional barriers these women may face, but contribute to potential strategies for reducing them.

Two of the three Hispanic/Latina women described really liking the challenge of engineering, which fits into the theme Aversion to Quitting/Prove Can Do It, and these same two women also described Enjoyment of Engineering. The one Hispanic/Latina woman who discussed her reason for staying as more akin to an aversion to quitting (rather than proving oneself), did not describe Enjoyment of Engineering as a reason for staying. This could indicate that this student faced additional barriers or different barriers which negatively impacted her experience and detracted from her enjoyment. Delving deeper into Hispanic/Latino and other underrepresented student experiences could help explicate impacts on student attitudes, persistence, and decisions to pursue engineering careers.

The fact that the most common rationale for Asian/Asian American students was Alternative Options Less Appealing feeds into some stereotypes around the push for Asians/Asian Americans to achieve in a science or engineering field. For example, one Asian/Asian American male described being motivated because: *I'm good at it, I can't find anything else that I'd be equally as good at, or that would satisfy – or that would bring me to my goals to where I wish to be in life.* Interestingly, this remained the most common response among Asian/Asian American women, whereas Asian/Asian American men's responses spread evenly across multiple reasons. The results indicate that Asian/Asian American students likely bring their own racial/ethnic status culture values into engineering, as evidenced by their different primary reasons for staying compared to other racial/ethnic groups.

The significance of the multifaceted reasons for staying in engineering among White women (versus White men) should be considered in more detail. For example, how do different combinations of responses help us understand a higher-order rationale for staying in engineering? Further, how can institutions respond to these differences and better support women and encourage them not only to persist in engineering programs, but also pursue careers in engineering?

The differences described above highlight complexities that can exist for students when deciding whether or not to stay in engineering. This work also builds upon prior research. For example, the importance of academic integration for retention is echoed in this study, particularly for students who described needing time to adjust and that things got better for them as time went along [14,16]. Burtner's findings are highlighted here in that the rewards of an engineering degree, including the likelihood of a stable, lucrative career are in the forefront of most students' minds when thinking about what motivated them to stay in engineering [8]. This African American/Black female highlights these points:

Okay, so part of [what motivates me to continue is] that I don't really have very much longer to go; I only have two more semesters. It just doesn't make sense to me to switch out at this point, because you definitely can't get another degree in two semesters. And I think I've sort of found my place in the department; I've created my group of study friends, and found my mentor, and I'm doing research that I like to do, and sort of becoming a little more active in the department…it's just become a little bit more friendly to me. I feel like it's a large department; we have 150 students in my graduating class. So I think it would be really easy to just fade into the background. But now that I'm feeling like there are a few people in the department who I actually have a connection to I'm enjoying it more. And it's also really cool that in these classes we're starting to reference material from previous classes, so everything is being put in perspective.

Differences among gender and racial/ethnic groups, as well as among different gendered racial/ethnic groups, point to the need for differentiated support for engineering students. They also elucidate distinctions among underrepresented groups, and the need to recognize groups as distinct, versus treating them as one subset of engineering students, and addressing their issues through this broad lens. Additional research focused on developing a deeper understanding of the distinct experiences of underrepresented student groups is much needed.

This exploratory analysis helps us understand what experiences or how status group values might result in students deciding to stay in engineering, enabling schools to focus on what works. Analysis for this paper indicated the complexity of student responses regarding what motivates them to stay in engineering. However, there is more work to be done in examining the combinations of reasons that students gave, with an eye toward understanding how multiple reasons given by a student can create a full-bodied picture of that student's motivation for staying in engineering.

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Examining the Correlation between Religion and Social Responsibility in Engineering

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***Abstract*— The development of social responsibility, both personally and professionally, is critical in the movement toward developing more holistic engineers, as called for by many professional engineering societies to address the complex problems that face our society. This paper presents correlations between engineering students' religious beliefs and their views of personal and professional social responsibility. Data were gathered from 895 engineering respondents to the Engineering Professional Responsibility Assessment tool and from 25 semi-structure interviews with engineering students. It was found that students who considered themselves 'very active' in their religious preference had stronger beliefs of their ability and personal obligation to help others, and in a professional sense of obligation to help others as engineers.**

Keywords—Social Responsibility, Service, Religion, Spirituality, Ethics, Morality, Engineering Identity

I. Introduction

The relationship between individuals' spirituality and higher education is complex, and is a subject that is largely avoided, especially in engineering. Many professional engineering societies, however, are calling for the development of more holistic engineers [1], including skills such as "consideration of others, respect, sensitivity, thoughtfulness, thoroughness, and tolerance" [2, p. 172]. For some students these skills and how they see themselves as engineers is rooted in their religious beliefs, especially how they view their social, ethical, and moral responsibilities as an engineer. Examining the correlation between students' religious beliefs and their views of personal and professional social responsibility starts the conversation for what role engineering educators can play towards developing more holistic engineers.

The term 'social responsibility' has been used in many different ways in engineering education research. Studies use this term to focus on civic duty [3], the development of democratic views [4], cheating [5] or social considerations which are critical for engineers to consider [6]. For this study, social responsibility is seen as an obligation to be aware of the impacts of engineering work on others and to see engineering problems from the perspectives of others, with special consideration for underserved populations [7]. Because this perspective of social responsibility focuses on objectivity, or the ability to step outside of one's self to see issues from another's perspective [7, 8], religious views are an interesting element to examine when looking at the development of social responsibility in engineering students as many religions challenge their members to adopt similar foundational perspectives.

There have been, however, very few studies which have looked specifically at the relationship between engineering and religious beliefs. Beyond engineering, several studies have recently looked at the role of spirituality in the college experiences of students. Some point to an increased number of students engaging in spiritual or religious practices in college [9, 10]. With respect to the role of the institution in student spirituality, the National Study of College Students' Search for Meaning and Purpose found that "educational experiences and practices that promote spiritual development – especially service learning, interdisciplinary courses, study abroad, self-reflection, and meditation – have uniformly positive effects on traditional college outcomes" [11]. Findings from the 2012 National Survey of Student Engagement showed that 31% of seniors across all disciplines (n=327,946) felt that their institution contributed to their developing a deepening sense of spirituality 'quite a bit' or 'very much', while only 20% of engineers (n=20,012) said the same [12]. Correlations between volunteerism and religiosity have been mixed [13, 14], but studies have correlated institutional religious affiliation with gains in students' ethical development [15].

Connections between engineering and religious beliefs can be seen by looking at some religiously affiliated institutions. George Fox University advertises that they "prepare technically competent and broadly educated engineers for a life of responsible service emerging from a Christian worldview" [16]. The mission statement of the College of Engineering at the University of Notre Dame states:

"Consistent with the University's Catholic mission and heritage, the College of Engineering's mission is founded on the principle that the creation and transfer of knowledge should reflect a profound and complete respect for the dignity of all persons and for the greater common good of humanity… To that end, the college will continue to engage

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in transformational research in its core competencies… as they address the important needs of humanity, while inspiring students of all levels to scholarship and service" [17]

Several non-profit organizations also work to establish strong connections between one's religious identity and their engineering abilities. Engineering Missionaries International and Global Appropriate Technology Ministries are two which help facilitate "discipline-specific service" through a lens of using ones' gifts from God to serve those who are less fortunate. For those who hold those religious perspectives, the connection between the personal and professional can become seamless, critically informing that individual's engineering identity.

Because the connections between religious or spiritual beliefs and engineering identity can be strong for some individuals, it is important examine those relationship, especially when considering the development of holistic engineers. This study seeks to examine those correlations in engineering students. Specifically, to see how one's religious or spiritual preference plays a role in their views of personal and professional social responsibility in engineering.

II. METHODS

A. Survey Tool

The Engineering Professional Responsibility Assessment (EPRA) survey was developed to gauge students' attitudes and beliefs regarding personal and professional responsibility based upon the Professional Social Responsibility Development Model [7]. EPRA consists of 49 7-point Likert questions (Strongly Disagree to Strongly Agree), questions about the importance of different job attributes, motivations and limitations for engaging in community service, previous volunteer experiences, and demographic information. Students are also asked, in an open box question, to describe any other life experiences that had influenced their beliefs of community service and social responsibility. Reliability and validity are in the process of being established for the EPRA tool.

EPRA was developed to address three realms for the development of personal and professional social responsibility: Personal Social Awareness, Professional Development, and Professional Connectedness (which is a combination of the previous two). The Personal Social Awareness realm is rooted in Schwartz's model for the development of altruistic behavior [18]. This realm consists of three construct (Awareness, Ability, and Connectedness) which describe 1) recognition that there are others that need help, 2) recognition of one's ability to help, and 3) a feeling of moral or social obligation to help others, respectively. The Professional Development realm also consists of three constructs (Base Skills, Professional Ability, and Analyze) and draws from a combination of Schwartz and from Ramsey's model which incorporates social considerations into the scientific process [19, 20]. Base Skills (Base) construct addresses student views of the importance of both technical and professional skills in engineering, while Professional Ability (ProfAb) and Analyze describe a recognition that engineers or the engineering profession has the ability to help others and a recognition of the importance to including social aspects into the engineering process, respectively. The third realm, Professional Connectedness, consists of two constructs – Professional Connectedness (ProfCon) and Costs/Benefits (CB). This realm is cyclical whereby an individual weighs the costs and benefits of engaging in actions of service based upon their prior beliefs of the moral or social obligation to help as a professional. Based upon acting (or not) an individual's beliefs of obligation deepen (or not) and the cycle begins again. This realm draws from both Schwartz and Ramsey, and also from Delve et al.'s Service Learning Model which describes the deepening internalization of social issues through engagement [21]. Data from EPRA were examined through participant average scores for each of these eight constructs.

EPRA has evolved through pilot studies conducted at the University of Colorado Boulder. Through student feedback in the open box responses, it became apparent that religion was a significant influence for some students; therefore the demographic questions about religious preference were added into the final version. The specific wording for the four religious preferences was piloted on a group of engineering and non-engineering students and alumni before going out as part of the larger survey.

B. Survey Participants

As part of a larger study, the EPRA tool was distributed to engineering students at five different institutions in the Fall 2012 semester. The data from this distribution was used for this paper. Institutional characteristics for each university are provided in Table I. The survey was electronically distributed to first-year, senior and graduate students in Civil, Mechanical, and Environmental Engineering, with a $5 incentive for completion (except at one school, were incentives were not permitted). Each survey was open for three weeks at the beginning of the semester. In total, 895 students completed at least 90% of the survey. The Likert data were considered as ordinal data and averages and two-tailed pair t-tests were used to examine the significance of the differences of means [22, 23]. Student responses to the open ended question about other influences on their views of social responsibility were also examined using a mixture of emergent and *a priori* coding, guided by the study research questions.

C. Student Interviews

In addition to the EPRA results, data from 25 interviews with engineering students was used. These interviews were semi-structured and lasted 30 to 60 minutes and were conducted concurrent with the pilot study of EPRA and before the EPRA distribution used for this paper. Interviews

TABLE I. INSTITUTIONAL CHARACHTERISTICS

ID	Control	Carnegie Classification
School A	Public	High undergraduate, large 4-yr, primarily nonresidential, RU/VH
School B	Public	High undergraduate, Medium 4-yr, primarily residential, RU/H
School C	Private not-for-profit	Majority undergraduate, Medium 4-yr, highly residential, RU/VH
School D	Public	High undergraduate, Large 4-yr, highly residential, RU/H
School E	Military Academy	Exclusively undergraduate, Medium 4-yr, highly residential, Bac/A&S

were recorded, transcribed, and analyzed using emergent thematic coding techniques [24]. Students were consented prior to each interview, consistent with IRB protocols. The majority of interview participants were senior and graduate students in Mechanical, Civil and Environmental Engineering. One of the participants was a junior student in Civil engineering and another was a graduate student in Aerospace Engineering. Ten of the participants were females. Interview questions focused on why students chose engineering as a major, what their career aspirations were, how they saw engineering interacting with society, how they defined social responsibility, and which life experiences formed the foundation of their views.

III. RESULTS & DISCUSSION

A. Survey Results

At the end of the survey, students were asked a series of demographic information, including their religious preference. Response numbers for each of the five religious preference options are given in Table II. If they chose "religious, affiliated with an organized religion" then they were prompted to say how active they considered themselves to be in the practice of their religious preference ('very active', 'somewhat active', 'not very active', or 'not active').

Response rates by demographic are shown in Table III. Distributions were similar across female and male students.

TABLE II. RESPONSE NUMBERS FOR RELIGIOUS PREFERENCE

Religious Preference	Response Rates	
	N	*%*
Religious, affiliated with an organized religion (i.e. Christian, Muslim, Jewish, Hindu, Buddhist, etc.)	387	43
Spiritual but not affiliated with an organized religion (i.e. Humanist, Agnostic, etc.)	130	15
Atheist	105	12
Indifferent or not religious	226	25
Prefer not to say	47	5

More Civil and Mechanical engineers considered themselves 'religious' (47% and 46%, respectively) compared to Environmental engineers (32%). Environmental engineers reported as being more 'indifferent' and 'spiritual' than Civil or Mechanical students. Schools B and E both had significantly higher number of students reporting that they were 'religious' (67% and 70%, respectively) than the other three schools (A-34%, C-34%, and D-25%). We hypothesize that the military nature of School E is correlated with a more traditionally religious population of students.

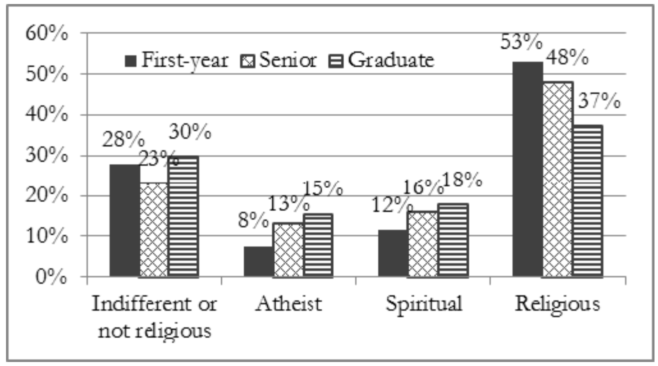

Fig. 1 Religious preference response rates by academic rank

Fig. 1 shows the distribution of religious preferences by academic rank. It is interesting to note that the percentage of students who say they are 'religious' decreases from first-year students, to seniors and graduate students. This could be due to first-year students still having strong affiliation with their parents' religion, while the students who are further along in their schooling have formed their own identity, straying from their familial influences. This is interesting when considering how schools affect religious formation. Traditionally, the standard practice is for universities to be 'hands off' when it comes to personal

TABLE III. RESPONSE NUMBERS FOR RELIGIOUS PREFERENCE BY DEMOGRAPHIC SPLIT

Demographic	Religious Preference			
	Religious	*Spiritual*	*Atheist*	*Indifferent or not religious*
Male (n=563)	44%	14%	15%	27%
Female (n=280)	48%	18%	7%	27%
Civil Engr. (n=227)	50%	13%	11%	26%
Mechanical Engr. (n=407)	49%	15%	14%	23%
Environmental Engr. (n=156)	34%	21%	12%	33%
School A (n=292)	34%	20%	16%	30%
School B (n=276)	67%	9%	8%	16%
School C (n=138)	34%	16%	16%	34%
School D (n=96)	25%	21%	11%	43%
School E (n=46)	70%	13%	7%	11%

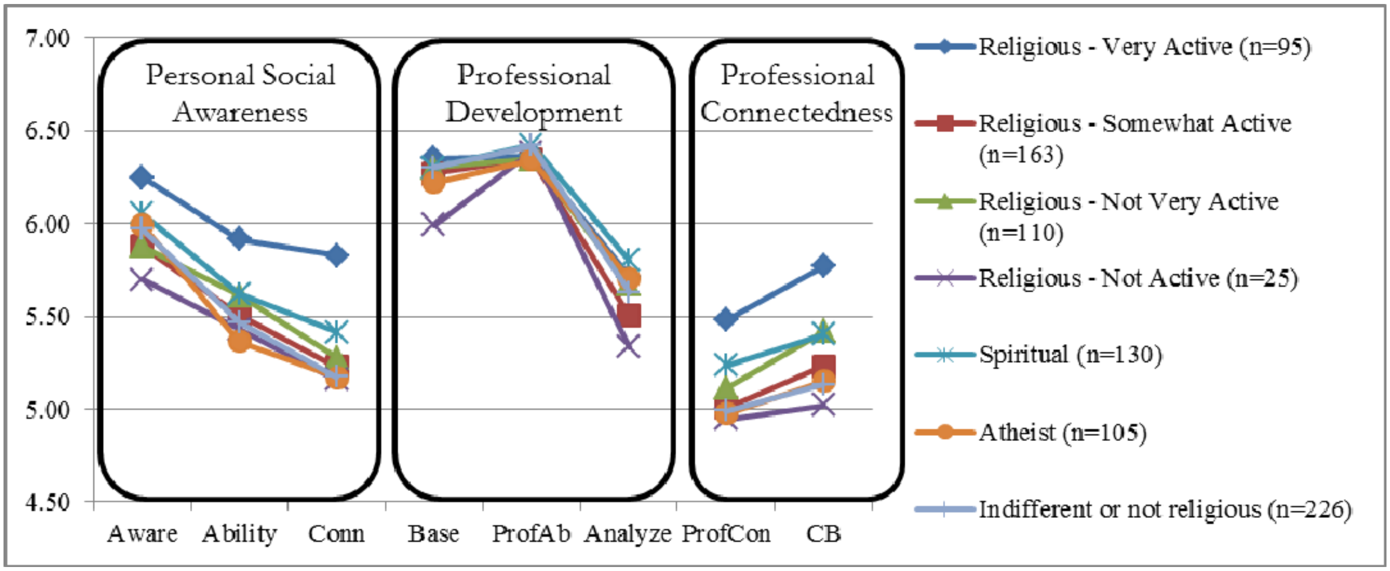

Fig. 2 Construct Averages by Religious Preference and Activeness

religious preferences, which could explain why students tend to disassociate with formal religious beliefs as they progress through college.

Of the 387 students who responded as ‘religious’, the distribution was as follows: ‘very active’ – 95, ‘somewhat active’ – 163, ‘not very active’ – 110, ‘not active’ – 25, ‘prefer not to say’ – 8. As seen in Fig. 2, those who reported that they were active in their religious preference had significantly higher construct averages than all other religious activeness as well as those who responded as ‘spiritual’, ‘Atheist’ or ‘indifferent’ in all Personal Social Awareness and Professional Connectedness constructs (significance determined with two-tailed t-tests, $p<0.05$). These two realms deal with issues of awareness of those in need and feelings of personal and professional obligation to help them. All groups were similar in the Professional Development realm (with the exception of Base Skills for ‘Religious – Not Active’, which is lower), suggesting that views of the engineering profession are not influenced by religious preference, until ideas of moral or social obligation are considered (ProfCon).

Similarly to religious preference, students were asked to share what elements motivated them to engage in community service from a prescribed list. The list included options such as “to meet new people”, “to build my resume”, “to help others”, “for an international experience (to travel)” and “because of my religious beliefs.” Fig. 3 presents construct averages based upon if “because of my religious beliefs” was checked as a motivation or not. Similar to the ‘Religious-very active’ group, those who were motivated by their religious beliefs (n=174) had significantly higher construct average in the Personal Social Awareness and Professional Connectedness realms ($p<0.05$). The majority (90%) of the respondents who checked this box also reported that they were religious, 80% were ‘very’ or ‘somewhat active’, so religious activeness was a confounding factor with participant motivation by religious beliefs.

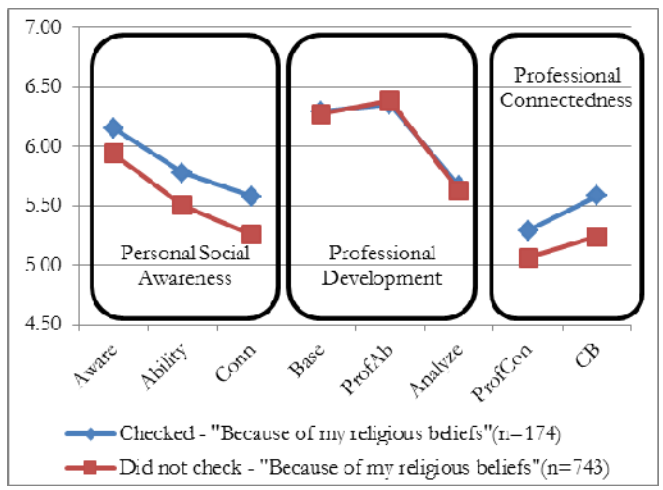

Fig. 3 Construct Averages by Motivation "Because of Religious Beliefs"

Using student responses to the short answer open box question about any other life experiences that had influenced views of social responsibility, 79 of the 730 responses included a reference to religious or spiritual practices. The majority of these 79 comments related to being raised in a certain faith, going on mission trips, volunteering through church activities, or going to religious primary or secondary schools. One student wrote directly, “my Christian faith prompts me to serve others.” Another student wrote in more detail about how their religious perspective influenced their views of obligation, saying “I also volunteer regularly for services within my church, and my experiences there have strongly implanted in me that it is my moral and spiritual duty to serve others, be they more or less fortunate than myself.”

Of those students who wrote a response relating to religion, 78% reported that they were religious and 41% of those were 'very active.' Therefore, of the 95 students who said that they were very active in their religious preference, nearly one third volunteered information about their religious preference as an influence to their views on community service and social responsibility. From the other three activeness levels for those who reported themselves as religious, only 28 (out of 298) mentioned something relating to religion in their open response. While there is no evidence of causation in the Likert data, some students do directly relate their high social responsibility to their religion in the short answers. This supports the notion that for some students, their religious preference plays a central role in the development of personal and professional social responsibility and the view of themselves as engineers.

Similar to previous studies, there was little correlation between students' religious preference and their engagement in volunteer activities, except for 'short term on-site service trips'. Given the majority of the write-in responses associated with religion, this difference is probably because of mission trips associated with religious organizations.

B. *Student Interviews*

Twenty-five students were interviewed as part of the larger study, focused on the development of social responsibility. The interviews were never designed to address religion, but seven students did talk about religion or spirituality, mostly when talking about influences to their foundational beliefs about personal and professional social responsibility. One student said about influences in his life:

"I guess the main thing probably would be just my family. My family's Lutheran, so just as a kid we were constantly doing things through church groups and doing community service that way… So, those values (of service) are kind of instilled in me, I guess, just because of the way that I was raised. So I feel like I just kind of want to now continue that because I've seen how rewarding it can be."

Here this student is pointing to his religious upbringing as instilling values of service in him that he has carried into his adult life. This student also talked significantly about how the engineering professional should take on pro bono work and that, while not required, service was an obligation of professional engineers. For this student, the values from his upbringing tied to his professional views, whereby if you have the ability and skills, you should help others. Several other students talked about how their views of social responsibility were influenced by their religious upbringing. One student talked about how she found peace at her church and often retreated there to escape the stresses of school and her mechanical engineering program. Perhaps if it had been asked explicitly, there would be more data regarding the ways in which students' religious preferences affected their views of themselves as engineers, but these seven students point to that relationship by their responses. More targeted interviews would be useful to further explore this connection.

IV. CONCLUSION

This paper presents exploratory findings that relate students' religious beliefs to their attitudes towards personal and professional social responsibility in engineering. For some students, their religious preferences relate to their views, and affect the ways in which they see themselves as engineers in society. The number of students who reported that they were 'religious' decreased with higher academic ranks, suggesting that views are changing through college away from organized religions. Also, students who reported that they were 'very active' in their religious preference had significantly higher construct averages with respect to Personal Social Awareness and Professional Connectedness than all other students. There were, however, very few differences in volunteerism based upon religious preferences, aligning with what previous studies had found.

While it is difficult to know the role that the engineering educational system should play in students' religious or spiritual development, it is clear that, when looking at issues of ethical and moral obligations for engineers, religious preference must be considered. Traditionally universities and engineering departments stay clear of religious issues in the classroom, but perhaps there is a place for engineering instructors to build upon students' existing foundational beliefs, including religion, to develop more aware, ethical, and moral engineers for the future. Hopefully, this study opens the door for other investigations into how religion and spirituality play into engineering identity and the social responsibility of the engineering profession.

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An Examination of Students' Motivation in Engineering Service Courses

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***Abstract*—To increase the number of science, technology, engineering, and mathematics (STEM) graduates, educators need to identify ways to increase student persistence from entry until graduation. The objectives of this study are to determine (1) if motivation affects learning outcomes in engineering service courses and (2) whether students' level of motivation tracks with specific engineering disciplines. Students enrolled in a sophomore-level engineering service course were surveyed to examine their motivation in engineering service courses and to assess the relationship between their motivation and their achievement and desire to persist in the engineering discipline. The survey measures for self-efficacy, task value, and achievement goals in engineering were created and evaluated during an initial pilot study. Initial results showed internal consistency among the items in each measure.**

***Keywords*—student motivation; self-efficacy; task value; achievement goal; academic achievement; intentions to persist; engineering service course**

I. Introduction

Attrition of undergraduate students in engineering programs is at its highest level during the first two years [1, 2]. In most engineering programs, undergraduate students are required to take entry-level engineering courses that are not discipline specific and are therefore considered service courses. Service courses are often characterized as having large class sizes (> 50 students) [3]. Students in these courses have indicated that compared with other courses in their discipline, service courses have a more demanding course load and they have smaller amounts of interaction with instructors in these courses [1]. Engineering students develop personal beliefs and attitudes about engineering during these service courses that influence their decision to persist within their current engineering discipline. Student motivation in these courses is worth examining to better understand its relationship to academic achievement and intentions to persist in engineering. Examining whether these relationships differ as a function of gender, class-standing, and engineering sub-discipline (major) is also warranted.

Though engineering students' motivation has been examined in previous research, most researchers use omnibus measures or measures for engineering-related domains such as mathematics and science [e.g., 4]. Our study seeks to determine the relationship of motivation constructs (i.e., self-efficacy, task value, achievement goals) to achievement and persistence using measures providing clear activities and tasks in engineering and not only in engineering-related domains. Ultimately, we want to know which motivation construct better predicts student achievement and intent to persist in engineering.

II. Theoretical Framework

With interest in multiple motivation constructs, we begin by examining students' engineering self-efficacy. Using social cognitive theory as our framework, we propose that students' continued matriculation in engineering programs may be due (in part) to their self-efficacy - the belief they hold about their capabilities. Social cognitive theory is based on the view that personal factors, behavioral factors, and environmental factors are interconnected and affect one another [5]. Bandura's [5] research showed that the belief individuals hold in their capability to bring about results is a primary motivator in a variety of life situations. Self-efficacy helps determine the amount of effort people exert in an activity, and their persistence and resilience in the face of adversity [6]. Students who believe they are capable of performing certain engineering tasks are typically more motivated to complete them [5].

III. Method and Participants

Participants for this ongoing study include students enrolled in an introductory materials science and engineering (MSE) service course at a large southeastern research-intensive university. Table 1 shows the respondents' demographics.

TABLE I. Characteristics of Respondents

Factor	Fall 2012 (N = 64)	Spring 2013 (N = 97)
Gender		
Male	64.1 %	71.1 %
Female	35.9 %	28.9 %
Class-Standing		
Sophomore	59.4 %	52.6 %
Junior	29.7 %	41.2 %
Senior	7.8 %	6.2 %

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Pursuing 2nd Degree	3.1 %	0 %
Academic Major		
Bioengineering	32.8 %	12.4 %
Industrial Engineering	1.6 %	27.8 %
Materials Science & Engineering	18.8 %	12.4 %
Mechanical Engineering	43.8 %	45.4 %
Other	3.0 %	2.1 %

The pilot survey was administered in the fall semester of 2012. A revised survey was administered to another cohort of students at the beginning of the spring 2013 semester. After evaluation of the initial self-efficacy scales, most items were retained. One item originally considered a source of self-efficacy (i.e., I can use engineering tools to assist me in completing engineering assignments) was added to the general engineering self-efficacy scale. The data collection instruments used for this study were approved by the institution's Institutional Review Board.

Students were asked to complete an online survey about their attitudes and beliefs about engineering. Survey items were either created or adapted from validated measures. Engineering self-efficacy measures (i.e., general engineering self-efficacy, engineering skills self-efficacy, and materials science engineering [MSE] self-efficacy) were designed in consultation with experts in engineering education and self-efficacy and in keeping with Bandura's [7] guidelines for constructing self-efficacy scales. Using a 6-point Likert-like scale (1 = *completely uncertain*, 6 = *completely certain*), students indicated the level of certainty that they can do specific engineering tasks. Table 2 shows examples of items in each scale. The scales were found to be reliable with Cronbach's alpha values greater than 0.70 [8] (Table 3).

TABLE II. EXAMPLE OF ITEMS IN EACH SELF-EFFICACY SCALE

Scale	**Example**
General Engineering Self-Efficacy	I can do a good job on almost all my engineering coursework if I do not give up.
Engineering Skills Self-Efficacy	I can design new things.
Materials Science & Engineering Self Efficacy	I can explain the difference between primary and secondary bonding in materials.

TABLE III. RELIABILITIES OF ENGINEERING SELF-EFFICACY SCALES

Scale	**Alpha**	
	Fall 2012	***Spring 2013***
General Engineering Self-Efficacy	0.93	0.91
Engineering Skills Self-Efficacy	0.92	0.94
Materials Science & Engineering Self Efficacy	0.94	0.96

To examine the relationship between self-efficacy and academic achievement, students' grades in the service course were obtained. Two dimensions of intentions to persist in engineering were measured, namely, academic persistence (intent to graduate with an undergraduate engineering degree) and professional persistence (intent to practice engineering for at least three years after graduation) [9].

IV. PRELIMINARY RESULTS AND DISCUSSION

Zero-order correlations were calculated among the variables of interest. General engineering self-efficacy was positively related to grades in fall 2012 ($r = 0.42$, $p < 0.01$) and to MSE self-efficacy ($r = 0.35$, $p < 0.01$). Previous studies have shown a positive relationship between self-efficacy and academic achievement [10, 11]. Successful academic performance in an introductory class in MSE calls for the execution of MSE-related skills (e.g., identifying effects of defects on mechanical properties of solids) and general engineering tasks (e.g., learning engineering concepts) [12]. Spring 2013 grades are not available at this time and will be included in the correlational analysis when obtained. In the spring semester of 2013, general engineering self-efficacy and engineering skills self-efficacy were significantly related to professional persistence ($r = 0.31$, $p < 0.01$; $r = 0.42$, $p < 0.01$, respectively). Judgments of capabilities matched to specific outcomes afford the greatest prediction of behavioral outcomes such as practicing engineering [13]. Being able to perform general and specific engineering skills necessary for engineering practice likely solidifies students' intentions to be engineers. On the other hand, none of the three engineering self-efficacy measures was significantly related to academic persistence. This result suggests that other factors may motivate students to enroll in engineering courses and to complete their engineering degrees.

Independent-samples *t* tests revealed significant gender differences in participants' engineering skills self-efficacy and MSE self-efficacy. Men ($M = 4.89$, $SD = 0.67$) reported significantly higher engineering skills self-efficacy scores than women ($M = 4.54$, $SD = 0.66$), $t(95) = 2.38$, $p < .05$. Men ($M = 3.25$, $SD = 0.99$) also reported significantly higher MSE self-efficacy scores than women ($M = 2.53$, $SD = 0.83$), $t(95) = 3.34$, $p < .01$. Our findings are consistent with other studies that found significant gender differences in students' self-efficacy in engineering [14, 15]. Previous work has shown that women seem to report a lack of self-efficacy related to specific areas of skill, knowledge, or ability [16].

Due to the small number of senior students in the sample ($n = 6$), class-standing groups were collapsed into two categories: lowerclassmen (i.e., freshmen and sophomores) and upperclassmen (i.e., juniors and seniors). The independent-samples *t* test revealed a significant mean difference between upperclassmen and lowerclassmen. Upperclassmen reported higher general self-efficacy scores ($M = 5.07$, $SD = 0.69$) than lowerclassmen ($M = 4.80$, $SD = 0.64$), $t(95) = 2.08$, $p < .05$. This result echoes previous findings that lowerclassmen have significantly lower self-efficacy [17]. Students further along in their engineering programs might be expected to have higher engineering self-efficacy due to their successful completion of requirements in their engineering programs compared to those students who are just beginning to take courses in their major.

To understand the effect of student major on self-efficacy, an analysis of variance was performed. Results of the analysis of variance revealed a significant difference in engineering skills self-efficacy as a function of students' engineering major, $F(4, 92) = 2.69$, $p < .05$ (see Table 4 for mean values). Considering that each engineering sub-discipline requires the mastery of specialized skill sets, students may possess specific skills and beliefs about those skills depending on their major. Some engineering skills may be more relevant to one major, and therefore students in that major have more opportunities to demonstrate those skills. This possibility could explain differences in self-efficacy levels.

TABLE IV. ENGINEERING SKILLS SELF-EFFICACY MEAN SCORES BY ENGINEERING MAJOR

Engineering Major	N	Mean	Standard Deviation
Bioengineering	12	4.69	0.57
Industrial Engineering	27	4.78	0.78
Materials Science & Engineering	12	5.15	0.46
Mechanical Engineering	44	5.00	0.68

V. CONCLUSIONS AND FUTURE WORK

Through this initial and ongoing work, we have created an instrument to assess undergraduate students' engineering self-efficacy. Initial data suggest that there is a positive correlation between efficacy beliefs in general engineering and specific to MSE. Significant differences in the mean values reported as a function of gender, class-standing, and engineering sub-discipline were also found. Engineering self-efficacy was positively associated with achievement (term grades).

Our preliminary findings suggest a positive relationship between engineering self-efficacy and academic achievement. Further examination of motivation in relation to academic persistence is also necessary. Examining multiple motivation variables may be helpful for understanding the educational goals that engineering students pursue [18]. In addition to self-efficacy, we will examine the *value* students place on the tasks to be mastered and the achievement goals they have. Researchers have shown that task values are related to course plans and enrollment decisions [19] and that achievement goals are related to enrollment in major courses and to academic performance [18]. However, few have examined these constructs in the domain of engineering. Our hope is to include diverse motivation constructs to help us better understand engineering students' academic performance and intentions to persist in engineering.

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Measuring Student Engagement in Thermodynamics Courses

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***Abstract*— This paper will discuss an on-going NSF-CCLI grant that addresses improvements in student pedagogy and educational materials for the engineering thermodynamics curriculum by completing development of an online material titled "Engaged in Thermodynamics". The Engaged material is a textbook supplement based on actual engineering facilities and equipment. During Fall 2012 an engagement Opinionnaire was administered in two separate, and distinct, thermodynamics courses. Results indicate a student perception that preparing better for a course leads to improved performance in the course. However, there was no correlation between students' desire to learn and the amount of questions they ask in class. Regarding student interest, the results indicated it was higher for the course that used the Engaged material. Additional data collection and student focus groups will be ongoing.**

Keywords— active learning, pedagogies of engagement, problem based learning, thermodynamics.

I. Introduction

As the basis for this paper we will limit our dialogue to the thermo-fluid components of the engineering curriculum, specifically thermodynamics. Many of the thermo-fluids courses tend to be taught with lecture based teaching methods and textbooks. Thermodynamics, in particular, is prone to elicit a negative impression from students "who perceive the subject as dry and abstract [1]." To address this, a Course, Curriculum, and Laboratory Improvement (CCLI) Phase I grant was received from NSF to study the creation of course material for thermodynamics which would bring more real world content into the classroom. By basing a textbook supplement on actual engineering facilities it was hoped that there would be greater inquiry-based or student centered learning, student expectations of real world content would be better met, and an increase in overall engagement would result. Based on promising assessment and feedback from students a Phase II grant for full development was awarded.

The Engaged material is a textbook supplement based on actual engineering facilities and equipment. It expands on the case study concept by including skills-based problems (see Fig. 1) that can be used in place of traditional homework problems but written in the context of the real-world environment, as well as additional design problems based on design methods and actual solutions at real facilities. Accompanying supplementary and background information promotes increased inquiry-based or student-centered learning, better addresses student real world expectations, and leads to an increase in overall student engagement. The development of

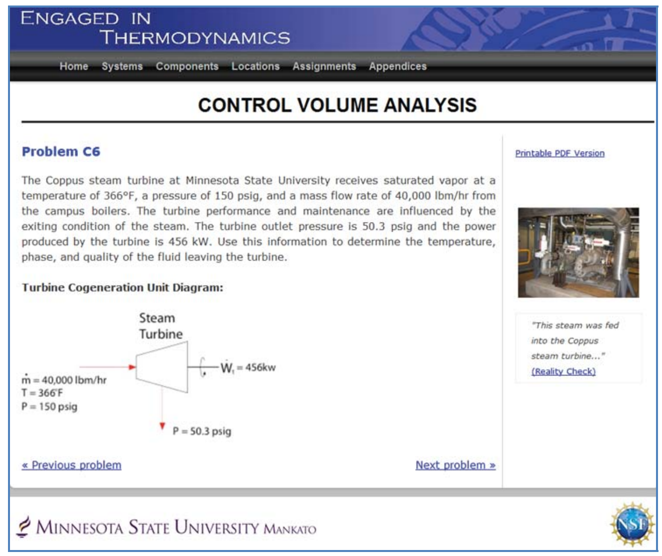

Fig. 1. Example of a skill based problem for an actual steam turbine.

the Engaged in Thermodynamics material has been detailed in a number of papers [2,3]. There is great pedagogical flexibility in allowing varying levels of use by the faculty member. The connection to reality is achieved by formulating the problems within the real world setting.

Results from Phase 1 of this project demonstrated that students who finish the semester with higher levels of engagement performed better. This portion of the research seeks to determine if students who use the expanded Engaged material are in fact more interested and engaged in the course.

II. Assessing Student Engagement

To assess the impact on student engagement a quick, yet simple, tool was required. One of the most popular methods of measuring student engagement is the National Survey of Student Engagement (NSSE). The NSSE survey focuses on aspects of student participation in activities as an indication of engagement and pedagogical quality [4]. While the NSSE survey is a well-documented instrument it was decided that it was too time intensive to provide the quick assessment snapshot this project was seeking. Using this, and other, surveys as a guide and with substantial feedback from undergraduate students a shortened survey was created. It consists of five questions measured on a 5-point Likert scale

TABLE I. QUESTIONS ON THE STUDENT OPINIONNAIRE.

1. Compared to other courses in engineering, do you find yourself wanting to learn more in this course?
2. Compared to other courses in engineering, are you asking more questions about the material? (in and outside of class)
3. Compared to other courses in engineering, do you talk/think more about the material in this course?
4. Compared to other courses in engineering, do you find you are preparing better for this class?
5. How well do you think you are doing in this course so far?

(Table I). In their current form these questions have been referred to as an "Opinionnaire".

During Fall 2012, the engagement Opinionnaire was administered in two separate, and distinct, thermodynamics courses (each at a different institution). The survey was given near the end of the semester. Basic statistics on the results are shown in Table II. A value of 5 indicates a positive response and a value of 1 indicates a negative response. The primary difference between the two courses was size (N = 51 versus N = 5). In addition, Course A made use of the Engaged in Thermodynamics material while Course B did not. The average response concerning students "wanting to learn more" (#1) was higher for Course A, which made use of the Engaged material, but Course B had higher performance expectations (#5). Average responses for questions #2-4 were essentially identical for the two courses.

Correlations between the five opinionnaire questions were conducted to help understand these results (Table II). For both courses, the correlation coefficient between question #1 and #2 was essentially zero. This would seem to indicate that there is no correlation between students' desire to learn and the amount of questions they ask in class. The correlations between question #3 and #4 for the two courses were 0.46 and 0.78, respectively. This indicates a moderate to high correlation between students talking about the material and preparing for class. Similarly the correlation between questions #4 and #5 indicated a moderate to high correlation, with values of 0.49 and 0.78 respectively. This indicates, at least a student perception, that preparing better for a course correlates to performance in the course. Taking these two correlations together one might conclude there would also be a positive correlation between questions #2 or #3 and #5. In other words, that an increase in asking more questions in class or thinking about the material more would result in an increase in performance. However, while positive correlations were found these were weaker and ranged from 0.19 to 0.36.

III. DISCUSSION

Based on these results, impromptu discussions were held with students at the authors' institution. A possible justification for having an interest in the material but a lack of activity in class was sought. The students did indicate that they are often very interested in a class and the material but they

TABLE II. RESPONSES FOR THE OPINIONNAIRE QUESTIONS.

Course A (N=51)	#1	#2	#3	#4	#5
Average	3.8	3.3	3.7	2.9	3.0
Std Dev	1.2	1.2	1.1	1.2	0.9
Correlation to #2	0.08		0.48	0.29	0.19
Correlation to #3	0.28	0.48		0.46	0.27
Correlation to #4	0.37	0.29	0.46		0.49
Correlation to #5	0.26	0.19	0.27	0.49	
Course B (N=5)	#1	#2	#3	#4	#5
Average	3.2	3.3	3.7	2.8	3.4
Std Dev	1.5	1.6	1.2	1.0	1.3
Correlation to #2	-0.03		0.37	0.54	0.3
Correlation to #3	0.04	0.37		0.78	0.37
Correlation to #4	0.44	0.54	0.78		0.78
Correlation to #5	0.54	0.3	0.37	0.78	

may not devote much activity to it for other reasons (e.g. time commitment for other courses).

Engagement has no universally accepted definition. The NSSE associated definition looks at "the frequency with which students participate in activities that represent educational practice" [5]. Other terms that have been used for engagement include "quality of effort", "involvement", and the related term "motivation". Motivation in turn has been defined as a relationship between interest, value, and autonomy [6]. It has also been pointed out that "most students will not struggle to achieve a deep understanding of material that they cannot readily connect to their interests and the problems they are likely to be called upon to solve as professionals' [7].

Engagement may be too complex an issue to be solved solely with the Engaged in Thermodynamics material. The material itself appears to currently serve as a motivator. The situational factors of a course and how the material is used will still be the determining engagement factors. However, when considering the combination of interest, value, and autonomy the material is very well positioned.

IV. FUTURE WORK

Currently the assessment data is limited. Additional data will be collected during Spring 2013 and the following academic year. As part of this process focus groups are planned with both instructors and students. The information gathered will help to identify links between classroom practices, methods of using the Engaged in Thermodynamics material, and the resulting impact on student motivation and engagement. Specific attention will be paid to feedback on the three aspects of interest, value, and autonomy. During the next year the material will continue to be developed. This will involve the addition of new real world scenarios and additional information on actual engineering installations.

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The Effects of Extra Credit Opportunities on Student Procrastination

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***Abstract*—Many techniques have been attempted to encourage students to exercise better time management on class projects, such as staging an assignment into multiple deliverables, requiring students to keep records of the time they spend, and offering extra credit for early completion. This paper reports on a study of the effects of offering extra credit for early completion. Students in an introductory course completed four programming assignments throughout the term. For two assignments, no extra credit was offered. For the other two, students were offered a 10% bonus if they finished at least three days before the deadline. While one might expect this incentive to encourage students to shift their work habits, we found that there was no positive change in their time management. In fact, students started on the assignments where extra credit was offered *later* than on those where it was not offered. This leads us to believe that there were other pressures or concerns that outweigh the possibility of earning a bonus on an assignment, so that this kind of incentive only helps students who already manage their time well.**

Keywords—Procrastination, extra credit, study habits, programmer productivity, student performance, programming assignment.

I. Introduction

Everyone procrastinates. But a significant number of students procrastinate so much on assigned projects that it makes them more likely to turn in work late, receive lower scores, and even experience stress and illness. Some studies indicate that up to 95% of undergraduates procrastinate on coursework to some degree [1][2][3][4], while 20-30% exhibit chronic or severe procrastination [3]. Instructors know that procrastination can have adverse consequences, particularly on project-based assignments that take a significant amount of time outside of class to complete. As a result, many educators have tried a variety of strategies to combat poor time management choices. Some of the techniques that have been attempted to encourage or force students to exercise better time management habits include: staging an assignment into multiple deliverables with individual deadlines, requiring students track the time they spend on an assignment and plan out schedules for how they will allocate time to complete an assignment, and offering extra credit for early completion of an assignment. Yet, within engineering education, there has been relatively little experimental validation of the effects that such techniques have on student procrastination. While these techniques are often practiced in the classroom, there has been relatively little direct research on their effectiveness.

This research-in-practice paper reports on a study that analyzed the effects of one of the simplest techniques that educators employ in practice: offering extra credit for early completion. This experiment was carried out in an introductory computer science course where students completed four programming project assignments over the course of the semester. Half of the assignments were given normally, with no extra credit incentives for time management. The other half allowed students to earn a 10% extra credit bonus for completing their work early, offered as an incentive to encourage better time management. However, the results of this study indicated that the extra credit bonus had no significant effect on how early students began working on their assignments, or how early they completed them. This result suggests that there were other pressures or concerns that affected student choices, outweighing the possible extra credit bonus. Instead, this kind of extra credit incentive may not have the effect that instructors desire, and may only benefit the students who already manage their time well.

Section II summarizes previous work related to time management in computer science project assignments. Section III describes the study method employed, with results and discussion presented in Section IV. Section V summarizes the results, suggesting that instructors need to consider other factors before using extra credit as a time management incentive.

II. Related Work

A. Previous Work on Programming Habits

Edwards et al. [5] analyzed a five-year data set of student work on programming assignments—the largest dataset of its kind—in order to draw conclusions about effective and ineffective habits of novice programmers. This study provided valuable insight into the time management habits of students and how their performance on assignments was driven by those habits.

This study examined student submissions to programming assignments in the first three introductory CS courses at one university over a five-year period. Students who consistently performed well (over 80%) on all assignments for a particular course and students who consistently performed poorly (below 80%) on all assignments for a course were eliminated from the dataset, leaving only students who performed well on some assignments and poorly on others. The study then used a within-subjects comparison to determine whether changes in habits were associated with changes in performance. Because the within-subjects nature of the comparison controlled for differences in individual abilities, observed differences were

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most likely due to other factors affecting how the students pursued their assignments. This reduced data set included 3,437 programs written by 623 students across 105 assignments.

As students worked on their assignments, they were allowed to self-check their work using an on-line assignment feedback system as many times as they wished, making corrections and refining their work before turning in their final submission. Students averaged 14 submissions on each program they completed, and timestamps from these efforts provided a window into how early students began working, how much time they spent refining their work, and when they completed their final program submission.

In summary, the study of Edwards et al. found a statistically significant difference ($N = 3437, F(1,1) = 227.2, p < 0.0001$) in the time of the student's first submission attempt when students scored above 80% (the A/B group) and when they scored below 80% (the C/D/F group). The A/B group started on average 64.9 hours before the assignment's deadline ($\sigma = 72.0$), while the C/D/F group started on average 29.6 hours before the deadline ($\sigma = 61.6$). Approximately two-thirds of the A/B scores were received when students made their first submission at least a day in advance of the deadline, while a similar proportion of the C/D/F scores were received when students did not make a submission until the day of the deadline or later. Since assignments in different courses were available to students for different lengths of time depending on their difficulty, this earlier study also normalized the starting times and finishing times of students by the length of time each assignment was available, producing similar results.

From this study, it seems clear that when students began working earlier on an assignment, they were more likely to score higher, while when the same students started later, they were more likely to score lower—a result that replicates general studies of procrastination [2].

B. Improving Bad Habits

These results suggest that the mere act of starting earlier on an assignment is associated with improved student performance. Since both groups spent roughly the same amount of time on the assignments, the difference in performance might then be attributable to increased stress as the deadline approaches or a student's inability to seek out sufficient help from instructors or TAs at the last minute. Given this evidence, how might an instructor seek to improve those behaviors for at-risk students? What incentives might be offered, or what policies can be enacted, in order to encourage students to start and finish their work earlier?

Several approaches to improving student time management have been explored by educators. Students can be directed to academic enrichment resources at their university; many schools provide short seminars or courses intended to help students learn to manage their time and workload in multiple classes [4]. Instructors can also present students with the results of studies, such as the one by Edwards et al., although the mere act of presenting statistics as proof to students may not motivate them. Dividing large projects into multiple staged deliverables [6] can be useful in preventing students from waiting until the last minute to start, as can requiring them to keep detailed records of the time that they spent working on the assignment [7].

While these approaches have met with varying degrees of success, they all tend to require an additional (and sometimes significant) investment of time an effort on the part of instructors or teaching staff. Instead, many instructors look for other interventions that do not require additional contact hours or course staffing. Extra credit incentives are often viewed as an easy, low-cost alternative, since they can be added to assignments with little effort, even if they are not as effective as more intensive strategies. Therefore, the study reported in this paper focuses on the extra credit approach to investigate its impact.

C. Extra Credit Incentives

Extra credit opportunities are commonly used to reward students who go above and beyond the requirements of an assignment [8], or to attempt to affect changes in student behaviors. In computer science courses at Virginia Tech for example, instructors have sometimes given additional points to students who finish their work ahead of the deadline. Through an automated assignment processing system such as Web-CAT [9], such a bonus can be automatically applied to each student's submission.

James Stodder raises some concerns about the ethics of such incentives, especially those that affect grades in the class [10]. Although his teaching and research is in the area of economics, his concerns about grading students on behavior that might be driven by luck are valid across many disciplines. We must also be careful when crafting extra credit opportunities to ensure that they can be—and have a good chance of being—attempted by students at all ability levels in the class, or if only the most advanced students will be able to earn it, further stretching the gap between them and the weaker students. Extra credit offered for work beyond what was required on the assignment might only be earned by students who were already advanced and/or creative. On the other hand, a bonus for completing the assignment sufficiently far in advance is something that students at all ability levels have a chance to earn—they need only imagine that the extra credit deadline is the true deadline and shift their work habits accordingly.

Intuitively, we might assume that offering students extra credit to finish earlier would result in a positive shift in the starting (and finishing) times of students on the assignments, as well as a positive shift in performance because the data above showed that students perform better when they start and finish earlier. In the following sections, we present our findings after carrying out an experiment to test this hypothesis.

III. Method

In Spring 2012, we collected data in CS 1044, a C++ programming course taken by a wide variety of engineering and business students at Virginia Tech. There were four programming projects assigned throughout the semester. The amount of time that students were able to work on the assignment, from its original posting to its deadline, was about two weeks on average—with the exception of the second project, which was available for approximately four weeks due to a spring break period.

The four projects in the course were, in order: writing a perpetual calendar (CALENDAR), performing basic image manipulation (IMAGES), computing the odds of a series of lottery games (LOTTERY1), and extending the lottery game to use more advanced data structures and algorithms (LOTTERY2).

The CALENDAR and IMAGES projects had no extra credit opportunities. After they were completed, all students received the following extra credit opportunity for the remaining two assignments, LOTTERY1 and LOTTERY2: Final submissions completed at least three days before the deadline were granted an extra 10 points (scores that would exceed 100% were not capped). All programming assignment due dates fell on Wednesdays, so the extra credit deadline would therefore be on a Sunday night, at the end of the weekend.

While it is common for projects to increase in difficulty as time progresses in the course, it is important to note that the two shortest assignments, in terms of the amount of program code written by students, were the first and third assignments (one in each group). Further, the assignment that required the longest solutions from students was the second assignment (in the non-incentive group). As a result, even though there might be effects due to the ordering of the assignments, the effort required to complete the assignments, as measured by the sizes of student programs, was comparable between the two treatment conditions.

Two decisions had to be made regarding the nature of this bonus. First, how far in advance of the deadline should the bonus be applied? The data above indicate that students perform better if they make their first submission even just one day in advance of the assignment's deadline. However, we did not simply want to reward behavior that fell right on the threshold of what the earlier study indicated, but instead aimed to affect a larger change in student work habits. For this reason, we chose **three days before the deadline** as the cutoff for the bonus.

Second, how big should the bonus be? A bonus that is too small might be ignored by students, whereas a bonus that is too large might have an undesirable effect on the grade distribution in the course. Programming projects in this course comprised 50% of the student's overall score. Earning the 10% bonus on both programming assignments where it was available thus corresponds to a 2.5% increase in a student's overall score—potentially, a large change. Students were not made explicitly aware of this fact, however; only those who made the effort to do the calculations themselves ahead of time would see this.

As in the earlier experiment reported in Section II-A, students submitted work electronically through an assignment processing system, and timestamps for all attempts at each program were recorded. The complete CS 1044 data set includes 1,083 programs authored by 285 students over the four assignments given in the course. Using the same 80% split point from [5], all program grades were partitioned into A/B and C/D/F groups. Students who consistently scored in either the A/B group or consistently scored in the C/D/F group were removed to allow a within-subjects comparison. After this pruning, 202 program grades from 55 students remained–a much smaller proportion than in the earlier study. This appears to be the result of some degree of "grade inflation" on the programming assignments in the course, so 80% might not be the ideal split point for this particular course. However, the notion of a student "doing well" is typically not relative to the other students in the course, but rather it depends only on that particular student's score, so the remainder of this study continues with the same 80% point used for partitioning in earlier work.

IV. RESULTS AND DISCUSSION

Before evaluating the extra credit opportunity, we wished to see if the trends in Section II-A also held for the students in this course. While students did start earlier when they scored better (mean = 91.7 hours for A/B grades, 57.6 hours for C/D/F grades), this difference was not statistically significant at the $\alpha = 0.05$ level ($N = 202$, $t = -1.76$, $p = 0.08$). This is likely due to the much smaller size of this data set compared to the one in Section II-A. However, there was a statisticaly significant difference in the times when assignments were completed, with students finishing 68.0 hours before the deadline on average when they achieved A/B scores, but only 25.2 hours before the deadline when achieving C/D/F scores ($N = 202$, $t = -2.81$, $p = 0.0054$). There was no significant difference in the overall time spent between the two groups, however.

Of the 285 students in the class, 56 (19.6%) started all four projects at least 3 days before the deadline, and 39 (13.7%) of them finished all four before that threshold. 122 students (42.8%) earned extra credit by finishing at least one of the final two assignments before the threshold. 107 of them, however, had also completed at least one of the first two assignments before the 3-day threshold as well. On the other end of the spectrum, there were 74 students (26.0%) who finished all four projects within 3 days of the deadline or after it had passed.

A. Behavior With and Without Extra Credit

We compared the effects that the extra credit opportunity had on students' starting and finishing times by looking for differences between the assignments that had extra credit and those that did not. There was a statistically significant difference ($N = 202$, $t = 3.71$, $p = 0.0003$) between the start times when students were working on programs where no incentive was offered (mean = 101.9 hours) compared to programs where extra credit was available for early completion (mean = 55.2 hours). Unfortunately, this difference is in the opposite direction than expected—students started *later* on the two assignments where extra credit was available.

These differences persisted, even among the larger population of 285 students in the course ($N = 1083$, $F(1,1) = 115.77$, $p < 0.0001$). The mean start time among all students for the assignments with no extra credit was 5.67 days ($\sigma = 5.80$); for the assignments with extra credit, the mean was 3.25 days ($\sigma = 3.85$). In other words, students started earlier on average on the assignments where extra credit was *not* offered.

Similarly, there was a statically significant difference in when students finished when extra credit was available ($N = 202$, $t = 3.75$, $p = 0.003$). In the smaller within-subjects comparison, students completed their work on programs where no incentive was offered an average of 76.8 hours ahead of the deadline, but the same students completed the assignments where extra credit was available an average of 26.4 hours ahead of the deadline. Again, this difference was in the opposite direction of the incentives offered.

Again, this same difference was present in the larger group of all students ($N = 1083$, $F(1, 1) = 104.83$, $p < 0.0001$). The mean finish time for all students on the assignments with no extra credit was 4.54 days ($\sigma = 5.30$); for the assignments with extra credit, the mean was 2.38 days ($\sigma = 3.39$). As before, students on average finished earlier on the assignments where extra credit was not offered.

Finally, in the within-subjects pool of 55 students, we examined how many of their assignments were completed more than three days ahead of the deadline. In the first two assignments where no incentives were offered, 66.3% of the assignments completed by these students were turned in at least three days ahead. For the second two assignments that included extra credit incentives, 80.6% of the assignments were completed at least three days ahead of the deadline. This difference was statistically significant ($N = 202$, $\chi^2 = 5.31$, $p = 0.0212$). Thus, at least some of the students—those who sometimes achieved higher scores and sometimes lower—may have been affected by the incentive. This trend was not present when considering the entire class of 285 students, however, where 48.4% of the assignments without incentives were completed at least three days early, while only 34.5% of the assignments where extra credit was offered were completed this early.

Seeing that there is a difference of roughly only a day between the mean start and finish times of assignments with and without incentives encouraged us to look into the time spent on the assignments as well. We found no significant difference in time spent between the two groups ($N = 1083$, $F(1, 1) = 3.029$, $p = 0.0821$). The mean time spent on the assignments without extra credit was 1.12 days ($\sigma = 2.85$); on assignments with extra credit, the mean time spent was 0.87 days ($\sigma = 1.97$). In fact, there were 348 scoring submissions to the extra credit assignments where the bonus was not earned because the student worked beyond that threshold. 75% of those submissions were by students who spent less than a day between their first submission and final submission to that assignment. Given the fact that the assignments were available for two weeks or more, many of these students probably could have shifted forward the time that they worked on the assignments and earned the bonus. This indicates that the extra credit did not provide as great a motivation as we had hoped it would.

B. Other Factors

Since the extra credit opportunity does not appear to be a significant motivating factor in the way students managed their time on these assignments, what other factors might have come into play? One possibility is that the difficulty of the assignments, or the amount of effort involved, outweighed any effects that the extra credit opportunity might have had.

In this course, the instructor's intuition is that the first assignment, CALENDAR, was the easiest, and that the second assignment, IMAGES, might have been a bit too ambitious, and

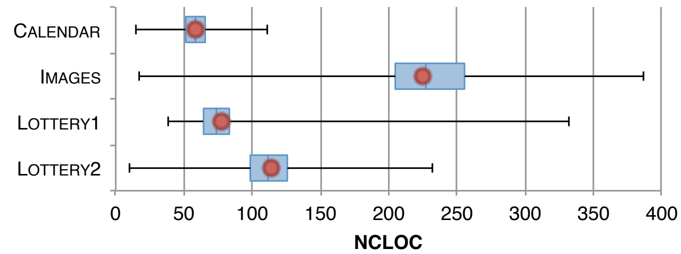

Fig. 1. Box-and-whisker plot showing NCLOC distributions for each of the four programming assignments.

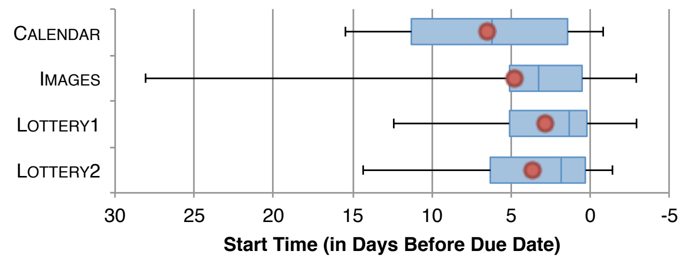

Fig. 2. Box-and-whisker plot showing distributions of start times (in days) for each of the four programming assignments.

in retrospect it was the most difficult in the course. LOTTERY1 and LOTTERY2 fell in the middle, as a way of pulling back slightly when students experienced significant difficulty with IMAGES.

To quantify this notion of difficulty, we can examine the number of non-commented lines of code (NCLOC) that students wrote for each assignment. Presumably, more difficult assignments require more effort to complete, and that effort is directly related to the number of lines of code that students were required to write.

We found that the four assignments did have significantly different NCLOC ($N = 1081$, $F(3, 3) = 1516.33$, $p < 0.0001$). Tukey's HSD test indicates that each of the four assignments is significantly different from the others. In increasing NCLOC order, CALENDAR had a mean NCLOC of 58.6 ($\sigma = 12.1$), LOTTERY1 had a mean NCLOC of 76.9 ($\sigma = 24.7$), LOTTERY2 had a mean NCLOC of 113.6 ($\sigma = 26.7$), and IMAGES had a mean NCLOC of 224.9 ($\sigma = 54.0$). These results are consistent with the instructor's impression of the relative difficulty of the assignments. Figure 1 shows the distribution for each assignment in more detail.

Figure 2 shows the start times across each of the four assignments, which are significantly different ($N = 1083$, $F(3, 3) = 55.00$, $p < 0.0001$). Tukey's HSD test indicates that CALENDAR and IMAGES differ significantly from everything else; LOTTERY1 and LOTTERY2 differ significantly from the former two but not from each other. The assignment with mean start time furthest ahead of the due date was the first one in the course, CALENDAR ($\mu = 6.54$ days, $\sigma = 5.29$). This is perhaps not a surprising result; students might have had more flexibility at the beginning of the semester to manage their time

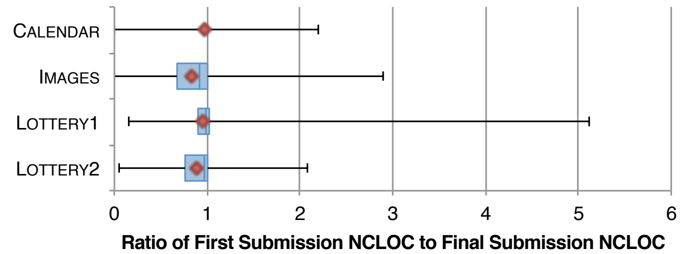

Fig. 3. Box-and-whisker plot showing distributions of the first/final NCLOC ratios for each of the four programming assignments.

between this and other classes they were taking. They may also have been less able to accurately estimate the amount of time that such an assignment would take and erred on the side of caution.

Recall that the time of the first submission does not represent the true time that the student started on the project. One way to estimate the amount of effort that a student has put into an assignment before their first submission is to compute the ratio of NCLOC in his or her first submission to NCLOC in his or her final submission.

In programming courses where students are expected to test their code using a prescribed methodology (such as writing JUnit test cases), they are able to get significant feedback during local development. Due to this, students in these courses typically have a considerable portion of their solution already written when they being submitting to Web-CAT and this first/final ratio is very close to 1. The remaining development time between first and final submissions is then devoted to debugging rather than writing large amounts of new code.

In the CS 1044 course, students were not required to follow any particular testing methodology; the only feedback they received outside of Web-CAT was from executing the program in its entirety with different inputs. However, the first/final NCLOC ratios for the assignments in this course do not appear to reflect a difference in that regard. Figure 3 shows the distribution of first/final NCLOC for students in the class, per assignment.

We found a significant difference between these ratios across the four assignments ($N = 1082$, $F(3, 3) = 14.465$, $p < 0.0001$). Tukey's HSD test indicated that Calendar and Lottery1 are significantly different from Images and Lottery2. More importantly, however, is the observation that the 25th percentile for any of the assignments is never less than 0.67. In other words, a vast majority of students in the class already had written at least two thirds of the code that makes up their final submission by the time they started submitting anything to Web-CAT. This indicates that students did spend an appreciable amount of time working on the assignments before the time of their first submission.

Despite these findings, we found no significant difference between first/final NCLOC when we compared the assignments with extra credit to those without ($N = 1082$, $F(1, 1) = 0.0668$, $p = 0.796$). The mean first/final NCLOC for submissions to assignments without extra credit was 0.907

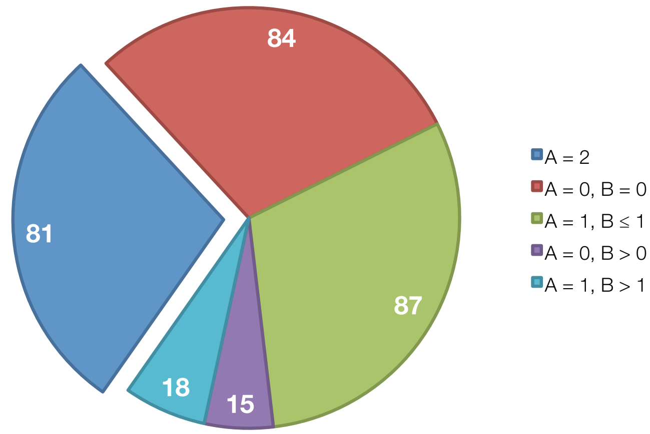

Fig. 4. Students grouped by time-based behavior on assignments. "A" represents the number of assignments where extra credit was not offered that a student finished at least three days early. "B" represents the number of assignments where extra credit was offered that a student finished at least three days early.

($\sigma = 0.291$); the mean for assignments with extra credit is almost identical, at 0.912 ($\sigma = 0.299$). Thus, it does not appear that students made a larger relative effort before their first submission on the extra credit assignments than they did on the ones without, so we have no evidence that they *started* significantly earlier.

V. Conclusions

Figure 4 breaks down the students in the class based on their time management habits on the assignments with and without extra credit. Out of the 285 students in the class where the extra credit was offered, 99 (34.7%) did not finish the first two assignments until within three days of the deadline (or after the deadline). Of those 99 students, only 11 finished one of the final two assignments before the extra credit deadline, and four finished both before the extra credit deadline. Likewise, 105 students (36.8%) finished one of the first two assignments at least three days before the deadline; 18 of them went on to finish both of the final two assignments before the extra credit deadline. In other words, there were 204 students (71.6%) in the class whose behavior could have strictly improved as a result of the incentive, but only 33 of them showed such an improvement. On the other end of the spectrum, there were 81 students (28.4%) who finished the first two assignments more than three days before the deadline, but 42 of them regressed on the final two assignments; 25 of them finished only one assignment before the extra credit deadline, and 17 of them did not finish either assignment before the extra credit deadline.

In other words, the offered bonus did not appear to have any positive effect on student behavior class-wide. It is true that of the 55 students who scored well on some assignments and poorly on others, there was a significant difference in their likelihood of turning in the assignments with incentives early. However, the number of students affected by this incentive was small compared to the class as a whole, and this trend is no longer visible when taking the entire population into consideration.

Students did not start significantly earlier on the assignments where extra credit was offered, even though those assignments required less effort to complete than one that came before them. Of the students in the class who earned extra credit on at least one of the two assignments where it was offered by finishing their work early, over 87% of those students had also completed one of the previous assignments just as early, when extra credit was not being offered. Therefore, we conclude that any potential incentive power of the extra credit opportunity was overshadowed by other factors that were not examined here. Given that students were not taking this course in isolation, we must consider the possibility that outside forces, such as deadline pressures in other courses, had a greater impact on their ability to manage their time in our course.

Further, for instructors considering how to address time management in their own courses, this study suggests that extra credit incentives may not be an effective choice. Some students may be affected by the incentive, but overall, extra credit did not produce a significant shift in student behavior. While extra credit is desirable because of the low effort and low cost of implementation, lack of demonstrable effectiveness overall suggests that instructors should also consider whether such incentives merely give a boost to students who already have good work habits, without providing much benefit to the students who procrastinate the most. As Stodder [10] warns, such incentives may be counterproductive, especially if they do not motivate many students to change behavior. Instead, further work is needed to evaluate competing alternatives to address procrastination on class projects, in order to find an intervention strategy that has the desired effect while also remaining within acceptable cost boundaries.

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Using Open Source Projects in Software Engineering Education: A Systematic Mapping Study

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***Abstract*—Context: It is common practice in academia to have students work with "toy" projects in software engineering courses. One way to make such courses more realistic and reduce the gap between academic courses and industry needs is getting students involved in Open Source Projects with faculty supervision. Objective: This study aims to summarize existing information on how open source projects have been used to facilitate students' learning of software engineering. Method: A systematic mapping study was undertaken by identifying, filtering and classifying primary studies using a predefined strategy. Results: 53 papers were selected and classified. The main results were: a) most studies focus on comprehensive software engineering courses, although some papers deal with specific areas; b) the most prevalent approach was the traditional project method; c) surveys are the main learning assessment instrument, especially for student self-assessment; d) conferences are the typical publication venue; and e) more than half of the studies were published in the last five years. Conclusions: The resulting map gives an overview of the existing initiatives in this context and shows gaps where further research can be pursued.**

I. Introduction

Learning software engineering (SE) entails more than acquiring content knowledge. It usually implies learning a set of skills and attitudes towards software production that are hard for students to master inside academia. For instance, it involves taking part in a long-term effort of software production lasting more than the usual four-month academic term. It also requires authentic environments and situations, where novices learn from experts, teams are assembled for different activities, customers communicate with team members, and team members practice skills such as communication, leadership, negotiation, and decision making.

Although there are initiatives to strenghten the ties between undergraduate programs and industry (e.g., co-op programs [1]), they do not solve the need for practicing concepts and skills as they are acquired in regular courses. Software engineering faculty usually approach the subject with "toy problems" whose size and complexity are managed at the expense of authenticity.

One approach that is gaining momentum in SE courses is getting students involved in open source software projects (OSP) with faculty supervision. Student participation can account for the practical section of SE courses. Open source projects allow practicing skills and attitudes required in such courses. Various OSP provide an authentic environment where experts and novices interact, work structure is well-defined, and real products are under development. Furthermore, most SE knowledge areas can be covered with this approach.

However, regardless of the authentic environment provided by an open source software project, it is the activities that students perform that ultimately leads them to significant learning. Skills and attitudes are better acquired with learning challenges, provision of resources, adequate advising, and follow-up. The more actively students behave in a project, the more likely they will master the content knowledge in their courses. It seems, thus, that active learning practices are a good combination with taking part in OSP to learn SE.

In this context, this study aims to review the literature of software engineering education related to OSP, and to uncover the experiences where OSP were used to facilitate learning of SE concepts, especially with active learning approaches. In the literature, we usually find examples of open source software used in academia as a development tool or a computer lab environment. However, in this study, our intent is to uncover studies where students actively work with OSP, analyzing their source code, proposing and implementing changes, testing, and participating in their communities. To reach this goal, we performed a systematic mapping study [2].

Systematic mapping studies are secondary studies similar to systematic reviews. In both, primary studies are searched in indexed scientific databases, selected and classified according to objective criteria. The main difference is that while systematic reviews examine primary studies in-depth, aiming to generate conclusions about a particular research question, mapping studies mainly intend to categorize them, usually providing a visual summary of results [2]. Not only evidence clusters are identified, but also evidence gaps where additional research could be conducted are uncovered [3].

In this study, we identified primary studies by means of a pre-defined search strategy performed in digital libraries, followed by a multi-step selection process to exclude duplicate studies and retain papers relevant to the study goal, and a classification procedure based on dimensions of interest. As a result, 53 papers were selected and classified. The main findings were: a) most studies focus on comprehensive software engineering courses (38 articles), although there are some studies on specific areas, e.g., design/architecture, evolution, tests and software development; b) there is seldom explicit information about a pedagogical theory or framework used as a basis to the studies, and the most prevalent approach is the traditional project method; c) when learning is assessed,surveys

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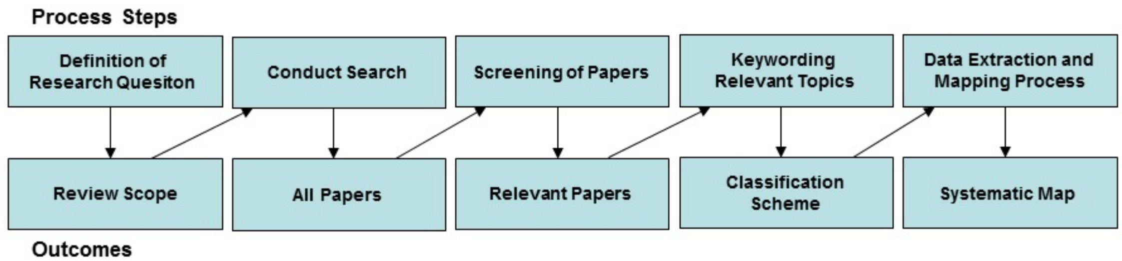

Fig. 1: The systematic mapping process, adapted from Petersen et al [2].

are widely used, mainly for student self-assessment, but other instruments are also applied; d) conferences are the typical venue where papers are published; and e) more than half of the selected studies has been published in the last five years (8 in 2008, 11 in 2009, 2 in 2010, 9 in 2011 and 5 in 2012), showing the community's recent interest in the topic.

This paper is organized as follows. Section II presents an overview of the mapping study process. Section III presents the main results and a discussion of the main findings and limitations. Finally, Section IV presents conclusions and areas for further research.

II. The Systematic Mapping Study Process

We performed a systematic mapping study [2] [4] to examine the extent and range of research activities related to the use of OSP in software engineering education. Figure 1, adapted from Petersen et al [2], describes the process used in our mapping study. The rest of this section describes how we performed each step of the process.

Definition of Research Questions. Several research questions were derived to allow for a broad view and cover the main topics of interest within this work. The main question to be answered was:

RQ1. How are Open Source Projects used in Software Engineering Education?

There is a bulk of literature on the use of open source software projects for pedagogical purposes and we aim to uncover the experiences where such projects were used to foster learning of software engineering. Since there are several knowledge areas in software engineering [5], we also would like to find out which topics are mostly covered or addressed by such initiatives (e.g., software engineering in general, requirements, modeling, design, quality, maintenance, among others).

The second and third questions focus on specific pedagogical aspects:

RQ2. Are there any initiatives that combine open source projects with active learning in software engineering courses?

RQ3. How is student learning assessed in such initiatives?

Conduct Search. The search string used in our mapping study was built using the following steps, defined by Kitchenham et al [6]: (a) derive major terms from the main question, by identifying the population and intervention; (b) identify alternative spellings and synonyms; (c) check keywords from known studies; (d) use the Boolean OR to incorporate alternative spellings and synonyms, finally (e) use the Boolean AND to link the major terms. To obtain a broad coverage, special attention was given to identify alternative spellings and synonyms. The resulting search string is presented in Table I.

TABLE I: Search String

"open source" **OR** " free software" **OR** "libre software" **OR** "FLOSS" **OR** "FOSS" **OR** "OSS" **OR** "OSP"
AND
"course" **OR** "curriculum" **OR** "education" **OR** "educational" **OR** "teaching" **OR** "learning" **OR** "mentoring" **OR** "training" **OR** "apprentice" **OR** "tutoring" **OR** "coaching" **OR** "skills" **OR** "competencies"
AND
"software engineering" **OR** "software requirement" **OR** "software modeling" **OR** "software analysis" **OR** "software design" **OR** "software architecture" **OR** "design patterns" **OR** "software verification" **OR** "software validation" **OR** "software evolution" **OR** "software maintenance" **OR** "software process" **OR** "software quality" **OR** "software metrics" **OR** "software management" **OR** "software testing" **OR** "software configuration management" **OR** "computing" **OR** "computer science"

The search strategy included the following scientific electronic databases: Compendex[1], IEEE Xplore[2], ACM[3], Scopus[4], Springer[5] and Elsevier[6]. These libraries are important sources for software engineering and computer science studies, indexing relevant conferences and journals. Furthermore, their search engines support automatic search based on different criteria and string formats – which may help to ensure adequate coverage.

With the search string, we applied automated searches against paper *title*, *abstract* and *keywords*. The standard search string had to be gauged for each database, to cope with different word stemming and syntax requirements.

The search was performed from 1st to 15th October, 2012. As a result, we identified 2204 papers, discarded 1099 duplicates (many studies were indexed by more than one digital library) and selected 1105 papers for screening.

Screening of papers. The main goal of the screening process is to select relevant studies that properly address the research

[1] http://www.engineeringvillage.com
[2] http://ieeexplore.ieee.org
[3] http://portal.acm.org
[4] http://www.info.sciverse.com/scopus
[5] http://www.springer.com
[6] http://www.elsevier.com

TABLE II: Research Types

Category	Description
Experience report	Paper describes the authors' personal experience using a particular approach, explaining what and how something has been done in practice. It usually includes lessons learned.
Case study	An empirical inquiry that investigates a phenomenon within its real-life context. Paper may deal with single or multiple cases, may include quantitative evidence, relies on multiple sources of evidence, and benefits from the prior development of theoretical propositions.
Action research	Interactive inquiry process that balances problem solving actions implemented in a collaborative context with data-driven collaborative analysis or research to understand underlying causes enabling future predictions about personal and organizational change.
Experiment/Quasi-experiment	A collection of research designs that use manipulation and controlled testing to understand causal processes. Generally, one or more variables are manipulated to determine their effect on a dependent variable.
Survey	Encompasses any measurement procedures that involve asking questions of respondents, generally by sampling them from a population. Most common types of surveys use questionnaires or interviews.
Opinion paper	These papers express the personal opinion of somebody whether a certain approach is good or bad, or how things should been done. They do not rely on related work and research methodologies.
Solution proposal	A solution for a problem is proposed, the solution can be either novel or a significant extension of an existing technique. The potential benefits and the applicability of the solution are shown by an example or a good line of argumentation.
Philosophical paper	These papers sketch a new way of looking at existing things by structuring the field in form of a taxonomy or conceptual framework.
Literature review	Critical and in-depth evaluation of previous research. It is a summary and synopsis of a particular area of research.

TABLE III: Learning Approaches

Category	Description
Does not apply	Paper is not related to an experience where a learning approach is needed.
Not specified	Authors do not state the learning approach used.
Active learning (general)	General term that refers to several models of education that focus the responsibility of learning on learners. Usually students engage in higher-order thinking tasks such as analysis, synthesis, and evaluation.
Case-based learning	Approach where students develop skills in analytical thinking and reflective judgment by reading and discussing complex, real-life scenarios. A case is already organized and synthesized for students.
Game-based learning	Learning that involves students in some sort of competition or achievement in relationship to an educational goal. Attempts to increase student motivation by providing a playful environment.
Peer/Group/Team learning	Educational practices in which students interact with other students to attain educational goals. Such approaches enhance the value of interaction and information sharing among peers.
Problem-/Project-/Inquiry-based learning	A collection of approaches that use projects or problems to drive the learning process. Students learn about a subject through the experience of problem solving, by working in groups with the help of facilitators. Assessment is performance-based and authentic.
Studio-based learning	Approach from professional education, where students undertake a project under the supervision of a master designer. It uses a learning cycle of construction, presentation, critique and response, that is repeated until project completion.
Other	Other approaches different from the previous categories.

questions. This means that inclusion and exclusion criteria must be carefully chosen and applied to the data retrieved. In our screening process, 4 inclusion criteria (IC) and 20 exclusion criteria (EC) were used, among them:

- IC 1. Studies that address the use of OSP to learn/teach Software Engineering should be included, regardless of their use being in SE programs or in other programs;
- EC 1. Documents not written in English should be excluded (the universality of this language supports reproducibility);
- EC 2. Documents whose full text is not available should be excluded;
- EC 3. Studies whose main content is not related to learning or teaching Software Engineering should be excluded.

The whole set of inclusion and exclusion criteria can be found in our mapping study website[7].

After we searched the papers and eliminated the duplicates, we applied two filters. In the first, two of the authors screened the remaining papers. Each reviewer examined title and abstract of each paper, and marked it as included or excluded, using the previous criteria. Subsequently the results were compared. A third reviewer analyzed conflicts and took the final decision. In this first step, 156 papers were included. In the second filter, two reviewers reexamined the remaining studies, skimming through introduction and conclusion. A third reviewer compared their results, and again, took the final decision. A total of 53 papers were selected as primary studies to be considered for answering the research questions.

TABLE IV: Assessment Perspective

Category	Description	#
Does not apply	Work is not related to an experience where assessment is necessary.	15
Not specified	No assessment is mentioned in the paper.	10
Student perspective	Students assess their learning by either self- or peer evaluation.	23
Faculty perspective	Students are assessed by faculty or teaching assistants.	14
Product perspective	Specific criteria are defined to assess students products.	2

Classification Scheme. Our classification scheme was developed by means of keywording relevant topics addressed by the research questions RQ1, RQ2 and RQ3, and refined during reading of the papers. As a result, the following facets were defined for classification purposes:

- *Software Engineering Area*, i.e., the SE topic(s) addressed in the study (software engineering in general, requirements, modeling and analysis, design and architecture, quality, testing, evolution and maintenance, development and construction, process, management

[7]http://sites.google.com/site/dmcnascimento/fie2013

TABLE V: Assessment Type

Category	Description	#
Does not apply	Work is not related to an experience where assessment is needed.	15
None	No assessment instrument is mentioned in the paper.	12
Exams	Students are assessed by means of written exams.	2
Reports	Students should write a report for assessment.	8
Software artifacts	Students are assessed through developed software artifacts.	12
Passing Tests	Automated tests such as unit tests are used to assess performed work.	1
Interviews	Interviews are conducted to assess learning.	5
Seminars	Students are assessed by their performance in seminars.	7
Portfolio	Students should produce a portfolio as result of their work.	0
Exercises	Students are assessed by means of exercises.	2
Surveys	A survey is conducted to assess learning.	18

and configuration management), based on the SWEBOK [5];

- *Research Type*, i.e., the research approach used in the papers. Table II provides a description of each category, adapted from Petersen et al [2];
- *Learning Approach*, i.e., which pedagogical approach was applied together with OSP in SE courses. Table III presents a description of each category;
- *Assessment Perspective*, i.e., the perspective from which student learning is evaluated – see Table IV;
- *Assessment Type*, i.e., the assessment instrument applied to verify student learning – see Table V;

The item "does not apply" was added to some facets to deal with situations in which no categorization could be applied.

Data Extraction. The data extraction strategy was designed to gather the information required to address the objectives of this study. Each paper accepted by the screening process was fully read to collect the required data. The extracted information was title, author(s), venue and year of publication for each selected paper, as well as the required information to classify it according to each defined facet. For some facets (e.g., software engineering area, assessment perspective and assessment type), studies were classified in more than one category.

III. Mapping

In this section, data extraction results are presented (Section III-A) and discussed (Section III-B) based on the previously defined facets and research questions. Some limitations of the mapping study are also discussed (Section III-C).

A. Outcomes

One of the main contributions of mapping studies is the *map*, usually a bubble plot representation of different facets or perspectives. Figure 2 presents the map for this study.

Since the main purpose of our mapping study was to find out how open source projects have been used in software engineering courses (RQ1) – and we were also interested in the learning approaches used (RQ2), we decided to arrange the map as a combination of the *Software Engineering Area* facet with the *Learning Approach* and *Research Type* facets (Figure 2). Other information can be found in our previously cited mapping study website.

Open Source Projects in Software Engineering Education. Concerning the *Research Type* facet, most papers fit into the *Solution Proposal* category, with 31 studies standing for 58.5% of the selected papers. Regarding the *Software Engineering Area* facet, 71.7% of the papers address *Software Engineering in general* (Figure 2).

Only 15 studies focus on specific software engineering areas such as design/architecture with 7 papers [7], [8], [9], [10], [11], [12], [13] and Evolution/Maintenance with 5 papers [14], [15], [16], [10], [17]. We did not find any paper relating open source software projects with specific knowledge areas such as requirements, process, project management or configuration management, which is the reason why they are not shown in the map. Conlon and Hulick [18] discussed the feasibility of building or buying software, contrasting it with the possibility of "downloading" software, encouraging students to analyze such questions.

Some studies were hard to classify within the Research Type facet, because their goals were not clear. For instance, Toth [19] presents a solution proposal but also discusses learned lessons. Likewise, Gehringer [20] states it presents the results of a *Survey*, but it is more likely to be categorized as an *Opinion Paper*.

Very few studies paid explicit attention to research methodology: Jaccheri and Osterlie [21] applied the action research method, while Krogstie [22] and McCartney [17] used the case study method.

We classified some studies in more than one category in the same facet, leading to different totals in the map. For instance, the studies [23], [8], [10] were categorized twice in the *Software Engineering Area* facet.

Learning Approaches in Software Engineering Education. Concerning the learning approach, Figure 2 shows that most selected studies – 22 studies (41.5%) – applied the traditional *Project Method*.

Two studies have explicitely mentioned the use of *Active Learning* [24], [12], while four studies mentioned *Project-Based Learning* [25], [26], [27], [28], but neither presented detailed explanations on how these approaches were applied. Papers [29] and [30] used *Service Learning* and *Collaborative Learning*, respectively, and were concerned with how these methods were applied.

Assessment of student learning. Tables IV and V help to answer the research question on the assessment of student learning (RQ3).

Table IV shows that 25 studies (47.2%) do not deal with the assessment of student learning; from these studies, only 15 describe an experience where assessment was not needed. The student perspective was more frequently used than the faculty perspective, and 17% of the studies applied both perspectives.

Table V presents results related to the instruments used for assessment. The most used instrument was the *Survey*, with 18 studies, followed by *Software Artifacts* with 12 studies, even though other instruments were used as well. *Surveys* and

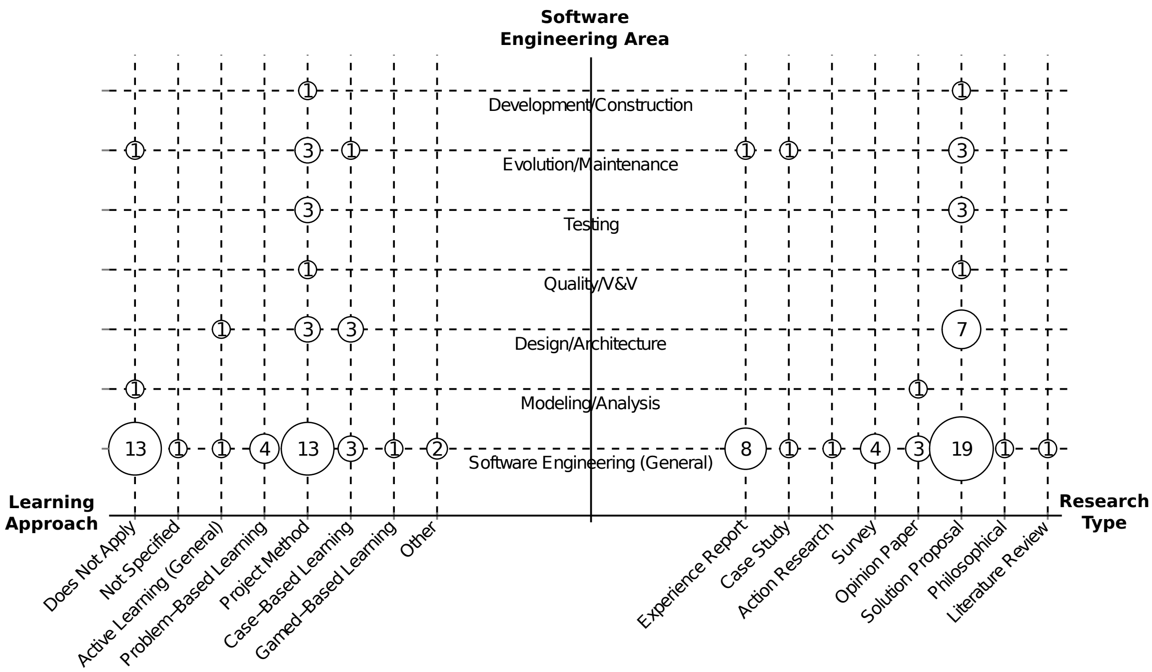

Fig. 2: Learning Approach *versus* Software Engineering Area *versus* Research Type

Interviews were the main instruments used to gather student feedback on their perception about their own learning.

Only Butcha and colleagues [14] presented detailed criteria related to the evaluation of students outcomes. Paper [31] was about software tests and the evaluation criterion was that the developed tests should find bugs. Paper [32] talks about the students' opinion about the course, and instructor's opinion about students' results, even though it did not mention the instruments used. Two studies addressed the *Peer Review* assessment type [33], [13].

Temporal View and Publication Sources. Figure 3 shows how this theme has been approached along the years. Conferences have been the typical venue for publishing results (42 studies). Discussions addressing open source software and software education begin to show up in 1998, although the term "public software" [34] was used instead of "open source". Nevertheless, more than half of the selected studies has been published in the last five years (8 in 2008, 11 in 2009, 2 in 2010, 9 in 2011 and 5 in 2012). Finally, the main forums on the theme that emerged from our mapping study were ITiCSE - Annual Conference on Innovation and Technology in Computer Science (8 studies), FIE - Frontiers in Education Conference (7 studies) and SIGCSE - ACM Technical Symposium on Computer Science Education (4 studies).

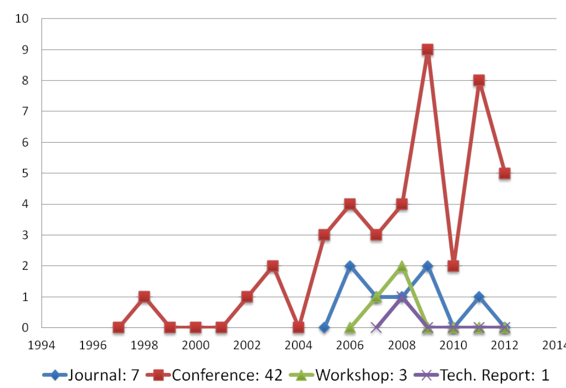

Fig. 3: Publications *versus* Venue *versus* Year

B. Discussion

Need for research methodology. One of our main findings is that most studies are not concerned with research methodology: among the relevant selected papers, two of them used case studies, only one used action research, and none of them considered the use of experiments. This happens in contrast with the recent growth of evidence-based software engineering. Software engineering research has been submitted to an increasing scientific rigor in the last few years. Furthermore, software engineering education is also an interdisciplinary area that can benefit not only from software engineering research methods, but also from research approaches of areas such as sociology, anthropology, pedagogy and communication. Therefore, it seems important to pursue interdisciplinary research, and to identify which research methods are more appropriate in this intersection.

Learning approaches for particular SE areas. Due to the number of available open source software systems, ranging in different sizes, domains and complexity, we believe they are an important source of examples to learn software design, architecture and quality [35]. However, we found very few studies using case-based learning, three of them related to design and architecture, one to evolution and three to software engineering in general.

No study focused on learning requirements, configuration management and project management areas. Nonetheless, if we recall that OSP also deal with management and requirements traceability, that developers in OSP largely use configuration management tools, and that they must deal with time and effort estimation, it seems that these specific areas would benefit from open source projects.

We also believe that additional work in other areas such as evolution, quality, design and testing is important, especially in proposals dealing with active learning approaches.

Assessment. It is important to state that student assessment deserves more thorough work, by establishing objective criteria to evaluate students' products, and defining learning objectives in terms of performed tasks, desired skills and attitudes. Finally, both student and faculty perspectives are needed to formative evaluation. Thus, they must be combined in the assessment repertoire of SE education.

C. Limitations

Results of this study must be interpreted within the following limitations: (a) publications that were available after October 2 and 15, 2012 were not accounted for; (b) results may be subject to the limitations of the automated search engines of each digital library used (IEEE, ACM, Scopus, Springer, Science Direct and Engineering Village); (c) only studies written in English were selected; (d) the classification of each paper with respect to the *Research Type* facet was not straightforward (e.g., many studies are related to experience report, opinion paper and proposal of solution); and (e) due the lack of time, the classification of each study was performed by only one reviewer.

IV. CONCLUSION

This work presents a mapping study that summarizes and categorizes information on how open source projects have been used in the context of software engineering education. The goal was not verify the use of open source software as a tool or computer environment, but to identify initiatives where students participate in the development effort of open source software, because this allows students to deal with real projects, often large and complex, such as the ones they will find when working in industry.

Results show some trends and issues in the research community: popularity of solution proposals as main research type; few papers focusing on specific software engineering areas; use of the traditional project method as the main learning approach, and lack of criteria to evaluate students' learning based on their outcomes or developed skills. These trends and issues provide future directions for research.

We plan to perform snow-balling to assure improved coverage of this mapping study, and, with improved results, to extract additional data and classify the studies according to other facets such as: level of control of the OSP, how the OSP is chosen, reasons to introduce OSP in the courses, and how the approach is included in the curriculum.

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A Tale of Two Projects: A Pattern Based Comparison of Communication Strategies in Student Software Development

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Abstract— **Preparing students for the communication realities of software development is as difficult as it is important. Training in specific genres of oral and written communication is vital, but successful software developers must also design their communication, choosing appropriate genres and styles to fit the audience and context. We introduce a pattern language for classifying and describing communication strategies. Communication Patterns serve both as an approach for rigorous qualitative analysis and as a library of established practices that students can draw from. The approach has clear links to software design patterns and highlights the fact that communication, like software, is a designed artifact. We focus on two software projects from our case study repository, using Communication Patterns. The two case studies have a great deal of overlap in objectives, stakeholders, responsibilities and timescales, but the outcomes are drastically different. Through patterns, we assess communication at strategic and tactical levels, and we find major differences in communication choices. We also discuss our attempts to expose students to Communication Patterns in the classroom. We conclude with a look at future efforts to deepen our pattern library and diversify our approaches to building and using them.**

Keywords—Software Engineering; Communication; Design Patterns; Case Studies

I. Introduction

As computer science and software engineering educators, we are charged with preparing students for the challenges of the software industry. There is a consensus among software professionals that some of the biggest challenges in this relatively new field lie in the decidedly old technology of communication - oral, written, and otherwise - between humans. The sheer invisibility of software and the constant change of the technology make it difficult to build a common vocabulary. Software development is complex, due not only to the functionality of the software itself, but also to the competing and often conflicting goals of different stakeholders. The wide range of application areas draws together stakeholders with different backgrounds. Moreover, software developers work in a world of incomplete, imperfect information, and they must be proactive in seeking input from other stakeholders [1].

Although many professional software engineers are effective communicators, they typically do not have practice in articulating what it is that makes communication effective (or ineffective). That is, their knowledge remains at a tacit level, from which it is difficult to impart to students. A major obstacle is the lack of a common language for discussing the specialized forms of communication that take place in software teams and between developers and other stakeholders. "Whereof one cannot speak, thereof one must be silent." [2]

The situation is improving. Agile development methods in particular stress the importance of flexible communication practices, deployed as the developers see fit (in contrast to the static organization and communication practices of waterfall development). Ward Cunningham's WikiWikiWeb, the "original wiki", contains a wealth of named patterns for agile practices, many of which fall into the domain of communication [3]. The Scrum framework is notable in this respect for the way in which it names - and therefore honors - particular communication practices (standup meetings, retrospectives) that would otherwise remain tacit and invisible to students [4].

Of course, instruction in communication has long been part of the computer science and software engineering curricula, but typically there has been a divide between the formal, highly technical documentation taught within the disciplines and the "softer" (but no less important) instruction that is typically provided through ancillary courses. A recent positive development is a project to bring the expertise of writing instructors into the computer science and software engineering curricula [5]. This project has produced a repository of assignments that engage students in authentic communication activities. Some initial effort has been made to categorize the genres of communication that arise in software development settings [6].

We enthusiastically endorse this focus on training students in relevant genres of communication, but our focus is slightly different. We are concerned with the senior student who - armed with an array of communication skills - engages in a team software project, with its intimidating mixture of freedom and responsibility. She must think both strategically and tactically about the current problem at hand and the form of

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communication that will solve it most effectively. This is not a new concern: Aristotle alludes to it in his definition of rhetoric ("the faculty of observing in any given case the available means of persuasion"[7]) , and modern rhetoricians like Linda Flower conceive of communication as “strategies for problem solving” [8]. Students in computing disciplines enjoy problem solving and are well versed in principled approaches to solving technical problems. We want to give them similar tools for problem solving in the communication arena.

II. Communication Patterns

The architect and designer Christopher Alexander used the term “pattern language” for his process of identifying and using recurring structures and design [9], then famously introduced the possibility of patterns for software design. The most popular and familiar product of this crossover is the concept of Design Patterns [10] that are used in object-oriented design by using customizable classes at different levels of abstraction for problem solving. As Alexander describes it, “[e]ach pattern describes a problem that occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice.” Hence patterns denote the essence of solutions to problems without overspecifying them - a key advantage when dealing with the fluid nature of the “softer” aspects of software development. A pattern language approach was used to analyze the recurrences of configurations of roles in software organizations, “using patterns in a generative way” [11]. As with natural language, patterns from within an established pattern language can be combined or morphed into new patterns when new situations are encountered. This was applied to the concept of Organizational Patterns [12].

We introduce Communication Patterns as a tool for rigorous qualitative and quantitative analysis of software project communication [13], at varying levels of abstraction. In particular, we distinguish between *strategic* and *tactical* patterns.

Strategic patterns represent high-level communication choices that practitioners can make at a time and place outside of the communication act itself. For instance, Scrum instills certain communicative practices as required components of a sprint: an example would be the retrospective activity that follows the completion of a sprint, where team members each answer predefined questions: what went well, what could be improved, what should be changed in the process for next sprint. Another strategic choice is the style of daily meetings, requiring participants to stand and thereby keeping the length of meetings minimal.

Tactical patterns represent lower-level decisions taken while the communication is taking place: for instance, during a face-to-face meeting, or during the shared editing of a document. Again taking Scrum as an example, the structure of daily meetings is determined at a strategic level, but after the preliminary standup component, where each participant answers the “questions three”, there is a strategic choice to let participants choose the next activities to do. In action, this “free time” is an opportunity for participants to act tactically, choosing (for instance) to engage in pair programming, ad-hoc brainstorming, whiteboard sketching, and so on.

Each communication pattern describes a set of properties associated with a communicative act. Patterns may define particular genres of communication (for instance, client demo, requirements gathering session, burndown chart), but others describe properties that cut across genre (for instance, given “brainstorming session” as the genre, whether to perform the act synchronously with a facilitator, synchronously with all participants acting collectively, or asynchronously with participants providing input independently). In this way, patterns can be overlaid on one another, and a single communication act can be the combination of multiple patterns.

Each pattern captures particular aspects of the communication act, along various axes of interest. Table I describes the main attributes and the general structure of a communication pattern. We use the six basic journalist questions of *who, what, where, when, why and how* as a guide to determine what we capture about the communication. These aspects of communication vary from the objective (medium of communication – telephonic, video, face-to-face) to the subjective (style – informal, formal).

TABLE I. Communication Pattern Structure and Attributes

Attribute Category	Attribute of Communication Pattern
What	Established Scope (Input)
	Expected Result (Output)
Who	Type of participants
	Number of Participants
	Direction
	Role or Authority
	Shared knowledge or goals
How	Style
	Type of Artifact
Where	Medium
	Physical Location
When	Duration
	Synchrony
	Frequency
Why	Perceived Benefits
	Associated Risks

The expected scope of performing the communication act can be considered the input, like a meeting agenda or bug report, and the results produced can be considered the output, whether it is a written document or a change to one like a design change or code change, or an implicit decision or solution.

The duration of the communication act can vary from very short like a quick chat in the hallway or of a pre-defined length like a fixed time meeting. The frequency of occurrence of the communication act forms a part of the "when" attribute. Whether the nature of the communication act is synchronous like a face-to-face meeting or asynchronous like email may contribute to its urgency.

The attributes under the question of "who" describe whether the participants in the communication act are actively contributing, as in a directed presentation where the presenter is the main contributor and the attendees may be reactionary contributors, whether there is a hierarchy of authority and position among them or whether they are equal contributors like in a brainstorming session. The nature of the communication pattern is also determined by what the participants of the communication act have in common: whether they share the same goals but have different types of knowledge, like different teams collaborating on the overall system design, or if the participants share knowledge, like within a team working on a component, etc.

The nature of the communication is also determined by the presence of an *artifact*. An artifact can be any object affecting, assisting or documenting the communication. It can range from formal design documents, presentations to informal meeting notes or sketches on a whiteboard to explain ideas. Artifacts often become central to the communication act and even evolve as the communication does.

III. Communication Patterns in Case Studies

In earlier work, we developed detailed case studies in communication, based on real, "home grown" student capstone projects [1]. To illustrate the use of Communication Patterns, we use two connected case studies from our repository. The two case studies are referred to as *Seabase I* and *Seabase II*. As part of the Seabase project, teams from Computer Science and Mechanical Engineering worked with Mechanical Engineering professors to develop control software for a crane mounted on a ship for the US Navy. The data for the Seabase I project is primarily in the form of emails and detailed meeting minutes, whereas the bulk of the Seabase II project data is available as emails and recorded conversations.

Seabase I refers to the first three-person Computer Science team which participated in the project over the course of a semester. A second, similarly structured team which we call Seabase II took over where the Seabase I team left off and completed the project over the next semester. One student was a member of both the teams. Their immediate client was a professor in the Mechanical Engineering department Dr. Hank Taylor, who represented the interests of the US Navy, the sponsors. (All names in the case studies are pseudonymous.)

The Seabase I team consists of JoAnn, Bob and Ken and the Seabase II team consists of Bob (from Seabase I), Denise and Justin. From the overall impressions, it appears Seabase I did not succeed as a project, as the team did not produce the desired crane controller code and Seabase II appears to be a relative success as the team produces the code deliverables. It also appears that the Seabase I team spent a lot of time stuck in "requirements churn" while the Seabase II team spent significantly more time on the code.

The broad forms of communication in a student project are typically limited to face-to-face meetings with the client or internal to the team, email and occasionally phone conversations. The two projects were similar in terms of the forms of communication employed, time span of the project and the stakeholders involved. These similarities allow for fair comparison of communication patterns in the projects.

If we look at the difference in Communication Patterns across the two case studies, then more differences in behavior emerge. One major different between the two projects was in choice of focus. The Seabase I team's efforts were directed towards determining whether to pursue "the big picture" or "jump into coding" and dealt with many different types of stakeholders, and conflicting requirements. The Seabase II team started with established requirements and immediately wanted to "jump into code" and dealt primarily with one stakeholder.

At a finer granularity, the communication patterns allow us more insight into the communication choices that took place in the case studies. As the major types of strategic communication in the context of a student project tend to be limited to face-to-face meetings and emails, a lot of the attributes concerning the medium of communication, number of participants and role and authority hierarchy of participants are common across most of the patterns. However, differences in style, synchrony, scope, artifact, expectations and results emerge. Reading through the case studies, we encounter not only patterns but also *antipatterns* – commonly occurring but counterproductive communication choices. Some examples of patterns and antipatterns are discussed here.

Unheeded Request (antipattern): This antipattern occurs when requests are repeatedly acknowledged but not answered. It is associated with an asynchronous communication mode, where the requester cannot achieve an immediate confirmation or acknowledgement; in the time after a request is made, communication on other topics fills the void, and no response to the request emerges. In particular, the asynchronous *Remote checkin* pattern that Dr. Taylor and the team employed is susceptible to Unheeded Request.

Dr. Taylor, the client, repeatedly asked the Seabase I team to familiarize themselves with the programming environment MATLAB at several moments over the course of the project. Internally, the team acknowledged his request, but no team member followed up on it, and replies on the topic of MATLAB were left out in favor of discussion of other matters. By the end of the semester, the team members had still not learned MATLAB. Excerpts from the Seabase I case study are presented in Table II.

TABLE II. UNHEEDED REQUEST

Occurrence	Excerpts
Seabase I Week 3	(excerpt from Meeting Minutes) TO DO LIST -share the matlab app and check it out, check out simulink in helpdesk, try to get familiar with d-space -do flow plan/chart of functions that are needed
Seabase I Week 5	(excerpt from Meeting Minutes) TO DO LIST *4.* LEARN matlab (faculty are starting to ask about it) – (JoAnn) *5.* pass matlab cd around (Bob)
Seabase I Week 7	(excerpt from Meeting Minutes) TO DO LIST 1. learn Matlab/simulink - all
Seabase I Week 9	(excerpt from Meeting Minutes) SUMMARY -Really should run the simulation Hank sent early in the term, read the readme and it will tell how to run it exactly -Its CODE to set up the scheme in matlab, not click and drop GOALS for [next meeting] -have tried simulation (see above) -have spent at least four hours with matlab *DETAIL* -Later suggestions from Hank: when playing with demos in matlab, try adding an … Do an empty scheme in matlab that is similar to the crane … as our next goal or deliverable
Seabase I Week 10	(excerpt from Meeting Minutes) *SUMMARY* -Have one teammate become an expert in matlab s-functions *GOALS for this meeting:* -Get empty prototype in matlab going - all

Tutoring Session (pattern): This is the pattern of synchronous learning in the presence of a tutor. The Seabase II team, when tasked with learning MATLAB, spent some time trying to learn from Hank's directions and reference material, but solicited Hank's time to ask specific questions about the language and platform where Hank (in the role of the tutor) resolved their queries through demonstration. Ironically, the team realized that the MATLAB portion of the code only sets up the initial flow of control for the C code and did not require extensive MATLAB knowledge. They were then able to work on the controller code. The different participants were able to arrive at shared knowledge.

Artifact Facilitated Discussion: This pattern occurs when the presence of an artifact, like a diagram, or piece of code, or design document becomes the centre of discussion and facilitates and captures the understanding of the participants. It is associated with communication situations where participants have large gaps in their shared knowledge. It requires a synchronous communication setting, so participants can confirm understanding with each other through the "catalyst" of the artifact.

The Seabase II team made the "flowchart" of the existing sample code that client, Dr. Taylor, asked for. This served them in many ways. It demonstrated to Dr. Taylor that the team understands the code clearly and was serious about getting the project done – hence an instance of the *Show Your Work* pattern. It became the subject of discussion and most code related questions were referred back to the chart and helped ground what they knew and needed to know. All communication between the Seabase II team and Dr. Taylor after the creation of the "flowchart" diagram was primarily centered around the diagram of the code that the diagram refers to. The client and the CS team members would often point to different places in the chart to describe what they are talking about.

The Seabase I team had also been repeatedly asked by the client to produce a flowchart, but they did not produce anything that would impress the client (another instance of *Unheeded Request*). Excerpts from the Seabase II case study for artifact-facilitated discussion are presented in Table III.

TABLE III. ARTIFACT FACILITATED DISCUSSION

Occurrence	Excerpt
Seabase II Week 4	(excerpt from conversation) Dr. Taylor: Do you know from that [the chart] what values you will need? (They look at the diagram and discuss some input parameters like sway, swing angle, hoist, lock, etc.) Dr. Taylor: It might be a good idea to have this picture when you talk to them.
Seabase II Week 6	(excerpt from conversation) Denise: This is where we need some help. So this is what happens in the code [pointing at Denise's chart] [Denise explains on her chart that she has color coded based on which locks are her responsibility and how the chart describes the blocks.] Dr. Taylor: Can you show me some example within the code? This is great. Don't throw this out. Is this hand-drawn?
Seabase II Week 9	(excerpt from conversation) [They are looking at the diagram and Denise is explaining.] [Denise explains how init runs and affects other S-functions. Dr. Taylor asks what some of the functions do. Especially init.] Dr. Taylor: Oh that is sweet! That makes sense now. So when this one is high, that value becomes high and this one goes low, that value is low. I finally get it. Dr. Taylor: What is setup? [Denise explains what setup is.] Dr. Taylor: I love it. I love it! The beauty of something like this is that I can understand it. Someone with a high level of knowledge of how the code or the function works can look at it and completely understand it.

Translation to Familiar (antipattern): This antipattern occurs when participants translate a term to a familiar version, due to differences in perception of the term in their respective domains or because of desire to change to a more convenient form. It is associated with communication situations where there are gaps in shared knowledge.

TABLE IV. TRANSLATION TO FAMILIAR

Occurrence	Excerpt
Seabase I Week 4	(excerpt from Meeting Minutes) • good starting point might be to take the existing code, which has no flow chart, and flow chart it out so ME's have way to see what's happening with the control… • CS team come up with block diagram of how to chunk the functions into s-functions and write the s-functions and test.
Seabase I Week 6	(excerpt from Meeting Minutes) 1. Dave thinks old fashioned control flow graph is overwhelming and unreadable and could be some UML instead 2. use case diagram not helpful, feasibility study not helpful 3. could do UML activity diagram or state chart diagram, might be helpful 4. Bob thinks Dr. Taylor might want a block diagram, not exactly a flowchart

The Seabase I team discussed with Dr. Taylor, the client, about the need for a "flowchart" explaining what the current code does. As the Seabase II team eventually discovers, Dr. Taylor's intended meaning for this term is a high-level block diagram indicating input and output. The term "flowchart", however, gets translated to different terms like "control flow graph" or "activity diagram" – each of which have a specific meaning within the team's "comfort zone" of computer science, but which entail more detail and effort. Excerpts from the Seabase I case study illustrating the translation to familiar pattern are shared in Table IV.

TABLE V. DECIDING GRANULARITY OF FOCUS

Occurrence	Excerpt
Seabase I Week 3	(excerpt from Meeting Minutes) • general discussion of how quickly move into coding or working with matlab, thinking we should be doing more planning and big picture and maybe UML and such, rather then leaping into coding as sounds like Dr. Taylor thinks we should??
Seabase II Week 1	(excerpt from conversation) Dr. Taylor: …we could start talking about the big picture a little bit. Denise: Are we building a model like this or are we building one S function or do we have it plug into a larger system? Dr. Taylor: … And you would want to do both - learning Matlab and dissecting the code simultaneously… Learning the code will be kind of orthogonal and more challenging. Denise: We are programmers; we are just dying to rip into the code. Dr. Taylor: Is that so? That's good…

Deciding granularity of focus: The pattern of discussing and determining which granularity to focus on for the project is an interesting pattern. Participants can get caught in the repeating pattern of reviewing granularity of operation but spending more time reviewing than actually operating. Both projects discuss and decide whether they should be focusing on the "big picture" or they should be "jumping into code".

The Seabase I team discusses it repeatedly and decides to divide the team and focus at different granularities. The Seabase II team also decides about dividing up the team and operating at different foci and followed up with it both sets of operations for looking at the big picture and making the overall system diagram and jumping into code. Table V describes some excerpts from both case studies of the discussion about granularity of focus.

IV. THE CLASSROOM EXPERIENCE

In two pilot studies, we exposed computer science and software engineering students to the notion of communication patterns. In earlier work, we engaged senior-level software engineering students in open-ended investigation of communication using our case studies [1]. Here we were interested in seeing what happens if we bring instruction earlier in the curriculum and frame the investigation in the context of our pattern language.

Two separate instances and two different classes – a senior level course and a junior level course, were selected to allow students to be familiar with communication patterns. The junior level course is a team software project course, required for computer science and software engineering students, where teams of three students each work on a common project given by the instructor. The senior level course is a lecture-based course on software process and management, required only for software engineering students. In both the classes, we were given two sessions of seventy-five minutes each to present our material and engage students in activities.

A. Activities

The first session in both courses was introduced students to the communication pattern idea through the Seabase I case study and motivated them to identify communication patterns of their own from the material. A brief description of communication patterns was given, with examples taken from the Seabase I case study. Students in groups of 3-4 identified patterns in different sections of the story and presented the patterns they identified with the class.

For homework between the first and second sessions, they identified patterns from their personal experiences of working in teams for software development. In preparation for the second session, they were also asked to read part of the Seabase II case study and identify patterns. Many students shared their experiences from industry or working in teams for class projects, and they identified different types of communication patterns they employed.

In the second session, the students compared communication patterns in the Seabase I and II case studies. The emphasis in this session was moving from identification to assessment: what choices were effective, and which were less so? They were divided into groups of 3-5 and asked to find communication patterns that were different from the ones already identified and presented in the material. The groups that presented them discussed the merits of the identified communication patterns.

For the junior level course, a Seabase I *vs*. Seabase II timeline was constructed on the whiteboard and patterns were plotted on it using paper and tape. The occurrences of patterns, their order and relationship with each other were plotted, to get a visual overview of communication in the entire project. Then students voted for their favorite patterns and the selected patterns were discussed further for their merit. Students identified different attributes of the selected patterns and discussed what attributes they would change to improve it.

There was a consensus that in both projects, making requests to the client more "directly" would have clarified some uncertainties earlier. When we pressed them for a strategy to increase directness, there were no concrete ideas forthcoming, so we guided them toward a "structured questions" pattern. Some students suggested switching to a more "professional" tone. In one instance, a Seabase I team member chose to broach an uncomfortable question through a phone call to the client, rather than the usual medium of email. Some students questioned this decision, and the topic of appropriate situations for synchronous ad hoc communication like a phone call was discussed.

In both the classes, the discussion was quite lively, and the students were able to identify many different types of patterns with ease, specially strategic and tactical patterns. However, for the material that they were supposed to turn in as homework assignments, the answers were minimal for many students.

In both attempts, we were able to get students to identify communication patterns but not really use them in many different ways and their purpose as an analytical tool was not explored.

For the junior level class, we administered pre- and post-evaluation surveys to determine attitudes towards the importance of communication. 16 students in all responded: 4 with the pre-evaluation survey only, 1 with the post-evaluation survey only, and 11 with both surveys. Students were presented with statements about communication and were asked how much they agreed with the statement on a Likert scale of 7 points ranging from -3 to +3. The statements were designed to assess the student's attitudes towards the importance of communication in the software context, whether communication can be improved, whether the communication patterns idea was easy to understand, whether they thought the communication patterns were useful, whether the case studies were a good tool to illustrate the communication patterns and whether they were satisfied with the current level of communication instruction in the curriculum. We also asked the students open ended questions about their experiences of working in teams for software development and their perception of the different types of activities involved in the software context.

For the senior level class, the level of exposure to industry and software development in teams experience was captured in the first homework assignment.

B. Findings

The responses to the survey questions indicated that a large majority of students consider communication something that can be analyzed and improved, and something that they as future software developers must have responsibility for. There was movement in attitudes in the pre- and post-evaluation results, but the sample size was too small for it to be significant. In the survey after the two sessions, all students indicated that communication patterns are easy to identify, and a large but smaller majority stated that they are easy to understand and useful.

We share some excerpts from the attitude assessment surveys given to juniors. In the survey to assess attitudes towards communication, one student wrote "It is the nature of the major, those who are software developers or programmers in general lack basic communication skills / social skills." and went on to say "Communication is natural and you are either good at it or you are not. I feel that the assigned task to complete is, by far, more important than how we '*communicate'* about it". This statement raises an interesting speculation: do some students diminish the value of communication in their field because of an impression that it cannot be learned or improved? We can see that the importance of communication in the software process was not necessarily evident to all the students even after exposure to the communication patterns idea in the case study framework.

In the junior level course, among the 4 respondents with internship experience, we find a more amenable to considering communication in the software project context. One student who had two software internships shared their impressions and reflections on the software process in industry, "Two programmers discussing a fix for a bug often looks like a bullfight, I admit…", their impression of work in teams, "As I understand it, most teams spend far more time arguing, flailing wildly on their keyboards, etc." and the place for good communication "The better you know the *people* in your team, the better you communicate."

When asked to make a chart describing their impression of the time taken by major activities in a typical software project in the industry, the student with multiple internship experiences estimated ~20% time on "status updates for all members", ~15% of time on "current events chat", ~30% of time "discussing present issues, assigning work, etc." and ~35% "working on code and design, working together as needed, resolve bugs where possible, any code work". In contrast, a student without industry experience described the main kinds of activity in professional software teams as ~35% of time "programming", ~15% of time "refining code", ~20% of time "testing", ~12% "implementation details", ~18% "design details". We see that exposure to industry tends to make the students appreciate the place and importance of communication as opposed to students who have not had software project experience in the industry, where the belief is that programming, implementing, testing and design are the main function and communication is not a primary focus.

C. Conclusions

In both the classes, we feel that the time constraint of only two sessions was insufficient for explaining the importance of communication and of communication patterns. More time is needed to discuss why students would use communication patterns, how communication is important in the big picture, and how the communication patterns are meant to be a tool to analyze communication in software projects.

We conclude that with students earlier in their career we must make a better case for the importance of communication, and demonstrate that communicating effectively will be part of a software professional's job regardless of their role or position. It would help if students are given an opportunity to use communication patterns in their own team project contexts. This could be done relatively easily in the junior software project course, by including exercises that ask students to reflect on their own team communication.

We are pleased to see that communication patterns appear to be easy to use and understand. They allow the students to think about communication analytically through relatable student case studies. Many students still do not believe that communication as a whole in the software project context is important, but prolonged exposure to communication patterns in student case studies or in industry software project situations should help motivate a greater appreciation of the realities of the software development process.

V. FUTURE WORK

Our pattern concept is still in a proof of concept stage. To make it a truly useful tool, we must enrich our library of patterns with more real project examples. One source we intend to target is the vast array of open source software projects. Open source projects capture communication in different forms than traditional industry projects and their nature of organization and activities is also different.

As part of the classroom activities, the timeline of the communication patterns in the two projects was plotted. It helped serve as an artifact for discussion but also allowed us to observe the "pattern of communication patterns", displaying the times in the project characterized by bursts of communication acts and the type of communication in that occurred in different phases. The "shape" of a project indicated by patterns of patterns can help determine "hot spots" of communication activity, establish correlations between patterns, and define classes of software project along communication lines.

We feel that it is important for students to identify pattern instances, as well as new patterns, on their own, but we would like to build more structure into this discovery process. We intend to explore the POGIL technique [14] for inquiry driven learning. POGIL provides a framework for guided learning by inquiry, with an established team structure and process. In addition to keeping students on track, it provides a good model of team communication.

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Can Natural Language be Utilized in the Learning of Programming Fundamentals?

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***Abstract*—The complexity and importance of learning programming fundamentals (*i.e.*, sequences of sentences that express actions, conditions, and repetitions in computing) for undergraduate students has motivated the development of an intense educational research area. One frequently studied problem is the difficulty in the learning of traditional context-free grammars which are present, for example, in programming languages such as Pascal and C. This study experimentally investigates the use of natural language in the learning of programming fundamentals by two groups of undergraduate students without prior knowledge of programming and compares its use with that of a traditional grammar language. Results suggest that the use of natural language is a good alternative, despite the small differences, to the use of traditional programming languages defined by context-free grammars. This alternative is attractive and promising because the student does not need to learn a formal grammar to learn the fundamentals of programming.**

Keywords—programming fundamentals learning; CS1; natural language programming; human factors.

I. Introduction

The learning of programming fundamentals (*i.e.*, sequences of sentences that express actions, conditions, and repetitions in computing) by undergraduate students is a notoriously difficult task. Programming languages such as C and Pascal are often used for this purpose. These languages are defined by grammatical constructions typical of the context-free class in the Chomsky hierarchy [1]. The main features of these languages are: (i) the generation of nested sentences that may be imperative, conditional (*e.g.*, "if"), or repetitive (*e.g.*, "while"); (ii) the existence of markers for the beginning (*e.g.*, "begin" or "{") and the ending (*e.g.*, "end" or "}") of blocks of sentences; (iii) the use of balanced parentheses to change the priority of operations within expressions; and (iv) the explicit declaration of the subject (the thing about which something is said) in all clauses by means of parameters and arguments of functions and procedures.

Natural language grammars, on the other hand, differ from context-free grammars in that they: (i) do not usually produce texts with nested sentences; (ii) use capital letters to mark the beginning of a sentence; (iii) use punctuation (*e.g.*, periods and question marks) to mark the end of a sentence, and use commas to separate clauses within a sentence; (iv) allow the generation of expressions composed of articles, prepositions, and adverbs; and (v) allow the writing of sentences in which the subject is not explicitly stated.

This study investigates the use of natural language in the learning of programming fundamentals and compares its use with that of a language with traditional grammar. A microworld composed of robots, walls, and disks was used as the source of problems, and two languages (and corresponding compilers) were developed: one following a classical context-free grammar notation (MRt), and the other with a grammar similar to that of the Portuguese language (MRp). The learning of programming fundamentals was experimentally investigated using two groups of undergraduate students with no previous experience in programming. Group I used the MRt language, and Group II used the MRp language.

One of the main contributions of this work is the way the study was planned. With the intent of studying only the effects of the type of grammar between groups, the experiment was carefully designed so that all other variables that might affect learning remained constant, with the type of grammar being the only variable to be measured.

The rest of this paper is organized as follows. Section II describes the two main streams of research in the field that motivated this study. The materials and methods used in the experiments are described in detail in Section III. In particular, the languages created are presented, along with the precautions taken to isolate the type of grammar from other variables. Finally, Sections IV and V present results, discussion, and conclusions.

II. Related Work

This study was motivated by the difficulties that novices face when learning the grammar of traditional programming languages. On this issue, there seems to be two main streams of research that are noteworthy. One of them is characterized by an attempt to facilitate the understanding of traditional programming language grammars, a line of research that has been extensively explored to date.

Contributions along this line range from the proposal of new pedagogical components [2] aimed at the development of programming skills in general and at the learning of specific language grammars, such as Interactive Learning Objects (ILOs) [3], for example, which draw on software visualization

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work from the early 1980s, to visual programming platforms that show graphical representations of the program in a flow control diagram (flowchart) (*e.g.*, [4]). In the meantime, other alternatives have been proposed, such as new didactic methods and software tools which exemplify how the involvement of eyesight, hearing, and kinesthesia can help in the teaching and learning of a programming language grammar [5]; the use of 3D object animation, along with the development of an editor with a drag-and-drop tool to make it easier to write programs [6, 7, 8]; and the suggestion that writing the solution of a problem in English before coding reduces the cognitive load for novices, thus enabling them to better cope with the difficulties of learning of programming language grammars [9].

The second line of research investigates how languages for novices might be designed which are in line with their natural way of thinking about programming. The very idea of closing the gap between programming languages and natural language grammars has found support in some empirical studies [10, 11, 12], which show that novices writing in English exhibit fairly advanced problem-solving skills, but that programming languages pose barriers that create difficulties for them in expressing these same skills in programming. In addition, studies [13] have used knowledge from the field of human-computer interaction (HCI) to understand how people think about programming tasks when trying to create a new program or trying to find and fix bugs in existing programs. Finally, Metaphor [14] and Pegasus [15] are examples of efforts to develop natural language programming systems (for a brief overview of the contributions and challenges of redesigning programming languages to make them more accessible to beginners, see [16]).

III. MATERIALS AND METHODS

The World of the Robots (Fig. 1) was designed for the experiments we describe here. This source of problems is an adaptation of the Karel's World [17]. It is made up of a rectangular board representing the "world", robots that can move within this "world", walls, and disks. The World of the Robots creates a source of problems related to the movement and manipulation of objects (disks) on a board possibly including barriers formed by walls. A robot can perform the following elementary operations: move forward, rotate 90º degrees left, and collect or drop a disk (at the robot's position). It can also test whether the space in front of it is clear (*i.e.*, if there is no wall before it), if it is sitting above a disk, and if there are any disks in its bag (each robot has a bag where it keeps its collected disks). It can also check whether it is pointing north, south, east, or west.

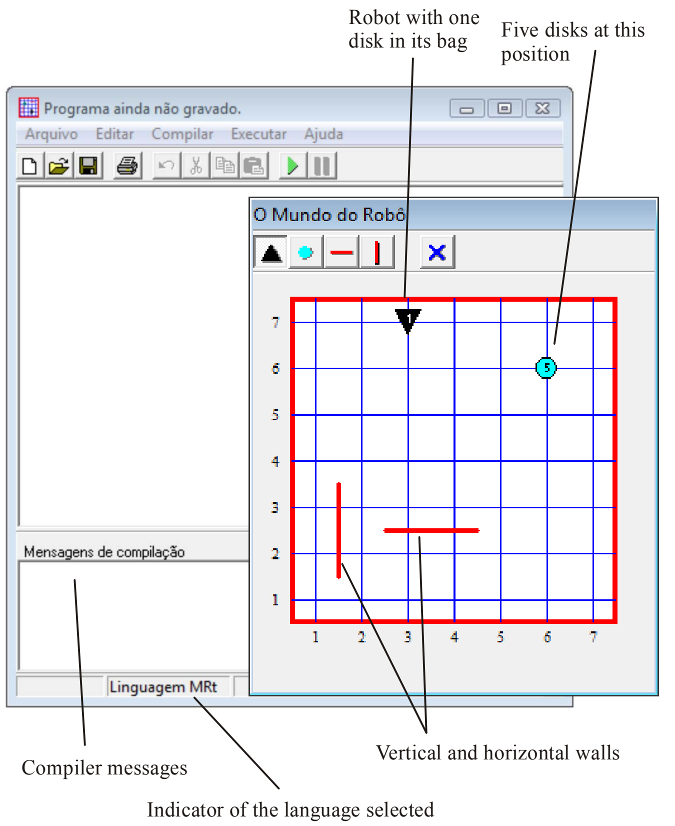


Fig. 1. The Integrated Programming Environment Developed.

The following components of the integrated programming environment were also developed: a graphical editor, used to design configurations for the World of the Robots; a text editor to edit programs; compilers for both languages used in the experiments (MRt and MRp); and a debugger (Fig. 1). By selecting buttons on the graphical editor toolbar, the user can create and delete robots, disks, and vertical and horizontal walls. In response to a request to execute a program, the programming environment shows an animation of the programmed movements. The program can also be run in debug mode to trace the execution of the source code, line by line, and to view the corresponding animation in the World of the Robots.

A. MRt Language

MRt was designed with the traditional flow-control structures of the imperative paradigm based on a context-free grammar, as found in programming languages like Pascal and C. Thus[1]:

- Sentences such as *MoveForward(r)*, *TurnLeft(r)*, *TakeDisk(r)*, and *DropDisk(r)* make a robot *r*, respectively, move one step forward, turn left 90º, and catch or drop a disk in its current position.
- Boolean expressions using the operators *and*, *or*, and *not* can be built up from Boolean functions such as

[1] The languages developed in this work use Portuguese terms. To facilitate the reading of this article, these terms have been translated into English sentences.

FrontClear(r), OnDisk(r), ThereAreDisksInBag(r), HeadsNorth(r), HeadsSouth(r), HeadsEast(r), and *HeadsWest(r)*, which evaluate to true or false, respectively, if before the robot *r* there is no wall; if *r* is on top of a disk; if there is at least one disk in the bag of the robot; and if *r* points north, south, east, or west.

- Conditional sentences, such as *if FrontClear(r) then MoveForward(r) else TurnLeft(r)*, test whether the space in front of robot *r* is clear and, if so, make the robot move forward, or else make it turn left.
- Repetitive sentences, like *while FrontClear(r) and OnDisk(r) do TakeDisk(r)*, repeat an instruction. In this case the robot named *r* should collect a disk if there is one at its position and the space before it is clear.
- Sets of sentences can be grouped by means of a sentence that begins with the word *begin* and ends with the word *end*.

An example of a complete program in MRt language is shown in Fig. 2. The program solves the problem of making a robot find a disk within a rectangular circuit. The initial orientation (north, south, east, or west) of the robot is unknown. A possible initial problem configuration is shown in Fig. 3.

```
while not HeadsWest (r) do
  TurnLeft (r);

while not OnDisk (r) do
begin
  if FrontClear (r) then
    MoveForward (r)
  else
    TurnLeft (r)
end
```

```
programa AcharDisco;
Usa r: Robô;
início
   enquanto não ApontaParaOeste (r) faça
      GirarEsquerda (r);

   enquanto não EstaSobreDisco (r) faça
      se FrenteEstáLivre (r) então
         AndarFrente (r)
      senão
         GirarEsquerda (r)
fim.
```

Fig. 2. A program written in the MRt language.

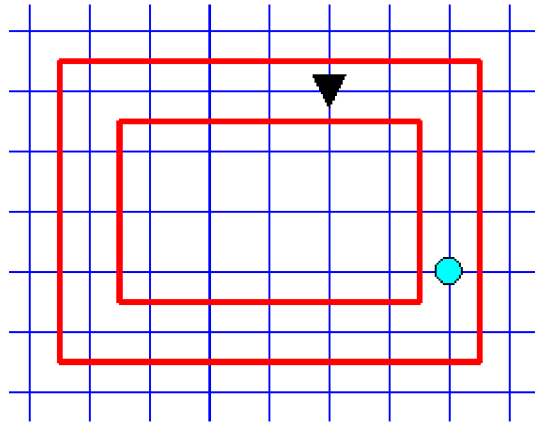


Fig. 3. An initial problem configuration.

B. MRp Language

The MRp language was designed to allow the generation of sentences similar to those of Portuguese. The body of a program written in MRp consists of a sequence of zero or more sentences, each ending with a dot. Every sentence consists of one or more clauses, separated by commas or by the conjunction *and*. For example, *Make the robot r turn left, move forward and drop a disk* is a sentence consisting of three clauses: (1) *make the robot r turn left*, (2) *move forward*, and (4) *drop a disk.*

A clause always has a subject, that is, the thing to which it refers. The subject may be explicitly declared as *r*, as in the clause *make the robot r turn left*, or it may be implicit, as in the clauses *move forward* and *drop a disk*. In the MRp language, implicit subjects always refer to the subject of the preceding clause. In the example, the subject of clauses *move forward* and *drop a disk* is therefore *r*, the subject of *make the robot r turn left.*

Here are some examples of sentences and clauses in the MRp language and their meanings:

- *If there is no disk in the bag of the robot r and the robot is on top of a disk, then collect the disk, or else turn left.* This sentence determines that the robot named *r* should collect a disk if it is currently above one and its bag is empty. Otherwise, it should turn left.
- *While there are disks in the bag of the robot r, drop a disk*. The meaning of this sentence is to have the robot named *r* empty its bag, putting all the disks in its current position.
- *While the space in front of the robot r is clear, make it move forward and if it's on a disk, collect the disk*. This sentence makes robot *r* keep on collecting disks that are in front of it until it hits a wall.

An example of a complete program in the MRp language, to solve the problem of making a robot find a disk within a rectangular circuit, is given in Fig. 4. A possible initial configuration of the problem is shown in Fig. 3.

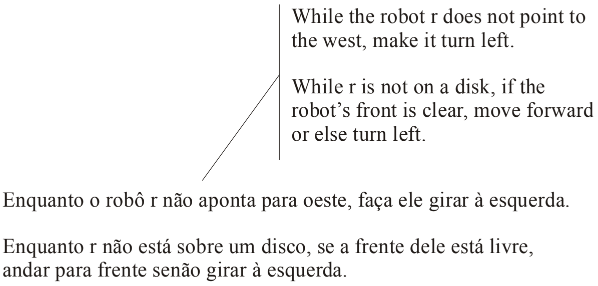


Fig. 4. A program written in the MRp language.

C. *Subjects*

Twenty-two volunteers participated in the study. All subjects were first-year students in undergraduate courses in a Brazilian university. Among these, 13 (59%) were male and 9 (41%) female, of whom 11 (50%) were studying exact or applied sciences and 11 (50%) were from the social sciences, with ages ranging from 17 to 28 (average 20 and median 18). Moreover, none of the participants had prior knowledge of programming, as determined by a questionnaire.

D. *Hypothesis*

The hypothesis tested was:

> The use of MRp language (with grammar similar to a natural language) is as favorable as the use of MRt language (with a traditional context-free grammar) to the learning of programming fundamentals.

E. *Experimental Setup*

Initially, participants were randomly divided into two groups:

- Group I: Participants studying programming fundamentals using the MRp language; and
- Group II: Participants studying programming fundamentals using the MRt language.

The experiment was conducted in two phases, occurring in the morning (phase 1) and afternoon (phase 2) periods of the same day, with a lunch break of 1.5 hour between phases.

In phase 1, each group participated in a 3.5 hour lesson, with a 15 minute break halfway through. The lessons discussed details of the World of the Robots and the concepts of sequence of sentences, and sentences that express actions, conditions and repetitions present in the programming language to be used by each group. Before the 15 minute break, participants performed an exercise in which they had to deal with these concepts. The experimenter interacted with the participants individually during the time that each tried to solve the exercise and subsequently developed and explained a possible solution. Students were given a text describing all the issues covered in the classroom, and thus, during the lesson, their only concern was taking additional notes on the subject matter.

In Phase 2, students took part in a test. The test took up to two hours, and consisted of four questions that described problems. They were then asked to write programs to solve these problems. Both groups received the same test, consisting of four questions:

- Question 1 evaluated the use of a sequence of sentences and could be answered with a sequence of sentences expressing elementary actions.
- Question 2 evaluated the use of conditional sentences and could be answered with one or more sentences expressing conditions.
- Question 3 evaluated the use of sentences denoting repetitions and could be answered with sentences describing a repetition of elementary actions.
- Question 4 evaluated the combined use of sentences expressing actions, conditions, and repetitions and could be answered with sentences expressing the repetition of clauses describing conditions and actions.

The test is fully presented in Appendix A. The questions answered by the participants were independently reviewed by two of the researchers and were assigned a score from 0 to 5. Inconsistencies were settled by the researchers in a meeting.

F. *Constant Factors and Other Precautions*

Because only the grammar of the programming language for the two groups was planned to vary, the following factors were held constant:

- The "World of the Robots" domain as the source of problems.
- The semantics of the MRp and MRt programming languages.
- The programming environment.
- The dynamics of the experiment (see section E).
- The experimenter administering the experiments.
- The problems addressed in phase 1 (lesson) and phase 2 (test) of the experiments (Appendix A).

As a way to avoid bias in the resulting data set, additional measures were also taken, such as:

- Restricting the experiment to the time interval comprising morning and afternoon, thereby reducing the interference of external sources, to the extent that the entire experiment took place in a single day.
- Splitting up subjects into two groups of 11 students, to facilitate the interaction between them and the experimenter, thus reducing the natural difficulty in communicating with large numbers of students.
- Designing the programming languages used in the experiments so that their statements could be written in Portuguese, the subjects' native tongue.

- Choosing the World of the Robots as the source of problems, because of the small number of involved concepts and also because these concepts are fairly intuitive.

IV. Results and Discussion

Table I shows the mean and standard deviation scores for both groups on a scale from 0 (insufficient) to 5 (excellent). Means and standard deviations were almost identical: 3.91 ± 0.79 for Group I and 3.98 ± 0.82 for Group II. The results showed no statistically significant differences between these averages (Student's $t = 0.20$ with significance level $p = 0.85$). This means that the proposed hypothesis could not be rejected.

TABLE I. Results (mean and standard deviation) of the test

Group	*n*	Mean (0 – 5) ± SD
I	11	3.91 ± 0.79
II	11	3.98 ± 0.82

Separating the syntactic and semantic aspects of the solutions, *i.e.*, isolating analyzing syntax and semantic mistakes, resulted in the mean and standard deviations shown in Table II. Still, the data show no statistically significant difference with regards to aspects of syntactic correctness ($t = 0.64$ with significance level $p = 0.53$) or semantic accuracy ($t = 0.22$ with significance level $p = 0.83$). In other words, the hypothesis is also confirmed with respect to a comparison between the syntactic aspects of the languages or between their semantic aspects.

TABLE II. Mean and standard deviation of test scores relative to syntactic and semantic aspects

Group	Syntax mean (0-5) ± SD	Semantic mean (0-5) ± SD
I	4.02 ± 0.93	3.80 ± 0.84
II	4.25 ± 0.72	3.70 ± 1.05

Appendices B and C present in detail the scores obtained by each student in Groups I and II.

V. Conclusions

These results show that, for the population studied, the use of natural languages is an alternative, not better or worse, to the use of traditional programming languages defined by context-free grammars. This alternative is attractive and promising because the student does not need to learn a formal grammar to learn the fundamentals of programming. Using a natural language as the first programming language enables the student to focus on the logic of the solution, thus decreasing his level of effort in writing a program.

Natural language programming is also an alternative for end-user programming environments, *i.e.*, environments that include programming and are targeted at users whose main interest may not be intrinsically computational. For example, Scratch [18] has been used for educational and entertainment purposes for children to create interactive stories, music, works of art, and games. Scratch tries to alleviate the difficulties in syntactic development of programs by dragging-and-dropping blocks of sentences. The use of natural language makes solutions like these unnecessary.

Signs to mark the beginning and end of blocks of sentences are used to organize the structure of a program written in a traditional context-free language, allowing also the nesting of sentences and the resolution of ambiguity. The absence of these context-free language elements in natural language forces the writing of texts which are often less structured. For example, consider the text in natural language *Make the robot r move forward until it finds a wall. While it is walking forward, make it pick up a disk at each position where it passes*. The two actions (*move forward* and *pick up a disk*) were structured in two sentences. Typically, in a context-free language, these actions are structured in a single block within a single repetitive sentence. Future research by the authors will investigate the relationship between the structure of programs written in natural language and in traditional context-free languages. A better understanding of this phenomenon may help in the development of better compilers for natural language and also improve programming courses based on context-free languages.

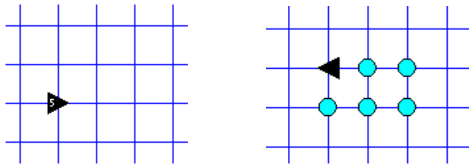
Finally, educators can use in courses and researchers can use in other studies the programming languages, compilers, and integrated programming environments that have been developed for these experiments. These will be made available to the community under a General Public License.

Acknowledgment

We would like to thank all subjects that volunteered to the experiment for their invaluable contribution to this work.

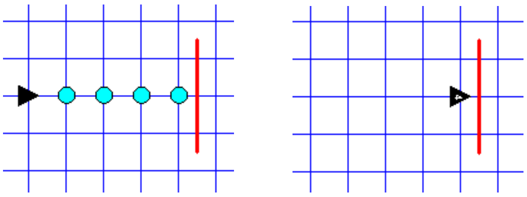
Appendix A. The Test Questions

Question 1: Write a program to signal a path with disks. The left figure presents an initial configuration in the World of the Robots and the right figure the final configuration that must be reached after executing the program.

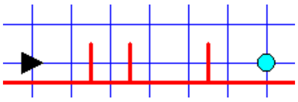


Question 2: Write a program that makes the robot *r* point north. You do not know the initial configuration of the robot in the World, in other words, you do not know whether the robot is currently pointing north, south, east or west.

Question 3: Write a program to make the robot *r* take all disks in a line situated before it until it reaches a wall. The figures show a possible starting (left) and final (right) condition. These figures are only an example. Your program must work with lines with an undetermined number of disks.



Question 4: Write a program to make the robot *r* jump over barriers such as those in the figure until it finds a disk. Again, this figure is merely illustrative. Your program must address an undetermined number of barriers at unknown positions. The barriers are always equal in size to those indicated in the figure.



APPENDIX B. SCORES OBTAINED BY STUDENTS IN GROUP I

Student	Syntax score (0 - 5)	Semantic score (0 - 5)	Global score (0 - 5)
A1	4.25	4.50	4.38
B1	5.00	4.50	4.75
C1	4.25	4.00	4.13
D1	4.00	4.25	4.13
E1	2.50	3.75	3.13
F1	4.75	3.50	4.13
G1	2.75	1.75	2.25
H1	4.50	4.50	4.50
I1	4.50	3.25	3.88
J1	2.75	3.25	3.00
K1	5.00	4.50	4.75

APPENDIX C. SCORES OBTAINED BY STUDENTS IN GROUP II

Student	Syntax score (0 - 5)	Semantic score (0 - 5)	Global score (0 - 5)
A2	4.50	4.25	4.38
B2	4.50	4.00	4.25
C2	4.25	4.25	4.25
D2	5.00	4.75	4.88
E2	4.75	5.00	4.88
F2	5.00	4.00	4.50
G2	3.50	2.50	3.00
H2	4.00	3.75	3.88
I2	2.50	2.00	2.25
J2	4.25	4.25	4.25
K2	4.50	2.00	3.25

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Dynamic programming – structure, difficulties and teaching

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***Abstract*—In this paper we describe action research on our third year Algorithms, Data structures and Complexity course, in which students have considered dynamic programming hard in comparison to the other topics. Attempting to amend this, we wanted to know which difficulties the students encountered, where they gained their knowledge, and which tasks they were most certain that they could perform after the course. Such work resides in the didactics of the subject taught, but the general methods of attacking perceived difficulties in a course can be tried on any course.**

We identified subtasks that could be taught separately, and adapted the lectures to Pattern Oriented Instruction in order to help students cope with the cognitive complexity of solving problems using dynamic programming. For this, we prepared new clicker questions, visualisations and a lab assignment. We also constructed self-efficacy items on the course goals for dynamic programming, and administered them before and after the teaching and learning activities.

Among the self-efficacy items, determining the evaluation order and solving a problem with dynamic programming with no hints had the lowest score after the course. As for the activities, arguing correctness of a solution was something many students claimed that they did not learn anywhere. Students considered the lab exercise most useful, but they also learned a lot from the other activities.

I. Introduction

The course in which the experiments of this paper took place is a third year course in the 5-year Master of Computer Science and Engineering program at KTH in Stockholm, dealing with algorithms, data structures and complexity: ADC. Previous experience indicates that dynamic programming (below abbreviated dynprog) is considered difficult among the students. This work uses an action research approach.

A. Research questions

The questions that are addressed in this work are:

- Q1 What is perceived as difficult with dynprog?
- Q2 Which abilities do students judge they have after the course?
- Q3 Which of our activities do they believe to have helped them achieve those abilities?

We will not make an exhaustive examination of these questions, and the students are not interviewed on these topics. Rather, we ask them how well they believe they can perform tasks which we have defined, and where they have learned that. If they do not know things listed in the course goals after the course ends, we consider these subparts difficult. Items that students are less confident they can manage are also counted as difficult compared to the rest of the course contents.

B. Contribution

The contribution of this work is split into several areas. The answer to *What is difficult?* is in itself interesting to teachers, and our means of finding answers to this exemplifies teaching improvement attempts. We also compare our guesses and assumptions with students' answers. The self-efficacy instrument that we have used is not final, nor tested for internal reliability and validity, but it is still a partial result. The experience was also a small scale experiment with Pattern Oriented Instruction.

II. Background

A. The course

The part of ADC that is relevant to this paper is the first 18 lectures, 7 tutorials and 3 computer lab sessions on algorithm construction methods, and especially lectures 9 and 10 and tutorials 3 and 4 plus one computer lab exercise, all of which deal with dynprog. Each lecture is 45 minutes, and each lab or tutorial session is 2 x 45 min. The computer lab exercise is compulsory, performed in pairs, automatically checked for correctness and verbally presented to a teaching assistant (TA) in lab. ADC uses continuous assessment. The lab exercise, together with an individual, written home assignment which the students afterwards present personally to one teacher or TA, constitute the major part of the assessed student work on the topic. There are also supplementary tasks for those who are unhappy with their grades. The course is graded on a scale from A to E, or F for fail, and there are course goals and criteria connected with each grade. These are presented in a matrix and a flow chart on the course home page, and addressed on lectures and during peer review. Towards the end of the course, there is a written exam for lower grade content and an oral exam for those who aspire to higher grades. In the end, how well your work meets the criteria decides your grade, so *what* work you have fulfilled, and how well you performed, matters – not just the percentage of total work. The author has been one of the TAs on this course.

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B. Our guesses on what was difficult, or why

Recursion, a well known "difficult task", is part of the problem solving strategy of dynprog. Previous years' experiences suggest that the difficult parts of dynprog are finding a recurrence relation based on some structure of the desired solution, and tackling the complexity of solving a problem completely from scratch, without hints. Many students also struggle with, or avoid, any tasks involving "argue correctness" or "prove". Being able to cope with many dimensions – problems where a simple two-dimensional matrix is not sufficient to hold every subproblem that matters to the solution, is necessary for some problems.

C. Recursion and dynamic programming

The subject of recursion has attracted educational researchers' interest for a long time. In the 1980s Kahney and Eisenstadt [1] contributed by studying students' and other programmers' answers to problems involving recursion. Their results are further described by Kahney in [2], and describe a set of "mental models" of recursion that students had, out of which one was capable of capturing the things instructors want students to know about recursion, and some were not only incomplete, but misleading. Around the same time, Ford [3] concludes that iteration is really a special case of recursion, and that recursion is a generalised control structure in programs. Similar arguments are also used by others: recursion is an example of the paradigm "Divide, Conquer and Glue", and when using iteration, the glue step is missing and students get erroneous pre-images of the paradigm [4]. Scholtz et al. [5] claim that the difficulties with recursion are connected to understanding the passive flow, whereas other authors are investigating misunderstandings that can occur around base cases [6]. They also note that recursion *is* a difficult topic for students. Many authors dwell on the topic of where in the first course recursion should appear, or how recursion is related to iteration, the computational model, or similar issues.

Ginat et al [7] suggest that less focus on the computational model, and more focus on the abstract level and the algorithm in theory can help students not to mistrust recursion as a method or their own abilities on recursion. As an algorithm construction method, dynprog follows that recommendation. It does not deal with passive flow, and the algorithm construction task indeed treats recursion as an abstract phenomenon.

Dynprog can be seen as an alternative method for constructing algorithms where recursion can be used. Sometimes, keeping a table of all hitherto calculated values in a recursive algorithm speeds up calculations significantly, for instance with simple sequences like the Fibonacci numbers. This technique is called *memoisation*. Instead of doing memoisation, there is also the option of changing the algorithm so that calculations are made in "reversed" order - starting with the base cases and building increasingly complex subproblem solutions. This is the method named *dynamic programming* [8]. In this case, the recursive calls are not needed. Hence, dynprog is a technique that alters recursion into iteration. If students are more comfortable with iteration, this should only help. On the other hand, for someone who wants to think of iterations, the concept of "finding an evaluation order" is not all too clear. Also, it can be easily imagined that difficulties in discerning base cases for a recurrence relation makes the dynprog approach uncomfortable.

D. Pattern Oriented Instruction

Since coping with many aspects of a problem at the same time might be difficult, and since teaching everything at once might lead students to focus entirely on the algorithm that is constructed, and less on the construction process, we tried using Pattern Oriented Instruction(POI). POI is based on cognitive psychology theories on construction and organisation of knowledge in schemata. A schema is a connected chunk of "information", that has been constructed by repeated experiences which share some common ingredients. When, for instance, solving a complex problem, we are processing several different types of information at the same time. This is called cognitive load, and if the cognitive load gets too heavy, our problem solving skills are heavily reduced. When having seen the same type of problem many times before, we are able to process many interconnected pieces of information as one unit, a "chunk", which reduces cognitive load. A pattern is either distilled from several different experiences with certain ingredients in common, or generalised from some specialised example of a phenomenon. It can be employed in teaching to enhance the learners' ability to create new schemata. POI deals with structuring the teaching and the content in a way that facilitates the creation of schemata, which can later be processed as chunks.

POI preparations focus on identification, selection, progression and comparison of problems and patterns. The students get to meet with increasingly complex problems, encompassing different patterns already familiar. The comparison of problem characteristics is central, and patters are first introduced and later revisited in a different setting. The effect of POI on students' abilities in problem solving, abstraction and analogical reasoning in particular, are investigated by Muller and Haberman [9], [10], [11] and the effect on problem decomposition and solution construction abilities by Muller, Haberman and Ginat in [12].

E. Clickers and response cards

The use of clickers (or Audience Response Systems, or "voting" systems) for pedagogical or administrative purposes is widespread in the world today [13]. Among the reasons for using them is "anonymity", but since the systems are often built in a way that admits excessive data collection and even scoring on an individual level, it is worth noting that this anonymity is only towards peers, not towards the teacher. In other words, if the student is afraid of speaking up and answering questions on lectures because it could expose him or her to *the other students*, the argument is valid. If students don't want to expose possible lacks of knowledge to teachers, the system can actually be a greater threat, as temporary misunderstandings might be recorded and later graded. However, there are desirable benefits to clicker systems: they provide means for student activity; everyone gets to think and answer the questions, not just the fastest responder; the results of the small polls allows the teacher to address misunderstandings directly; and they provide formative feedback to the students. They also incentivise the teacher to plan good questions that are suitable for this type of exercise. The use of response cards, predecessors of clickers of sorts, has been studied academically since the 1960s, and have proven to have effect on student grades and student participation [14]. We have gradually included response cards in the course during the two past years, and it has been much appreciated by the students. We have employed cards of different colours which are administered to the students in the beginning of lectures. The votes are still made simultaneously, and the feeling of being exposed seems not to be present among our students, according to their evaluation responses.

F. Self-efficacy

In contrast with self esteem or confidence, self-efficacy is described as an individual's confidence in his or her own ability to, at a given moment, perform actions in order to achieve some desired outcome. The term was introduced by Albert Bandura in the 1970s and is further developed by him in [15]. The phrasing of the self-efficacy items should be direct and not involve guesses about the future or some sort of inherent capabilities of the subject to the study. Self-efficacy beliefs are not static - on the contrary, they change with the individual's experience. It is self confidence of a sort, but situated and very localised in time and subject area contents. These characteristics have given self-efficacy a role in education. The score of a self-efficacy test is known to be an important predictor of success [16]. There are studies in how self-efficacy correlates with performance [17], how self-efficacy changes during studies[18], and how it correlates with other factors around the individual [19].

We knew of no established instruments measuring self-efficacy for theoretic computer science. In mathematics, self-efficacy instruments have been developed [17], [16] and also in programming [18], [19], which is another related area.

III. Method

A. Plan the new course activities

Previous years, other aspects of this course have been reworked, and after that, students complained that dynprog seemed unreasonably difficult compared to other content. For this experiment, the short part of the course that dealt with dynprog had to be planned with a new perspective. We used visualisations of dynprog, a completely new lab exercise and clicker questions for the lectures. TAs were instructed on the plans and the goals of the new partitioning of the contents, and new tutorial session material was prepared. The new lab assignment was to modify and speed up a program that calculated the edit distance between two words. The system Kattis, described in [20] was used for automated online testing, and theory questions which would prepare the students for the optimisations needed were prepared. The visualisations shown in the introductory lecture exemplified calculation of the "degenerate" case of dynprog, the Fibonacci numbers, recursively, with memoisation and with dynprog.

For this "simplest" version of dynprog problems, number sequences, the order in which to calculate the answers seems natural, and coincides with the order you would calculate different subproblems when using memoisation - save each value the first time you need it, but use the recurrence as basis for your algorithm.

B. New structure the course content

We started by identifying what difficulties we could encounter, and what different dimensions we could allow to vary and needed examples of. The task of solving a dynprog problem can be thought of as solving three different tasks: 1) Finding a structure for the solution, 2) expressing a recurrence relation, and 3) defining and proving an evaluation order with the properties that we will always have solved "smaller" subproblems whenever we solve a "larger" problem, and that the evaluation order renders the same result as the recurrence relation would produce.

To help comparing and distinguishing various characteristics of problems, we identified what could vary between different dynprog problems: whether the history needed to be saved during computations or not; whether the evaluation order was intuitive or more intricate; whether new values depended on the indices of the elements to be calculated, or on some input, or both; whether the previous subproblems to be used for each calculation were the most recently calculated subproblems, or if some special method was needed to find relevant subproblems (for instance, "jump", skip cells, in a matrix of previously calculated values); the number of dimensions for the subproblems (do they fit in a sequence, matrix, higher order); that there could be several different recurrence relations for the same problem and that the same recurrence relation could be the basis of several differently posed questions; the "location" of the base cases, "the location" of the answer after calculation; whether only a number, or the entire path to that number was needed for the solution (constructive solution), and different combinations and variations of these features.

These were only the dynprog specific variations. Another important variation is in the structure of a problem, or rather, of its solutions. If subproblems do not overlap, divide-and-conquer is generally a better method than dynprog, and if they do overlap, dynprog might be best. A greedy solution can sometimes be proven to be the superior option. These algorithm construction methods are also covered in the first part of the course, and assessed on the same written home assignment.

C. Prototypes and patterns in dynamic programming

For the lectures, we decided to separate two phases of constructing a dynamic programming algorithm: 1) Recognising the structure of the problem and create a recurrence relation and 2) Finding and proving an evaluation order for a given recurrence relation. This was done to direct more attention to the evaluation order and correctness arguments. At the same time, we wanted to refer to prototype problems. Some of these had already been used in the course, and others were introduced as a complement to these. The prototype problems we chose were: Fibonacci (sequences), 2-dimensional recurrences without input (2-dimensional sequences), 2-dimensional recurrences with input, (values decided from input), Longest increasing subsequence (index and input dependent, need to save full history) Matrix chain multiplication (base cases on the diagonal, construction of the solution), Swamp walk (different questions, same "solution"), Coins (different recursions for the same problem, focus on proving correctness), Longest common substring (argue correctness of recurrence relation and algorithm, construct the solution, compare to 2D-with input that rendered the same recurrence relation) and Floyd-Warshall's algorithm for finding all shortest paths in a graph (more than two dimensions used). We do not argue that these problems are *the best possible* set of prototype problems, but they contained examples of the variations we wanted to show and most of them had appeared in one form or another on the lectures previous years, only not as explicit representatives of some technique(s) each.

D. Surveys

Several different surveys and questionnaires were administered throughout the course. Their content and goals are described in this section.

1) Self-efficacy surveys: We would like to know whether students find any of the different tasks we believe are involved in dynprog especially hard, and whether students improve their self-efficacy during the course. Based on the ADC goals, the guidelines by Bandura in [21], and supported by the spirit of knowledge taxonomies such as Bloom's taxonomy [22], we have constructed a 10 item self-efficacy scale on dynprog, together with an 8 item scale on complexity that is further described in [23]. The students are asked to grade their self efficacy on the course's dynprog contents on a scale between 0 and 100. This was done on lectures, before and after the section of the course that was part of the experiment. 110 and 79 students responded, respectively, and 68 responded to both. This survey was not anonymous, but the students were promised that it would not count towards grading, and that no one would read the material until after the course was finished. This is naturally a limitation in the usability of the responses for that year, possibly introducing errors in the form of more polished or adjusted answers from students. On the other hand, we wanted to both be able to see individual trends between the two occasions, and retain the option to later compare self-efficacy beliefs with results: both their predictive value from the first occasion, since it is known that self-efficacy affects motivation and possibly performance, and also possible correlations between results and self-efficacy beliefs after the teaching and learning activities.

2) Home assignment cover page: Together with the homework assignment, the students got a cover page to attach to their homework, with two types of questions. One half was a participation statement, and contained questions on what sessions or activities the student had attended in the dynprog part of the course, and the other half was a "Where was what learned" part, and contained a matrix where students could mark where they had learned to master different aspects of dynprog: on their own, on lectures, on tutorials, from visualisations, from the peer assessed theory questions before the lab assignment, from the lab assignment, or if they still did not master it.

3) Course surveys: At the peer reviewed, pseudonymous theory exam, a final survey on the course was distributed in two versions, one with pre-defined answer options, and one with free-text questions. The students were randomly assigned one of these, and the one with pre-defined answer options is the one we present here. There was also, as always at our school, an online course, where some questions were about related issues. This survey is completely anonymous, done on the students' own time, and has higher non-response rate.

E. Student results and comparisons

The written homework assignment is graded A-E, so the grades might have improved if the teaching was much improved. There is also another, similar homework assignment on complexity, which can be used for comparison. The grade on the assignment, however, is based on the performance on three algorithm construction tasks, out of which one had a good dynprog approach. Yet another task was possible to solve with dynprog, but as this was far less efficient than another method, and this task was meant to assess the students' ability to choose the best methods for new problems, the use of dynprog here did not improve the grade (unless the student proved here but not on the previous task that he or she could use dynprog.)

IV. Results

A. The self-efficacy instrument

One of the instructions from Bandura was that the items on a self-efficacy scale should be of increasing complexity, or level of challenge. If by this we mean that ideally, the items should be ordered so that the answer values was a non-increasing sequence, this was not achieved. As the relative scores for the different items was what we wanted to investigate, the order is not of crucial importance to us. Some items could be rephrased to make them easier to understand for someone unfamiliar with dynprog. The items were (translated from Swedish):

1) I could understand dynprog algorithms as presented to me by teachers or in books.
2) I could decide whether an algorithm is based on the algorithm construction method dynprog.
3) I could construct an algorithm that calculates a recurrence relation, using dynprog.
4) I could explain to an average peer why dynprog is better than a recursive procedure when implementing an algorithm to compute the Fibonacci numbers.

item	1	2	3	4	5	6	7	8	9	10
pretest average	76	49	70	88	34	49	71	69	47	36
posttest average	90	84	87	95	68	78	88	80	67	65
threshold = 25										
less certain	0	0	4	3	3	8	2	6	5	3
no change	45	21	35	52	22	21	40	42	34	21
more certain	23	47	29	13	43	39	26	20	29	44
threshold = 50										
less certain	0	0	1	1	2	1	0	2	3	0
no change	64	46	60	62	39	40	61	58	50	47
more certain	4	22	7	5	27	27	7	8	15	21

TABLE I
NUMBER OF STUDENTS INCREASING THEIR SELF-EFFICACY VALUES FOR ITEMS 1–10. (N=68)

5) I could choose a suitable evaluation order for dynprog for a recursive relation that depends on separate input (and not only on indices).
6) I could explain why dynprog with my evaluation order solves the same problem as does the recursion.
7) I could implement a dynprog algorithm that is presented as pseudo code, in some programming language.
8) I could determine from the problem statement whether a problem should be recursively solved , without it being stated anywhere, if I got some time to investigate it.
9) I could construct a dynprog algorithm that solves a problem presented to me in natural language, without recursion.
10) I could construct the solution to a problem if I have a dynprog algorithm that determines that the solution exists.

Along with the instructions, the values 0, 25, 50, 75 and 100 were interpreted in words, and the students had the instruction to mark 0 where they had never heard of some concept before. The students were also introduced to the scale and to using it by some simple examples, which had nothing to do with the course: “I could lift X”, where X was allowed values like “a pen”, “my laptop”, “this chair” and “the lecturer”.

The results of the self-efficacy surveys can be seen in Table I. Only responses from students who handed in both surveys are included. For some of the items, the students had high confidence in knowing them already at the beginning of the first lecture on the topic, especially item 4. We decided to just look for increases or decreases of at least 25, which had distinctly different interpretations according to the instructions. For comparison, we also present results where students had changed their answers with 50 or more. Items 1, 3, 7 and 8 also had rather high average values at the first lecture. Naturally, only a few students could increase their confidence a lot on these items. For all but the first two items, it also occurred that some students (at most 8) *decreased* their confidence in their ability, for all of these except from 7 and 10, also when the threshold was 50. The decrease in confidence could suggest that student actually became less skilled in tampering with certain tasks after the teaching and learning activities. This, though, would be quite an achievement of negative sorts for the teaching, and seems unlikely. Another interpretation is that students became aware of details or whole dimensions they had previously not seen, and hence became less certain that they could cope with some tasks. For instance for item 6, which is a milder version of proving correctness, some students might not have seen the need to prove this, and underestimated the difficulty of the task. On the online course survey, some of the comments about the course and the homeworks reveal that proving correctness is still considered difficult. Also, after having tried some of the tasks in the survey for real, some might have more realistic estimates of their abilities.

For items 2, 5, 6 and 10, more than half of the responding students increased their confidence, and about 30 percent increased it by at least 30 %. It seems that what students perceived that they learned, was to recognise a dynprog approach, to modify a recursive approach to a dynprog approach by the means of determining an evaluation order, and to explain why this still solved the same problem as the recursive algorithm, and also to modify dynprog algorithms to save more history and answer with more detailed answers. This, the tenth item, might have been a distinction that students had not considered before, and not really thought of.

The items 5, 9 and 10 had the lowest average scores at both occasions, but the similarly low scores on item 2 and 6 at the first survey had increased more the second survey. Still, as mentioned before, item 6 has special characteristics and could be investigated more. According to these surveys, out of the investigated items, the students perceive it most difficult to find a suitable evaluation order, construct a dynprog algorithm from scratch, and modifying an algorithm that answers “42” to one that answers “the best value 42 is obtained by making these decisions”, and also to argue correctness, although on this item many students improved their (self estimated) abilities.

B. Course survey at exam

The results from the previous section also include what students believe they know after the part of the course that dealt with dynprog. The responses from the students who got the closed form questions at the final exam survey are presented in Table II. Students were in general very positive to the “clicker questions”, but also towards the visualisations and the computer lab assignment, a little more positive in general speculation than in their particular case on whether these activities contributed to learning dynprog. Particularly beneficial, according to the responses, is working with the computer lab assignment. No one complained about the lack of privacy of the clicker votes, neither at the exam survey nor on the anonymous online survey.

C. Home assignment cover page

A more detailed view on what students on an earlier occasion believed that they learned, and where, is presented in Table III. These are the percentages of students (148 in total) who handed in the homework assignment. On the cover page they had to complete this matrix and some questions on what activities students had attended. They were allowed to mark

1. Was the pedagogical purpose of the activity clear?

	yes	questionable	no
clicker questions	90%	6%	1%
visualisations	81%	10%	1%
computer lab	79%	14%	1%

2. Did you find the activity meaningful?

	yes very	yes somewhat	not particularly	not at all
clicker questions	59%	36%	3%	0%
visualizations	40%	40%	10%	1%
computer lab	54%	40%	3%	0%

3. Did you learn dynprog by working with the activity?

	yes	no
clicker questions	66%	17%
visualizations	51%	24%
computer lab	87%	9%

4. Do you think that activities like this one can make it easier to learn dynprog?

	yes	no
clicker questions	76%	9%
visualizations	73%	6%
computer lab	90%	4%

5. Did the activity add something to the course?

	yes	no
clicker questions	94%	1%
visualizations	71%	6%
computer lab	96%	1%
self-efficacy surveys	17%	39 %

TABLE II

ACTIVITY SURVEY RESULTS. (DON'T KNOW OR BLANK OMITTED.)

Where did you learn to…
1. …tell if an algorithm is based on dynprog?
2. …tell if a problem can be tackled by dynprog?
3. …construct a recurrence relation for a simple problem?
4. …choose an evaluation order given the recursion?
5. …construct a solution given a dynprog algorithm that finds the optimal value?
6. …motivate the correctness of a dynprog-based solution to a problem?

	already knew or learned by myself	lectures	tutorial sessions	lab theory assignments	lab	homework 1	still haven't learned this
1.	18%	57%	30%	39%	42%	19%	0%
2.	16%	50%	30%	34%	37%	24%	1%
3.	72%	24%	19%	9%	6%	16%	1%
4.	26%	49%	29%	26%	25%	22%	4%
5.	11%	37%	23%	15%	32%	22%	15%
6.	6%	43%	17%	11%	15%	29%	24%

TABLE III

WHERE DIFFERENT TASKS WERE PERCEIVED TO HAVE BEEN LEARNED. (N=148)

Activities attended	mean grade hw1	hw2
>4	1.9	2.4
<2 and ≤ 4	1.2	1.5
≤ 2	0.68	0.84

TABLE IV

COMPARISON OF STUDENT PERFORMANCES AT HOMEWORK 1 AND 2 (HW1 AND HW2) GROUPED BY THE NUMBER OF ACTIVITIES ATTENDED.

several options, for instance, they could have learned to tell if an algorithm was based on dynprog both on lectures and by their own efforts.

Judged from this, all of the activities contributed to learning, but construction of recurrence relations for simple problems is not considered as hard, or at least, not considered to require the teachers' attention. Just as in the self-efficacy surveys, modifying an algorithm to output the construction of the solution rather than only an optimal value, is still difficult to some of the students, here 15 %. A quarter of the group found it difficult to argue correctness at this point. Since the question was not posed identically on the self-efficacy survey, the answers are not totally comparable. The fourth row in Table III shows that only 4 percent judged that they still could not find an evaluation order. This suggests that students who are not too certain that they could perform this task, still do not respond with "I still haven't learned this", or that they later re-evaluated their ability to choose an evaluation order.

Concerning the homework *results*, and any impact our methods might have had, in Table IV, the mean grades (where A counts as 5, and linearly down to 0 for F) for homework 1 and 2 are shown for the groups of first time students who had attended different number of activities, where the lab assignment was counted as 1.5 if submitted early. Homework 2 was on complexity. The grades are usually similar on both homeworks, but this year many students handed in a less efficient solution (based on dynprog) for one of the problems, and hence did not get the highest grade for this. The most ambitious students might have read too much into our questions on dynprog. These results are mostly telling that active students get higher grades, and show no special benefit for dynprog problems.

V. DISCUSSION

A. *Student activity and lots of evaluation intervention*

Surveys are often anonymous, but the concept of *self-assessment* in teaching is not usually associated with anonymity. It can be used as a means of facilitating learning, and it is possible that among the learning activities we provided this year was self-assessment. Some students indicated this, so this perspective was included in the exam survey. Most students, however, considered it an alien thought that their completing a lot of surveys had contributed to them learning dynprog. Even so, in making students reflect on their own abilities, this type of questions could help (a minority of them) to learn, or reduce administrative work load on the teachers. For instance exam wrappers (to be completed upon recovery of their graded assignment) are suggested to be used for such reasons by some institutions[1].

We plan to continue distributing the surveys, to monitor possible effects by altered teaching methods, and for the

[1]http://www.duq.edu/about/centers-and-institutes/center-for-teaching-excellence/teaching-and-learning/exam-wrappers

possible pedagogical gains. Although the criteria for each grade are specified in the course information, questions on what students felt certain that they could do also contribute to communicating the teachers' aims to students by building a list of distinct abilities that the teachers value.

VI. Conclusion and future work

The contribution of this paper in a general perspective is to show how to improve teaching of some particular concept, by an action research approach, aside from exemplifying methods for finding out how students feel about their own ability. The main contribution resides in the theoretical computer science didactics area. Ouf of a teacher-selected sample of abilities, which we deemed needed to solve problems with dynamic programming, we have investigated which activities students find more difficult to learn or to master, what they feel confident that they know, and where they learned the things that they know.

Returning to the questions in the introduction, for Q3 (which activities students thought contributed to learning) we can conclude that a variety of activities was good. Both mandatory activities, like the homework and the lab assignment, and optional ones like lectures, tutorial sessions and visualisations were considered helpful for learning. Regarding Q2 (what abilities the students felt that they had after the course), most students are confident that they can recognise dynprog, explain what it is, construct simple recurrence relations and implement dynprog algorithms. They are less certain that they can find a good evaluation order for a recurrence relation, solve a problem from scratch or motivate correctness, which constitute our answers to Q1.

Compared to what the teachers expected, this is both similar and different. The correctness part was expected, but fewer students than expected experienced difficulties with finding a recurrence relation. Further, other, or more detailed questions can be asked to find out more about this.

Next time this course is given, the prototypes will be refined and more emphasised. Correctness and writing pseudocode (i.e., describing ones algorithm on an appropriate level of detail) will get special attention.

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OUTCOME BASED ENGINEERING DIPLOMA CURRICULUM - 2012 GUJARAT EXPERIMENT

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Abstract— **In India, unlike the Western world, the universities have several engineering institutes affiliated to them that are geographically spread across large provinces. Gujarat Technological University (GTU) is one such example, that caters to the technical education needs of the state of Gujarat (size of Arizona) with a population of 65 million. More than one hundred such institutes offering undergraduate and graduate programs and about same number of 'Polytechnics' offering engineering diploma programs are affiliated to GTU. Around 100 thousand students take admissions every year in the 55 different technology programs being offered. Since examination and certification is the main responsibility of the University, it becomes necessary to conduct centrally administered end-of-the-term examinations every semester. This necessitates the curriculum for each program to be same in all the institutes. Hence, curriculum design became a centralized task to address the needs of today's globalized industry and also fulfill the aspirations and capabilities of the students, belonging to different strata of the society. Since curriculum designers and implementers are not the same in this experiment, a need-based curriculum model became imperative to be developed that could convey clearly and uniformly the intentions of the designers in letter and spirit to all curriculum implementers and stakeholders.**

In this backdrop, NITTTR Bhopal one of the four premium institutes established by the Government of India for quality improvement of the technical education, was assigned the task by GTU in 2012 to completely re-design the curriculum of twenty five engineering diploma programs to produce 'work ready' personnel. The authors were the core members of the core team who undertook this task. This paper highlights the challenges and opportunities faced by the engineering education system due to fast changes taking place in society, industry and education, for which an innovative outcome-based curriculum model was evolved to address these challenges and harness the opportunities. This paper discusses the various facets of the philosophy, approach and structure of this curriculum model evolved for this purpose. It also briefly describes the planning, designing, implementation and evaluation of the curriculum development process, as well as some of the strategies adapted in this innovative curriculum model.

Keywords—Outcome-based Curriculum; Competencies; MMS Type Industry; R&D Type Industry, Program Structure; Programme Outcome; Course Outcome; Domain; GTU; NITTTR Bhopal

I. INTRODUCTION

With liberalization, globalization and privatization of Indian economy in early 1990s, there was a spur in growth in all sectors of the Indian economy. This expanding economy needed thousands of appropriately skilled technical workforce and government owned engineering education institutes could not produce that many. This prompted the government to loosen its strings and allow greater private sector participation in the engineering education system. Much of the private sector saw this as a great opportunity to undertake a lucrative business and opened engineering education institutes to make profit rather than consider it as a social cause. A considerable number of such self-financed engineering institutes sprung up and affiliated themselves to the 'generic universities' (for recognition/accreditation of degrees awarded by the industry) in different parts of the country.

Many of these self-financed engineering institutes are owned by individuals or groups of persons coming together as so-called 'co-operatives' or 'trusts/societies' without having any noble aim or experience of imparting quality engineering education [2], but earning profit being the primary motive. This situation fuelled and spiralled the sudden splurge of large number of engineering education institutes all over the country whose quality became questionable for several reasons discussed briefly in this paper.

Due to the greater social status attached to engineering degrees in India, the parents are ready to send their wards to such institutes even though they levy more fees than the highly subsidized government engineering institutes. This is so because, the spending power of the people have greatly improved due to the developing economy [14], even if their wards were not fit for undertaking engineering studies.

In this scenario the quality of technical education system began to deteriorate and many deformities and discrepancies crept in. To stem this downward slide some of the State Governments established the 'technological universities' in an effort to bring some semblance to the system. But this also posed some new challenges due to the sheer size of the large number of institutes affiliated to them. Therefore GTU (Gujarat Technological University), one such university in the Western part of India assigned the task of developing the appropriate curricular strategies to deal with these challenges to National Institute of Technical Teachers' Training and Research (NITTTR) Bhopal, and the authors as the core design team took up this task of curriculum development.

To begin with, the team was entrusted to address the curricular issues of the engineering diploma programs being offered by GTU. After analyzing the scenario, the authors developed and implemented this model of 'outcome-based curriculum', keeping in view the challenges and opportunities thrown open by the rapidly changing social, industrial and educational environment.

II. TECHNOLOGICAL UNIVERSITIES OF INDIA

It would be relevant to understand the creation of the 'technological universities' in India, a unique feature in the Indian context. The 'generic universities' (awarding different types of diplomas and degrees) - to which most of the private engineering education institutes were initially affiliated with, neither had any expertise to monitor the quality of these institutes nor was it their main focus (as the number of basic humanities and science colleges associated to them were relatively many times more as compared to these newly started engineering education institutes). This situation raised several questions about the quality of engineering education and in such a scenario the concept of 'technological universities' exclusively catering to the needs of the engineering education got evolved in India [8]. Presently, many of the large states (provinces) of India have established government legislated (managed by Govt.) 'technological universities' which affiliate engineering education institutes.

The government's main intention of the creating such technological universities was to bring a large number of engineering colleges and polytechnic colleges under a single umbrella so that the good quality curriculum may be framed, to be uniformly implemented and assessed to fulfill the essential needs of the two broad categories of industries – R and D (research and development) type of industries and the MMS (manufacturing, marketing and servicing) type of industries [4]. It was also envisaged that technological universities would be able to pool the best talent available in the region in every branch of engineering to develop world class learning resources and laboratories to pursue advance researches.

By the time the state government legislated 'technological universities' took shape, the number of engineering institutes also had increased several fold within a very short period. The rapid changes taking place in society, growth in economy and the establishment of such technological universities provided new opportunities as well as posed new challenges [1].

Many of these private engineering institutes and polytechnics prefer to affiliate themselves with the state government legislated 'technological universities' awarding undergraduate and diploma engineering degrees. This is because the Indian society and industry has more trust in the degrees awarded by the government legislated universities rather than private ones and hence most of the parents like to admit their children only in such institutes that are affiliated to government legislated 'technological universities'. Further, the industry also generally gives greater credit to government awarded degrees rather than those from the private.

However, these mega state legislated universities affiliating hundreds of engineering education institutes also have some inherent problems because of the geographical spread of these large numbers of affiliated institutes. The common syllabi applicable to all students across the state become difficult to implement uniformly and effectively to develop the capabilities and needs as envisaged. This is the genesis of the 'outcome-based' curriculum project which NITTTR Bhopal is undertaking and discussed over here.

III. CHALLENGES OF GUJARAT TECHNOLOGICAL UNIVERSITY

The young Gujarat Technological University (GTU) was established in 2007 and currently, it has a whopping 200 engineering and polytechnic colleges affiliated to it with about 400,000 students studying in them. These institutes offer bachelor's degree and diploma in 31 and 25 different branches of engineering respectively. Some of them also offer graduate and Ph.D. engineering programs.

In India, in the last three decades there have been drastic changes in the society, industry and engineering education system that has posed new challenges. However, the philosophy and approach of curriculum development remained aloof to these changes. By the fall of 2011, GTU realized the need for a complete reengineering of the curricula of its 25 engineering diploma programs to begin with (and later for curriculum restructuring for undergraduate programs in 2013) and NITTTR, Bhopal – which is established by Government of India for the development of the technical education system of the country was given this task, where the authors work.

The authors along with other members of the core team studied the changed situation and analyzed the challenges faced by the engineering education system in general and GTU in particular, which are discussed below:

A. Knowledge Explosion and Ease of Access

There is an increase in volume of knowledge associated with every discipline of engineering due to advancement of technology. For example, till few decades ago, in electrical engineering it was necessary to teach only thermal, hydro and nuclear power generation in detail, but now wind and solar energy has also become commercially viable and hence it has become essential to include these technologies in detail in the curriculum. Similarly, knowledge of power electronics has become essential for electrical engineers because of increased application of power electronics in electrical drives and transmission systems. Similarly, many other new materials/ procedures/technologies have been added in the realm of electrical engineering. Moreover, these methods/ materials/ machines, whether old and now both co-exist making it imperative to teach both and this tends to make curriculum cumbersome. Such knowledge explosion exists in nearly all other branches of engineering for which an innovative curriculum design became necessary.

Further, some inter-disciplinary courses, which were not part of the basic engineering education 30-40 years ago have become quite important such as courses related to computers, entrepreneurship, environment, management and others. The key issue was how to handle the increasing body of knowledge in every branch of engineering, as the period of study for an UG or engineering diploma program is always fixed of 4 or 3 years duration respectively.

In this complex scenario, where the body of knowledge is increasing day-by-day and quality of the entry-level students is deteriorating gradually, it was a big challenge for the authors to design appropriate curriculum.

B. Changed Expectations of Industry

Over last three decades the expected competency profile of engineers has changed due to market conditions and technological up gradations, followed by the changing work culture in the industries which made lifelong learning an imperative professional duty for engineers. They are expected to be good lifelong learners for learning emerging technologies. Similarly, they are supposed to handle different kinds of jobs as companies are forced to change their product profile and organizational structure due to changing marketing conditions. This also requires them to acquire new competencies and skills time-to-time. Educationists agree that for developing lifelong learning skills, opportunities must be provided within the curriculum itself for self-directed and experiential learning [5]. Most of the technical education system in India is 'teacher centered' focusing on learning only from books with the help of teachers, as against the much needed 'student centred'. This situation warranted a complete reengineering of the curriculum [12].

As more and more industrial organisations are shifting from 'hierarchical organizational structures' towards 'flat structures', many of the times the employees are required to take decisions and work in teams, both as leaders as well as members. Such situations demand better communication and decision making skills. However, the present structure of curriculum does not have enough scope for such learning experiences which can develop team working, leadership, decision making and communication skills. [10]

C. Geographical Spread

Being quite a large technological university catering for more than 200 institutes spread over extensive geographical area (196,024 square kms.) to plan, design and implement the curriculum has been a challenge for the curriculum development team. There is a marked difference in the quality of infrastructure (especially laboratories and library) across the institutes between rural ones and urban [11]. This geographical spread means that some of the institutes are located in or around big cities and students and faculty members of these institutes have access and exposure to nearby industries. Some of institutes are in remote areas, where interaction with industries is minimal. Because of these variations, the abilities of students and teachers widely differ from one institute to another [13].

Because of this situation, the expectations of students from the curriculum also differ widely. It has been found that if curriculum seems difficult to some students they may adopt superficial methods of learning. Whereas, if curriculum seems too easy to some, they will feel bored with it quickly. Therefore, the design of this innovative curriculum was to provide enough choices to motivate majority of students to choose courses according to their needs and harness the opportunity due to the nearby industries and to pose a moderate challenge to the most of them. 'Moderate challenge' is a must for in-depth and enjoyable learning. [Eraut].

D. Poor Quality of Entry-Level Students

Another problem posed by the proliferation of private engineering institutions is the less number of good students for diploma engineering programs. The Indian society, especially the middle class, accords better social status to bachelor degree in engineering rather than engineering diploma programs. Since there is more number of private engineering colleges, most of the students (irrespective of their aptitude and abilities) take admissions in undergraduate programs, even paying higher fees, as their 'neo rich' parents can afford. This has resulted in only academically or financially poor students joining the engineering diploma programs, since it is of lesser duration i.e. only of three years and that to after the 10^{th} grade. This helps them to get jobs earlier than the bachelor engineering students albeit at a lower level of hierarchy and salary [1].

E. Specialised Knowledge Growth in Various Sectors of Economy

The last few decades have transformed the Indian economy and it has grown in leaps and bounds due to public-private partnership (PPP) and globalization. Due to new knowledge being added to the body of knowledge, new specializations in the so-called conventional branches of engineering emerged in many sectors. In other words, the industry wants more specialized and competent persons to cater to the changing needs of different sectors of economy, rather than only generic engineers in civil, mechanical and other branches of engineering [10]. Moreover with more technology specializations, the economic scenario has changed and every sector has become large enough to provide specialist engineering employment opportunities in sufficient numbers on regular basis.

Therefore, there is enough scope for a greater number of specialized breed of technical workforce required to work in the new and changed technological and industrial scenario. For example, the civil engineers are required to have the expertise in four major specialized areas such as, 'Building Construction' (residential and commercial buildings), 'Transportation' (i.e. highways, railways, docks and harbours and Airports), 'Water Resource Management' and 'Irrigation' (Dams and Canal System), 'Environment and Public Health Engineering' (Drinking water, Sewerage, Effluent and Solid West Management). The current civil engineering syllabus attempts to develop expertise in all these areas leading to a generic civil engineering degree, with which the industry is not satisfied at all. In earlier times, such generic civil engineering degrees were required as there were limited job opportunities.

Moreover, the technological advances in each of these sectors has increased so much that the entire amount of knowledge cannot be included in the same time span which is always constant. Therefore, from employment point of view as well as meting out justice to the body of knowledge, there is a strong case for specialised engineering diploma in civil engineering such as the following:.

1) *Civil Engineering Diploma with specialization in Building Construction*
2) *Civil Engineering Diploma with specialization in Transportation Engineering*
3) *Civil Engineering Diploma with specialization in Water Resource Management*
4) *Civil Engineering Diploma with specialization in Environment Conservation*

Similar examples are seen in other branches of engineering and these curricular issues have been addressed in this innovative GTU curriculum model.

F. Curriculum for Greater Mobility for Jobs and Higher Education

The proportion of Indian population below the age of 20 is considerably more as compared to that in other parts of the world. This has created a situation of demographic dividend for India [6]. This means that India is in a position to supply workforce to other parts of the world as many of the better performing graduates from India are already taking up employment in Europe, USA, Middle East and Far East Asia, Africa and Australia. In addition to this, there is perception that the higher education in developed countries is better which is substantiated by the increasing number of Indian students taking admissions for higher education in Europe, USA, Canada and Australia. In this scenario, it was high time that India fell in line and designed curricula to match the Washington Accord for undergraduate programs and Sydney Accord for Engineering Diploma Programs [2] as these accords ensure the minimum level of quality and desired uniformity to render greater global mobility of individuals for jobs and higher education.

IV. Curricular Innovations vis-à-vis Challenges

In order to address the issues discussed in the previous section, the challenge with the core team was, what curriculum design is to be adapted for the engineering diploma programs offered by GTU. Several rounds of workshops were conducted by the core team with the stakeholders in which the following probable solutions emerged.

1) The existing curriculum did not provide clearly stated learning outcomes. Centralized development of curricula requires that it should give enough clarity to all concerned – first to the student, then to the teachers and the industry, followed by all the other stakeholders. This meant that the curriculum should explicitly state as to what are the observable and measurable 'competencies' expected by the industry which are to be developed in the students after the course of study. Such 'competencies' comprising of measurable 'Course outcomes' in the 'cognitive domain', measureable associated practical outcomes in the form of exercises in the 'psychomotor domain' and measurable social skills related to the 'affective domain' will help the students and teachers in knowing the 'length, breadth and depth' of the course necessary to achieve the competency [9].

2) In a large state like Gujarat, where students come from urban, semi-urban and rural backgrounds, job opportunities also differ in different parts of the state. Hence, the students' interests and abilities are also different requiring the curriculum design to have enough choices to cater to these differing needs. It was decided to provide sufficient options in the curriculum.

3) Another problem noticed in the existing curriculum was that, some of the foundation courses such as 'Physics', 'Chemistry', 'Mathematics', 'Drawing' and 'Workshop Practice' were common for every engineering program. Even those concepts and principles not required for that branch of engineering were being taught. For example, 'electricity and magnetism' was being taught in the course of 'Physics' to civil engineering students to the same depth as to electrical engineering students. Again, in the course of Chemistry 'cement' was being taught to mechanical engineering students to the same depth as to civil engineering students.

Similarly, the course of 'machine drawing' was being taught to electronics engineering students. In 'Mathematics' some topics which would never be used by the students of that branch of engineering was being taught and assessed. Same was true for the course of 'Workshop Practice' course where electrical engineering students were asked to work on 'lathe machine' which they would never do in their career. Because of this approach considerable amount of content which is not directly relevant was being taught to students. The authors formulated program specific courses of 'Physics', 'Chemistry', 'Mathematics', 'Engineering Drawing' and 'Workshop Practice'. This did away with the less relevant content thereby creating space for more relevant courses.

4) To cater to the poor quality of entry level students, curriculum should have enough space (especially in initial semesters) for giving practice to cement some of the fundamental concepts which they should have acquired from the school. Poor intake quality also means that teachers would require more efforts to make sure that students acquire core competencies, which would require for the provision of more tutorials in the new curriculum. This was achieved by making some of the advanced courses as optional to create more space for practice/tutorials in core competencies. Moreover, some of the traditional courses were shifted to later semesters in the new curriculum, thus creating more space for tutorials.

5) The industry needs 'work-ready' graduates with competencies not only in technological areas but also in the areas of communication, team working, decision making and lifelong learning. For development of these generic competencies, work-based learning experiences such as 'project work', 'problem-based learning', 'seminars', 'industrial visits/training', 'case studies', 'maintaining reflective portfolios' are some of the strategies incorporated in this innovative curriculum, which also require relatively more time[15]. This situation again warrants reduction in curriculum content judiciously to create more space and time for such assignments, which was made possible again by using the mechanism of converting some of the advanced courses in the new curriculum as optional.

6) Knowledge explosion and its easy access on the internet provide us both a challenge and an opportunity. It is neither feasible to teach every aspect related to the concerned program nor is it required to be taught, as it is easily accessible to learn by the student on the tap of the finger. This situation warrants that instead of transferring every bit of knowledge to students, they should be provided with opportunities to learn to access and apply the knowledge. The opportunities envisaged in this new curriculum are through micro, mini and major project assignments, problem-based learning, seminars and others. Provision of time for these activities was made in the curriculum, and this was done by reducing the number of advanced courses and concentrating mainly on core courses.

7) Emergence of new technology courses where earlier technology courses still co-exist, addition of inter-disciplinary special courses related to computers, environment, entrepreneurship, and management have made the curriculum too cumbersome. This problem was compounded with the poor quality of entry-level of students. In this situation, an option was to reduce the number of advanced courses so that core courses may be taught in detail with provision of tutorials for more practice.

In this situation, the authors suggested to keep only awareness level courses for all specializations related to the concerned engineering program. And further encourage the students to learn advanced courses related to any one of the chosen stream or specialization (as students are given the choice to choose a stream within the same program). This design helped in reducing the number of advanced courses while ensuring that students possess basic knowledge of all the streams related to that branch of engineering but is competent enough in his/her chosen stream and be work ready for employment soon after graduation.

8) As mentioned earlier, growth in many sectors of the economy have created large number of specialized jobs and hence special programs related to that particular sector are not only feasible but are very much needed. To address this issue, 'stream specific' engineering programs within the same engineering program were created some examples are given below for illustrating the concept further:

a) Mechanical Engineering Diploma with specialization in 'Manufacturing' (machining, casting, forging, fabrication including CAD/CAM)

b) Mechanical Engineering Diploma with specialization in 'Thermal Engineering (Air Conditioning and Refrigeration, Power Plant Engineering)

c) Mechanical Engineering Diploma with specialization in 'Automobile'

d) Electrical Engineering Diploma with specialization in 'Industrial Drives'

e) Electrical Engineering Diploma with specialization in 'Power Systems' (generation, transmission and distribution).

9) To avail the global opportunities of jobs and higher education it is essential that engineering education programs are in tune with Washington Accord for UG programs and Sydney Accord for engineering diploma programs. The National Board of Accreditation (an autonomous statutory body created by Government of India) has brought in the criteria for accreditation in line with these international accords [7]. The cardinal feature of these accords are that the engineering education should be 'outcome-based' by which 'program outcomes' and 'course outcomes' are in observable and measurable terms to be implemented and assessed in such a way that students are able to achieve these outcomes by the time they graduate.

In this backdrop, it became essential to design a curriculum based on competency (or outcome)-based education. This design rendered the curriculum to be explicit and understood equally well by all stakeholders to gauge its depth and scope in the same spirit as envisaged by the curriculum designers. However, the competency-based education requires that students should be given enough time and work-based learning opportunities to hone the all the skills in all the three domains of learning (i.e. cognitive, psychomotor and affective) and to integrate them holistically while performing in real life situations [3]. To meet these requirements the core team evolved a design to accommodate this time and space requirement within the curriculum, which was a major, but interesting challenge.

V. GUIDELINES FOR INNOVATIVE CURRICULM

In the backdrop of the discussions thus far, some guidelines and criteria for this innovative curriculum design for engineering diploma programmes were evolved which are stated in this section. Few of the terms used by the Indian industry are adapted in this curriculum design. The term 'competency' is the one which the industry generally uses for the 'observable and measurable' abilities required in the engineers and there will be several for each occupation. The term 'outcome' is what educationists and curriculum design team also used in the educational context to separate them out in different domains of learning:

a) Curriculum to be outcome-based where competencies / program outcomes and course outcomes are measurable.

b) The competencies/program outcomes to be based on the needs of the industry.

c) The course outcomes emerging out of the competencies/program outcome not only ensures its achievement, but also lead to the identification of the topics and sub-topics.

d) Foundation courses such as 'Physics', 'Chemistry', 'Mathematics', 'Engineering Drawing' and 'Engineering Workshop's to be program specific. Even if the course name may remain the same, course code will differentiate them. For example, separate courses to be created on engineering workshop for civil, electrical and mechanical engineering programs.

e) Tutorial classes for key and difficult courses such as 'Mathematics', 'Engineering Mechanics', 'Electrical Networks', 'Strength of Materials', 'Theory of Machines' and others were envisaged.

f) Provisions to be in place for micro, mini and major projects, problem-based learning, seminars, and internet-based assignments to develop technical and generic competencies in students. These activities to be undertaken by students in self directed learning mode and teachers to function only as facilitators so that students develop lifelong learning skills.

g) Space to be created in the curriculum for tutorials and self-learning activities by eliminating obsolete and trivial topics.

h) The number of advanced courses to be reduced or kept as optional courses so that sufficient space is created to develop the core technical and generic competencies necessary for that occupation/program.

i) In the final two semesters, students to choose a particular stream for specialization within the concerned program wherein three advanced courses are to be offered.

j) Students also to choose their major project from the same stream to ensure development of competencies in the area of specialization.

k) For accommodating certain advanced courses, only awareness level courses of important streams of the concerned program to be included in the curriculum in the final two semesters.

l) The curriculum to include the instructional strategies, detailed list of learning resources - books, software, websites, equipment and instruments with broad specifications; so that every stakeholder is able to implement the curriculum in letter and spirit.

m) The assessment scheme for each course to be well defined for progressive and end-of-the-term examination. Specification table for assessment of course outcomes related to the cognitive skills to be included.

n) The course outcomes ensuring the achievement of the competency/program outcome related to the psychomotor domain to be well defined in the form of practical exercises matching with outcomes to be listed starting with 'action verbs'.

VI. CURRICULUM DEVELOPMENT PROCEDURE

Based on the discussed guidelines, the 'NITTTR-GTU Engineering Diploma Curriculum Development Model-2012' illustrated in Fig.1 was adapted as explained below:

During phase-1 (see Fig.1), in consultation with few industry experts a team of experienced engineering teachers and the NITTTR core team designed twenty-five questionnaires containing the lists of competencies for twenty-five different occupations. In these questionnaires respondents were asked to rate the competencies on a scale of 1 to 5 depending upon their relevance. Information regarding latest materials/ machines/methods and software being used in the industry was also asked.

In phase-2, to validate the identified competencies, the questionnaires were administered to 600 industries both of the MMS (Manufacturing, Marketing, Service) type as well as R and D (Research and Development) type across the state of Gujarat. These were then statistically analyzed to rank the competencies relevant to the 25 engineering diploma programs. Based on these rankings competencies were classified as essential, desirable and trivial. It was decided to have courses related to essential competencies as core courses while courses required for desirable competencies as part of optional courses.

Based on the analysis in phase-2, program structures for the 25 engineering diploma programs were formulated in phase-3, which also involved sequencing of the courses, allocation of credits and marks to each course in the respective program, and balancing the various courses for a holistic outlook. The title of units to be included in each course was also decided at this stage so that an overall picture of the topics to be included in each program emerged, ensuring that nothing important was missed out or nothing trivial was added. These program structures were then displayed on GTU website for suggestions/comments from the stakeholders, on the basis of which the program structures were finalized. This whole exercise was undertaken through a series of workshops.

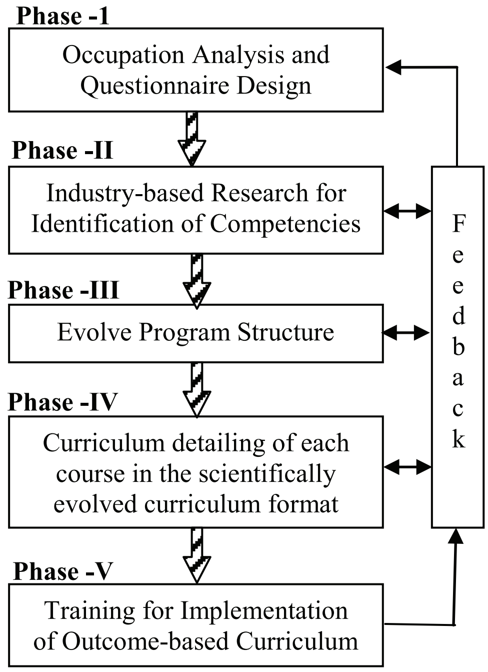

Fig. 1.'NITTTR-GTU Engineering Diploma Curriculum Development Model -2012'

The most time consuming exercise was phase-4, wherein each course was detailed out in a format (discussed in section VII) developed for this design. This was a massive exercise in which tens of teachers sat through a number of 3-day workshops spread over several weeks to develop each course (totaling around 700 courses for 25 programs) curriculum. The subject expert teachers were first trained by NITTTR core team to address all the issues discussed in the preceding sections in developing the course details. Then each developed course curriculum was edited and validated by NITTTR experts.

In phase-5 the engineering and science teachers from various regions of the state of Gujarat who were involved in the various curriculum development workshops of the various courses became resource persons to train the other teachers from different institutes of the state in the implementation of this innovative curriculum in letter and spirit.

VII. Curriculm Development Format

In order to fulfill the guidelines of the outcome-based curriculum and to develop the industry specific competencies and associated skills, 10-point curriculum detailing format was evolved, the sub-heads of which are given below (details available at GTU website):

1) Rationale

2) Competency (Programme Outcomes)

3) Teaching and Examination Scheme (Example)

Teaching Scheme			Total Credits	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	ESE	PA	ESE	PA	150
3	2	2	7	70	30	20	30	

Legends: L-Lecture; **T** – Tutorial/Teacher Guided Student Activity; **P** - Practical; C – Credit; **ESE** - End Semester Examination; **PA** - Progressive Assessment

4) Course Details (Example)

Unit	Major Learning Outcomes (course outcomes)	Topics and Sub-topics
Unit – I Transducer Basics	1a. State the basic requirements of transducers	1.1 Basic requirements of transducers
	1b. Describe the static characteristics of transducers	1.2 Static characteristics - accuracy, precision, error,
Unit– II		

5) Suggested Specification Table with Hours and Marks

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total
I		06	08	06	00	14
II						
III						
IV						
V						
	Total	42	12	46	12	70

Legends: R = Remember; U = Understand; A = Application and above levels (Revised Bloom's taxonomy)

6) Suggested List of Practical Exercises (Example)

S. No.	Unit No.	Practical Exercises (Course Outcomes)	Hours
1	III	Test thermocouple	2
2	III	Test the RTD	2
3			

7) Suggested List of Proposed Student Activities

8) Special Instructional Strategy (If any)

9) Suggested Learning Resources

A. List of Books with authors and publishers

B. List of Major Equipment/ Instrument with Broad Specifications

C. List of Software/Learning Websites

10) Course Curriculum Contributors

VIII. Conclusion

One uniqueness of this experiment is that it is being developed and implemented in real time as seen on the GTU website: http://www.gtu.ac.in/syllabus/NEW_DE_SchemeSyllabus.htm Another feature is that the formative evaluation is being undertaken (see Fig.1) and the informal feedback from the stakeholders is quite encouraging. Still another feature is that the self-directed and e-learning by the students is built into the design. Other features can be considered at the presentation. A formal impact study will also be undertaken soon.

Acknowledgment

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Women in Computing

A Case Study About Kuwait

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Abstract— **Female under-representation in the field of computing has been a global concern. According to recent research studies in the US, females are less likely than males to consider a career or a degree in computer-related fields. Opposite trends have been appearing in other parts of the world showing a high female turnout in computer studies. One of those countries is Kuwait, a small country situated in the Persian Gulf. According the UNESCO Institute for Statistics, the percentage of female graduates in tertiary education in Kuwait has reached 69% in 2009 (80% in science related disciplines). Female undergraduate enrollment in computing studies in Kuwait is in the range of 40 to 50 percent, which is considerably high compared to other parts of the world. In this paper, we present a case study about women in computing in Kuwait, through which we highlight their motivations for studying computer science and information systems. A survey was conducted among male and female university students in Kuwait about attitudes and perceptions on females in computing and reasons for joining computer studies. The results were analyzed and compared to similar studies in the US.**

Keywords—gender issues in computing; Kuwait; socio-cultural influences

I. INTRODUCTION

The difficulty to attract females to the computer science (CS) field has been a long standing problem around many parts of the world, especially the United States. In 1995, females comprised only 28% of those awarded CS bachelor's degrees in the United States. This percentage has even shrunk to 21% by 2006 [1] leaving a question lingering over the reasons behind this gender gap. Research studies have revealed a number of interrelated factors contributing to the declining representation of females in the field of computer science worldwide. These could include sociocultural, pedagogical, and psychological factors. However, the way these factors operate and interact with each other could differ from one culture to another [2].

A number of studies comparing women representation in CS across different nations have highlighted cultural factors as major contributors to the existing gender divide in those nations [3]. Arab countries, however, have not yet been included into those studies, up to the authors' knowledge. This research paper is an initial attempt to understand the perceptions of Arab students about computers and computer studies.

Initial secondary data in the Arab world show that the last few years are witnessing an increased demand for CS education and careers across many countries of the Arab world. Reasons and explanations behind this increased demand are yet to be studied.

Kuwait is one of those countries witnessing a rise in women participation in the field of CS. In order to understand the circumstances surrounding this fact, it is pertinent to examine the educational environment in Kuwait. This will be highlighted in the following section.

The rest of this paper is organized as follows:

- Section 2 includes country background and research environment.
- Section 3 includes a literature review of similar research in different parts of the world.
- Section 4 introduces the research idea and methodology.
- Section 5 includes results of the conducted surveys.
- Section 6 includes discussions and analysis of the findings.
- Section 7 concludes the paper and recommends areas of future research.

II. COUNTRY BACKGROUND AND RESEARCH ENVIRONMENT

A. *The Educational Environment in Kuwait*

Kuwait is a small country situated in the Persian Gulf and is part of the Gulf Cooperation Council [GCC] that incorporates: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and UAE [4]. With a 40% expat population, the government of Kuwait is working hard to encourage local employment and to generate qualified local caliber. Within this context, the Kuwaiti government is reinforcing educational reform at all levels [5].

Unlike most private schools in Kuwait, the public schools are segregated by gender starting the first grade. The gender segregation law has been recently amended to include also private and public higher education institutes including, the American University of Kuwait (AUK), which will be part of this study. By means of the new law, all private universities/colleges and branches of foreign universities started to apply gender segregation in all departments, disciplines and students activities [6].

B. The IT Employement Market in Kuwait

Employment in governmental organizations in Kuwait is considered the most prestigious and income generating employment option. Within the IT job market, computer engineers are the most demanded and come at the top of the pay scale [7]. Computer scientists, however, do not fall within the same category with computer engineers. So, students choosing between both majors would sometimes prefer computer engineering for being the most employable choice. Since computer engineering is offered only in one governmental and one private university in Kuwait, students enrolled in other universities may consider computer science as an alternative. This will be manifested in the results of our study, at a later stage of this paper.

C. Status of Women in Kuwait

Despite the ongoing debate around gender segregation in schools, Kuwait remains among the top performers in the Arab Region when it comes to narrowing the gender gap and empowering women. According to the Global Gender Gap Report 2012 [8], Kuwait ranks 2nd in the Arab world (after the United Arab Emirates) on the Global gender gap index.

Kuwaiti women comprise 70% of university students and 40% represent the Kuwaiti workforce. They are present in all professional fields including Education, Medicine, Business, Journalism, Banking and the Government Sectors.

According the UNESCO Institute for Statistics [9] , the percentage of female graduates in tertiary education in Kuwait has reached 69% in 2009 while the female tertiary graduates as percentage of all graduates in science has reached 80%. Interestingly, 37.1% of science researchers in Kuwait are women [6].

According to 2011 Kuwait Private Universities Council (PUC) records, women enrolled in undergraduate CS and information systems (IS) majors in some private universities in Kuwait has exceeded 50% [6], which is considerably high compared to other parts of the world. This raises a question on how Kuwait females develop interest in computer studies; and whether this is related to socio-cultural and pedagogical factors.

In this paper we attempt to answer these questions though understanding the difference between males and females when it comes to their relationship to computers and technology. At this stage of our research, we do not aim to develop hypotheses. The initial results will rather help set direction for future research through underpinning the factors that have greatest influence on females' attachment or detachment from computers and technology. Furthermore, our observations can help adjust "pedagogical, administrative, and social methods aimed at both attracting and retaining women students" [10].

III. LITERATURE REVIEW

Due to its multidisciplinary nature, the field of females in computing has received attention by scholars in various fields, including computer science, education, and women studies [10]. Research efforts in this area can be summarized under four main domains:

- Trying to identify the misperceptions about female abilities in computing [10, 11].
- Analyzing male and female intrinsic interest in computers and computing [12].
- Investigating decision making and motivation [10] to study computer among both genders.
- Examining solutions to generate more interest in computing among women [13, 14, 15].

A. Misperceptions About Females And Computing

- Evidence shows that both females and males believe that that males have better computing abilities than females [16, 17].
- A "Biased social environment" nurtures the assumption that computing is predominantly a male field [12].
- Due to stereotyping, a gap exists between women's perceived abilities and their actual performance. Once they start studying CS, female students realize that their performance is better than what they expected [10].
- CS students are perceived to be geeks, socially uninvolved, "have a single-minded focus" and no interest in social activities. These stereotypes deter females from studying computing [10].
- Research shows that linking success to ability instead of effort may lead to disappointment and withdrawal from the challenge. Counting on effort and hard work creates a momentum to continue and go through the challenge [18]. So females should never define their relationship with studying computing in terms of ability or inability.

B. Decision Drivers And Actual Performance

- Motivation to enrolling in CS varies among different cultural groups. American students make their choice based on passion, while other nationalities studying in the US base their decision on pragmatic reasons, like potential careers [11, 12].
- Non-American students, especially those from Asian countries, believe that hard work, rather than ability, is the driver for success in computing [10, 11]
- It is important that students and faculty understand that motivations for studying computing can change "from pragmatism to intellectual pleasure" if the experience is rewarding and engaging [11].

C. *Interest In Computing*

- Males perceive computers in the context of gaming, fun, software architecture. They have interest in computers as appealing objects and in computing as a process [10, 11].
- Females appreciate the fun aspect of computers but focus more on their broader uses and utilitarian aspects [10, 11] .
- Family has a significant role in shaping male and female interest in computers at an early stage [10].

D. *Proposed Solutions*

Introducing single-gender classes was one of the proposed solutions to generate female interest in computing [13, 14, 15, 19]. In Kuwait, observing performance in single-sex versus co-ed classrooms, single sex classrooms showed better performance among both genders [13]. In their study about Mauritius, Adams, et al. [15] relate the high representation of women in computer science to the separate gender education at Mauritian high schools, which "permits Mauritian women to discover their academic strengths and weaknesses in an environment that is separate from (but equal to) that of Mauritian men" [15]. Similarly, some experiments have proven that introducing female-only computing classes within a co-ed environment could be a good strategy for increasing male and female interest in computing studies [20]. Implemented in Sweden, this idea proved to be successful in attracting and recruiting more women in the field of computing [21]. In Malaysia, studies show that females outnumber males in the field of Computer Science [22]. The study aimed at showing if Malaysian males and females perceive CS in the same way. The study shows that both genders enjoy CS and feel prepared for the programs at the same level [22]. The case in Kuwait may be similar since the number of females is relatively high in CS.

Other research studies focused on administrative and pedagogical strategies to boost female confidence in their abilities. Fisher [10] noted that females "prefer to learn about computers in a purposeful context." Developing curricula in line with this philosophy may engage females' interest in computing [11]. A recent study conducted in Kuwait [13] shows that females tend to be more engaged with programing when assigned projects serving female interests, like fashion, children, or household.

In light of the forgoing literature, we attempt in this paper to explore the perceptions and misperceptions about the field of computing among males and females in Kuwait. We also aim to identify the key factors that attract females to computing.

IV. METHODOLOGY

A. *Procedure*

A survey was conducted among a small sample of male and female students from public and private universities in Kuwait. The survey was administered online through Survey Monkey (an online surveying and analysis tool). Referral sampling techniques were used, starting with at least two students and one professor from each participating university. To boost the sample, personalized emails were also sent to CS and IS students in some universities. In addition, university Facebook pages were used to call for participation in the survey.

B. *Sample*

The sample consisted of male and female subjects with the following profiles:

- Students majoring in computer science (CS) and information systems (IS) (drawn from private and public universities in Kuwait).
- Fresh graduates of both CS and IS employed within the fields of CS or IS.

C. *Tools*

A questionnaire was developed to measure two parameters:

- Male and female attitudes towards computer science and Information Systems
- Male and female decision drivers for studying CS & IS.

The questionnaire consisted of two sections; a set of closed ended categorical questions, and a set of even-point Likert scale questions. The first section of the questionnaire aimed at discovering the reasons behind joining the field of computer science. The list of choices provided was based on the results of exploratory focus groups and one-on-one interviews conducted among USA and Kuwait CS female students.

The second section of the survey aimed at discovering the attitudes and perceptions of computing through a 4-point Likert scale. The survey questions were adapted from the Wiebe, Williams, Yang and Miller instrument [23], which was based on the Fennema-Sherman mathematics attitude scale [19].

Mid-point responses have been omitted from the Likert scale. This has proven useful in attitude questions as it helps avoid social desirability, arising from the inclination to choose middle ground responses [24]. Reverse scoring was applied to negative questions to maintain consistency. We only used questions addressing the gender construct, which serve the purpose of our study.

D. *Responses*

The study rendered 65 responses, which is a sufficient number considering the following reasons:

- The number of computer science students across Kuwait does not exceed 300 students.
- The survey is not intended to provide quantitative statistical data. But rather, to identify parameters that need future investigation.

V. KEY FINDINGS

A. Reasons for Studying Computer Science/Information Systems

Fig. 1 reflects the motivations of both males and females for joining CS/IS majors. The reasons mentioned most frequently were career and future considerations, followed by the best alternative for Engineering and government scholarships. Other reasons, related to parent advice or interaction with friends or professors rendered lower scores. Interest in computers/videogames/programming was a common answer in the open ended part of the question that was left open for "Other Reasons". This has been added to the graph below for the sake of comparison.

Male and female scores came very close on most of the reasons, with a slightly higher male reference to career related reasons. The two reasons which were totally dominated by males were Interest in computers/videogames/ programming; and Interaction with CS/IS friends.

B. Attitudes Toward Females In Computing

The attitude question (Fig. 2, 3) is evenly split into 4 positive statements and 4 negative statements. Statements were given a score from 1-4 based on a Likert scale (where 4 corresponds to "Strongly Agree" and 1 corresponds to "Strongly Disagree"). As indicated in Fig. 2 positive statements about females in computing received high scoring, while negative statements received low scoring. The statement that remained clearly in the middle zone was "*It makes sense that there are more men than women in computer science"*.

Fig.3 shows the same results broken down by gender. Females scored higher than males on all positive statements, while males score higher than females on all negative statements. Both genders showed a clear disagreement on the statement: *It is hard to believe that female could be a genius in computer science.* Relevance and indications of these results will be discussed in the next section of this paper.

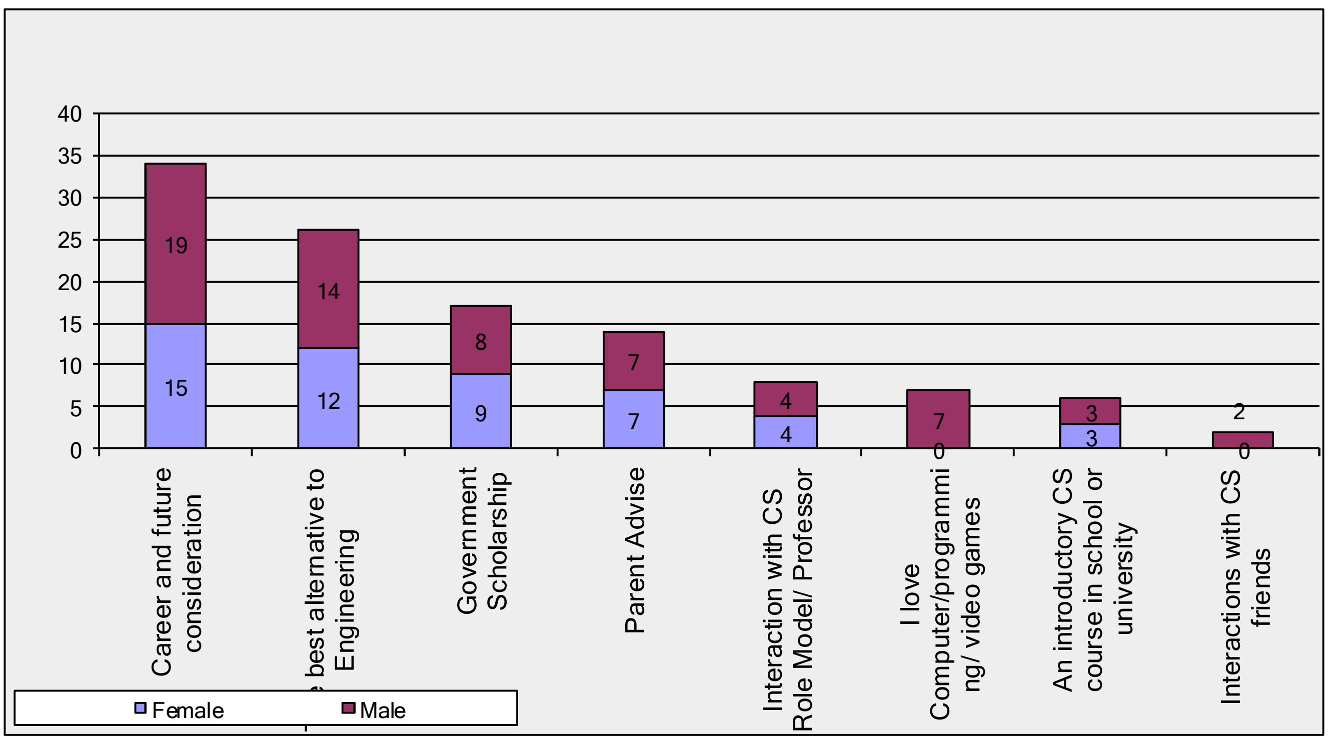

Fig. 1. Reasons for joinging Computer Science/Information Systems

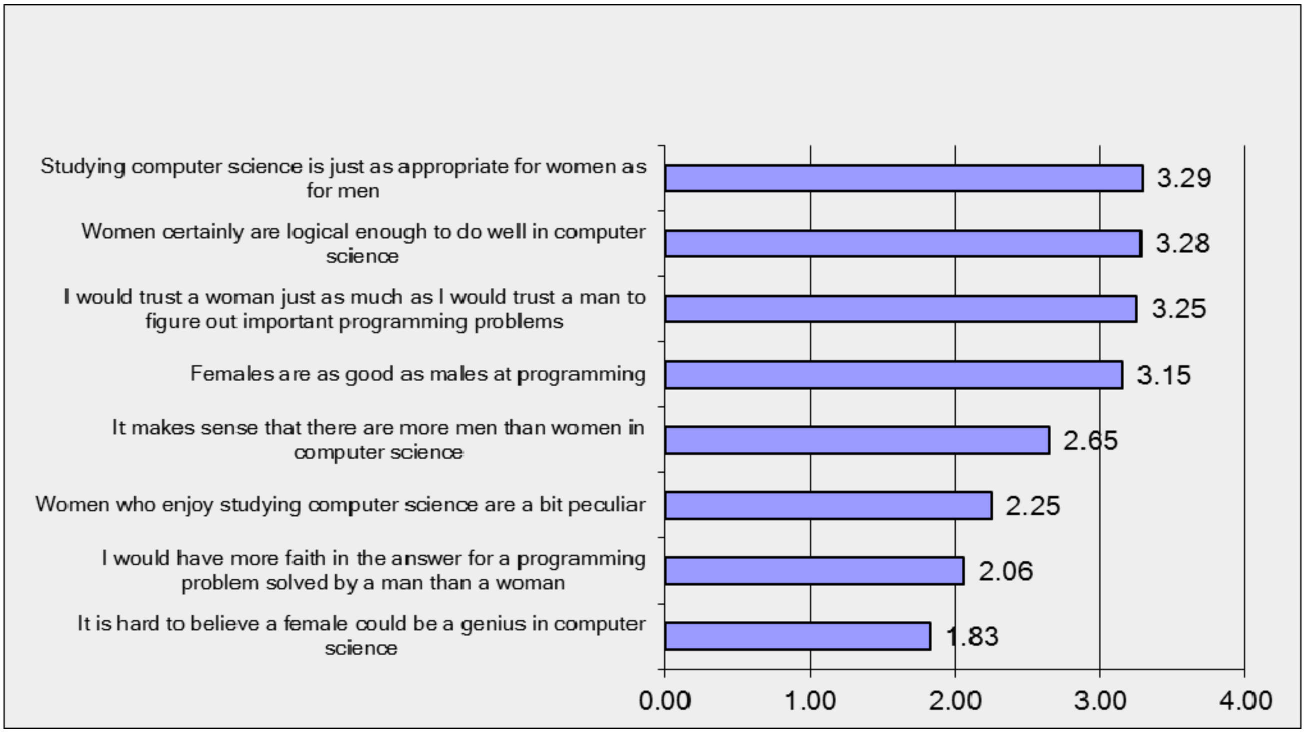

Fig.2. Attitudes and perceptions about females in computing

Fig. 3. Attitudes and perceptions about females in computing – males vs. females.

VI. DISCUSSION

In light of the findings shown in the previous section, we may assume that both males and females based their choice of CS/IS on more pragmatic factors (career and government scholarships) rather than interest in the field. Socio-cultural factors (role models, peer influence, or parent advice) were not among the top influential factors. It is surprising to see such a result, especially in a collectivist society like Kuwait, where social conformity and peer influence play significant roles in shaping people's preferences [25].

Whereas the scores of both gender closely match on most of the reasons for studying CS/IS, it is interesting to see that reasons related to passion with computers and programming were associated with males. Although, it scored lower, peer influence was a factor mentioned only by males.

When comparing Kuwait to the US (Table 1), females in both countries show common motivations for choosing CS/IS. This is not the case with males, whose results imply more inclination to pragmatic factors in Kuwait.

Moving to the attitudes and perceptions, the overall results in Fig.2 indicate that perceptions about females in computing were positive among both genders. However, by examining the detailed graph in Fig. 3, we noticed some gender bias in both positive and negative attitude statements.

As the figure indicates, males scored lower than females on positive attitude questions and higher than females on negative attitude questions. This indicates that the negative perceptions against females in computing are higher among male respondents. However, these perceptions do not have a significant effect on the overall average due to the high number of female respondents, approaching 50% of our sample.

As this figure increases, females' confidence in their abilities eventually generates more interest in the field. This relationship between confidence and interest has also been noted by Margolis et al. [12]:

> *"Our research identifies a "chicken and egg" problem that affects a female student as she thinks about her interest in computer science: ..is it lack of interest due to lack of confidence? Or is it lack of confidence due to lack of interest? It is hard to disentangle one influence from the other, to know how they interact"*

This relationship does not only exist within the CS female student population, but is also projected to the male students. From our results, we can contentedly claim that negative male attitudes toward females in computing still exist but they are being diluted by the increasing number of females joining the field. The balance that is starting to happen between the numbers of females and males in CS/IS in Kuwait is automatically limiting the effect of negative stereotyping that turns females away from computing in other parts of the world. Research on stereotypes strongly supports our conclusion. Recent studies demonstrate how "stereotypes, even those that people are not consciously aware of, can influence the careers of women and minorities" [25]. According to these studies, stereotypes can also bring down the "self-esteem, motivation, and intellectual performance of women and minorities through a process called stereotype threat" [25].

TABLE 1: DRIVERS FOR MAJORING IN COMPUTING- KUWAIT VS. USA

Categories	**Primary Drivers for majoring in CS/IS**	**Other Motivators**
USA Males	Intrinsic interest in computers	Introductory Classes Peer influence
KWT Males	Promising career Best alternative to engineering Government scholarships Intrinsic interest in computers and programing Parent advise	Interaction with role models Introductory classes Peer influence
USA Females	Promising career Interaction with role models Parent advise	Intrinsic interest
KWT Females	Promising career Best alternative to engineering Government scholarships Parent advise	Interaction with role models Introductory classes

VII. CONCLUSION

Putting it all together, we can say that the increasing percentage of females in CS and IS majors and professions in Kuwait might have been initially triggered by governmental incentives and openness of the job market. Over the past few years, the established presence of females in the field has created trust and confidence in their abilities among their gender group as well as their male counterparts. This, in turn, has eliminated the effect of negative stereotyping that turns off females in many other parts of the world.

Motivations to join computing among Kuwait males are very different from those of US males. The former group has pure pragmatic reasons, while the latter group has intrinsic interest in the process of computing. In females, the difference is not significant. Both Kuwaiti and US females choose computing for pragmatic reasons or socio-cultural influences.

Research on motivation gives us ideas on how pragmatism can change into intellectual pleasure through a rewarding experience. Creating a new female territory in the world of computing can get females more interested and engaged in the field. This can be done by remodeling educational curricula or introducing female-only classes. Research into this area and its cultural adaptations is still at an early stage. More research and case studies are needed to investigate the best practices in establishing female-friendly computing environments in both academia and industry.

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Preliminary Analysis of an Appealing Program for Outstanding Students at the School of Design Engineering (ETSID) of Valencia

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Abstract— **During the 2010/2011 academic year, the Universities of the Valencia region (Spain) started up a pioneer experience in Spanish Higher Education: the High Academic Performance Groups (in Spanish, the so-called ARA groups "Grupos de Alto Rendimiento Académico") aiming to support and attract the brightest students with the best skills, so that they can achieve a high academic performance.**

The Universitat Politècnica de València (UPV), as a result of its commitment to promote its quality and internationalization, has taken part in this project from the dawn of its implementation. Since then, ARA groups have been set up in five of the UPV Bachelor Degrees, two of them being offered at the School of Design Engineering (ETSID). In this work, we analyse the implementation process of the ARA groups at ETSID since 2010/2011, outlining some of the future strategies that should be taken into account for their consolidation.

Keywords: academic performance; engineering education

I. Introduction

During 2010/2011, the Regional Government of Valencia (Spain), in collaboration with five the public Universities of this region, started up a pioneer experience in Spanish Higher Education: the High Academic Performance Groups (in Spanish, the so-called ARA "Alto Rendimiento Académico" groups) [1].

The purpose of this ARA project is to support and attract the brightest students with the best skills [2-4], so that they can achieve a high academic performance [5], thus promoting their training as highly-qualified professionals.

In order to make this program appealing to students, some complementary activities and specific curricular benefits have been included in the educational offer of these ARA groups from the very beginning such as:

a) At least 50% of the core subjects are taught in English.

b) Participation in these groups is included as a major in the Diploma Supplement [6] (accompanying European higher education diplomas).

c) Participation in these groups is taken into account for mobility grants.

Moreover, during each academic year, seminars for the development of transversal competencies, lectures by renowned experts and visits to relevant companies are offered to ARA students.

Obviously, students aiming to join an ARA group must have a good academic record and a good command of English.

The Universitat Politècnica de València (UPV), as a result of its commitment to increase its quality and promote internationalization [7], has taken part in this project from the dawn of its implementation.

Since then, ARA groups have been set up in the following UPV Bachelor Degrees: Business Administration and Management, Biotechnology, Computer Engineering, Aerospace Engineering, and Industrial Electronics and Automation Engineering, these two latter being offered at the School of Design Engineering (ETSID) [8].

In this work, we focus on the analysis of the implementation process of the ARA groups that is being carried out at ETSID since 2010/2011.

We also outline the future strategies that should be had in mind for the consolidation of these ARA groups at ETSID, based upon the English proficiency of the students of these groups and the evolution of their academic performance, compared to other groups of the same year and degree.

II. Description

This preliminary analysis on the academic performance of the ARA groups has been performed on the basis of the grades percentage and the following average overall rates:

Performance rate = (nº pass students / nº enrolled students) x100

Fail rate = (nº fail students / nº enrolled students) x100

Dropout rate = (nº dropouts / nº enrolled students) x100

In particular, this analysis aims at comparing these indicators between first-year students of the ARA and non-ARA groups of the ETSID Bachelor Engineering (BEng) degrees in Aerospace Engineering, and in Industrial Electronics and Automation Engineering, during the first two consecutive years of implementation of these innovative groups (Table 1).

TABLE 1. Enrolled students in the first-year of the ETSID BEng degrees.

	2010/2011		2011/2012	
BEng Degree	ARA	Non-ARA	ARA	Non-ARA
Aerospace	94	-	44	63
Ind. Electronics & Automation	36	133	40	117

"Vicerrectorado de Profesorado y Ordenación Académica" of the Universitat Politècnica de València (Spain)

III. RESULTS

ARA groups were first implemented during the 2010/2011 academic year.

During this year, in the degree in Industrial Electronics and Automation Engineering, the newly created ARA group co-existed with traditional non-ARA groups, due to the large number of students that happened to be enrolled in this degree (Table 1).

In contrast, in the Aerospace Engineering degree no other groups were offered apart from the ARA group.

During this first implementation year, only 50% of the core subjects were taught in English in both ARA groups at ETSID.

And in order to be able to join an ARA group, a B2 English level (according to the Common European Framework of Reference for Languages, CEFR [9]) was strongly recommended for students, but not mandatory.

On the other hand, the fact that registration was performed according to admission grades to university ensured that all ARA students had a good academic record.

This good academic record was especially true in the Aerospace ARA group where, in addition, all the students accessing this degree are A-B levels.

Academic results during 2010/2011 revealed a higher performance rate and a lower dropout rate in the Electronics ARA group than in the other first-year groups of this degree (Table 2). This improvement approaches 3% for both rates.

In what concerns the Aerospace ARA group, the academic results were also found to be good during this first implementation year, displaying a performance rate close to 95% and fail and dropout rates lower or equal to 3% (Table 2).

However, some problems were detected in this ARA group concerning the appropriate follow-up of the subjects taught in English, by the students with a poor command of English.

Consequently, the following improvement proposals were raised for the implementation of these ARA groups during the 2011/2012 academic year:

a) Both degrees should offer the possibility of engaging either an ARA or non-ARA group.

b) Both ARA groups should extend English teaching to all the core subjects.

TABLE 2. Academic performance in the first-year of the ETSID BEng degrees.

		2010/2011		2011/2012	
BEng Degree	Rate	ARA	Non-ARA	ARA	Non-ARA
Aerospace	Performance	94.7%	-	99.3%	94.3%
	Fail	2.3%	-	0.7%	0%
	Dropout	3.0%	-	0%	5.7%
Industrial Electronics & Automation	Performance	80.0%	77.3%	86.3%	82.7%
	Fail	11.2%	11.0%	11.2%	8.6%
	Dropout	8.7%	11.7%	2.5%	8.7%

As a consequence ARA groups were therefore offered during the 2011/2012 academic year fulfilling the aforementioned guidelines.

Once again, a B2 English level [9] was strongly recommended, but it was not considered to be a mandatory condition for any student willing to join an ARA group.

Nevertheless, during the first semester of the 2011/2012 academic year, all first-year ARA students performed a compulsory English test with the goal of really checking their proficiency in English.

Results of this test revealed that while 95% of the Aerospace ARA students proved to have an appropriate command of English, only 48% of the Industrial Electronics and Automation Engineering ARA students had sufficient English fluency.

From these results, it followed that evidence of a good command of English should be demanded to all the students wishing to join an ARA group.

On the other hand, the analysis of the academic results of the ARA groups during 2011/2012 showed that the performance rate in the ARA groups of both degrees, the BEng Aerospace Engineering and BEng Industrial Electronics and Automation Engineering, was again higher than that corresponding to the non-ARA groups (Table 2).

The average percentage of students who passed was increased in about 5% and 4% in the Aerospace and Electronics ARA groups, respectively.

Moreover, the dropout rate was found to decrease in about 6% in both ARA groups compared with that of the other groups.

However, on average, the percentage of students who failed was somewhat higher in the ARA groups of both degrees, probably as a consequence of the lower dropout rate of these groups.

The analysis of the academic results of this pioneer experience was completed with the determination of the grades percentage for the ARA and non-ARA groups of both degrees (Figs. 1 and 2).

These results showed that, although the overall number of students who passed was higher in general in the ARA groups, as it has been previously described, the number of very good grades (A and B) in the ARA groups of both degrees was just slightly higher to that of non-ARA groups during the 2011/2012 academic year.

And surprisingly, in the case of the Industrial Electronics and Automation Engineering ARA group the number of good grades was even lower during 2010/2011.

Since the ARA project is an innovative experience aiming at supporting the brightest students, a logical consequence should be to have an increasing number of excellent records in the ARA groups.

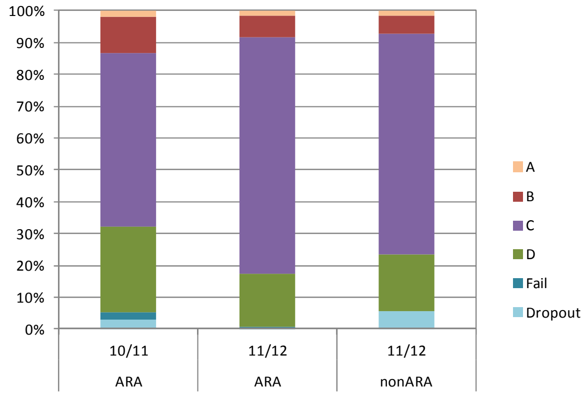

FIGURE 1. First-year grades of the BEng degree in Aerospace Engineering.

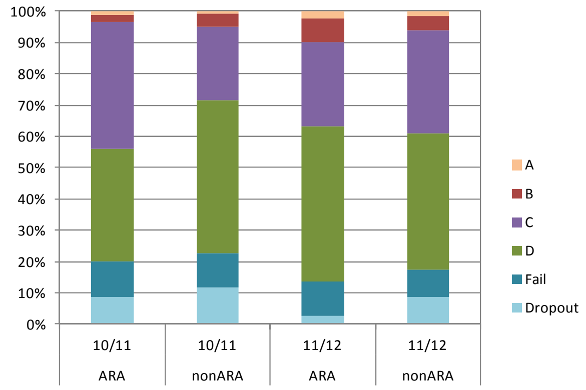

FIGURE 2. First-year grades of the BEng degree in Industrial Electronics and Automation Engineering.

As a result, the following admission requirements were settled for all students feeling like joining to join ARA groups during the 2012/2013 academic year:

a) Applicants should provide proof of their English language proficiency (either through an English level test or an officially recognized certificate).

b) In order to try to improve the academic excellence of these groups, only students who have passed all the subjects may stay in an ARA group during the following year.

c) Excellent students in the non-ARA group and willing to join the ARA group should be allowed to do so at the beginning of their second academic year.

IV. CONCLUSION

This work has provided a preliminary analysis of the implementation process of the innovative ARA groups that is being performed at ETSID since 2010/2011.

In general, academic results of the ARA groups are so far encouraging.

These results have revealed a higher performance rate and a lower dropout rate in the ARA groups, although this in turn seems to have subsequently led to a somewhat higher fail rate in these groups.

Based upon this analysis, initial strategies have been undertaken for the consolidation of these ARA groups that are mainly focused in attracting the brightest students to ARA groups and ensuring a good English command.

In the future, the effectiveness of the adopted strategies will be regularly monitored, thus contributing to the continuous improvement of this program.

In addition, as ARA groups are progressively implemented in subsequent years of study, this analysis will be addressed to second, third and fourth-year students, too.

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Introduction of Entrepreneurship and Innovation subjects in a Computer Science course in Brazil

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***Abstract*—The recent changes in the world and in technology present both challenges and opportunities to the computer education, which must be adapted / change to meet these challenges. More and more computer courses strive to include entrepreneurship and innovation in the curriculum. However, integrating entrepreneurship and innovation education in computing curriculum could have a significant effect on the creativity, innovativeness, leadership and entrepreneurial intentions of computing undergraduates. In this way, this paper present a view on teaching entrepreneurship to computer science students and describe an experience in introducing entrepreneurship and innovation in computing curriculum in a computer science course at Brazil.**

Index Terms — Entrepreneurship, startups, education, Brazil.

Introduction

The recent global changes in current world order stands out new challenges and opportunities to the computer science education. The existing environment is very different from one decade ago. The technologies, processes, methods and tools have been changing with the globalization, research and development. New interdisciplinary fields like sustainability, social remarks, bioinformatics and robotics has become reality to the computing and is even more influenced by Communication and Information Technology (CIT) [1].

On the other hand, young people face to several challenges in your lives; the rapid technologic advanced, multifaceted carrier, the life style changes and assume greater personal responsibility for achieving "success" in his personal and professional life. Young people need a higher education background, which will give them the qualities, skills and personality to mitigate the challenges during the professional timeline [2]. In Latin America, the young has a big responsibility to achieve successful and is almost inadmissible fail, whether in choice of profession or in whatever segment [3].

Related to these challenges, the computer industry is one of the most dynamic and it is becoming reality to several different areas. So, the introduction to the entrepreneurship education in computer science curriculum could be significant effect in creativity, innovation, leadership and entrepreneurship intentions to the students. Historically, the entrepreneurship education has fueled the generation of innovation and technological advantages. Therefore, the entrepreneurship education for computer science curriculum significantly increases the ability of the students lifelong and desire to innovate [3].

According to Global Entrepreneurship Monitor [4], the lack of education is the main barrier to the entrepreneurship. The problem in computer science degree is that the curriculum focus in technical lectures instead of complementing with business lectures in order to instigate the business creation during the course. Fry and Leman [5] comment that nowadays the renowned university in US, Europe and China solving this problem introducing lectures in the context of entrepreneurship in curriculum. Additionally, a research about entrepreneurship formal education and preview experience in entrepreneurship related that its increases the self-reliance in students, either to a job in a company as creating your own business [6].

In this context, this paper presents one initiative of computer science degree from UFSCar (Federal University of São Carlos), Sorocaba campus, in development of a lecture about Entrepreneurship and Innovation in CIT (Communication and Information Technology) such as the impact that could be observed during theses 3 years in this lecture. Section 2 shows the related work in literature; Section 3 presents the concepts about entrepreneurship and innovation in CIT; Section 4 describes the teaching methodology; Section 5 presents the main results achieved and lessons learned during this course; and, finally, Section 6 presents the concluding remarks and directions for future work.

Related Work

In literature there are some works that related several universities, mainly in US, Europe and China, trying to promote entrepreneurship and innovation. The initiatives could be mentioned in the following areas: (i) introduce technical abilities with non-technical areas like innovation, entrepreneurship, leadership, communication and business model (Mexico University [7], Arizona State University [8], Florida Atlantic University [9], Zhejiang University at China [10], program together with Hofstra University at EUA and Qatar University [11], State University of North Carolina [12], a set of universities from China [13]); (ii) development of startup acceleration and incubation centers (province of West Java at Indonésia [14]); (iii) achievement of studies in order to identify problems, challenges and case of success in introduction entrepreneurship and innovation in computer

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courses (Baylor University [5], Polytechnic University of Valencia [3], regional universities from China [15], a set of universities from China [16]).

Additionally, the Stanford[1], the Harvard[2] and the MIT[3] are the main pillars of the entrepreneurship education in US. These renowned universities mix technical with non- technical skills, where the focus is on entrepreneurship, innovation, leadership and merchant areas. From these three universities some startups were created like Yahoo!, Microsoft, Apple, Google, Facebook, among others.

The MIT's programs, although open to students from engineering and science, was centered in Sloan School of Management; the Harvard program's is also allocated in Business School; and the Stanford program's is performed by Engineering School. The MIT and Harvard offers a wide range of courses, looking for introducing management and business techniques based on available technologies. The course uses a variety of teaching methods: study cases, internship, lectures, external evaluations of students task by venture capitalists and hands-on projects. All courses involve teamwork and focus on presentation techniques.

The Stanford Technology Ventures Program (STVP) is hosted by Stanford School of Engineering. It is the main education program on entrepreneurship based on non-technical abilities like merchant opportunities, business, leadership, etc. To do so, the program offers introductory and advanced courses in marketing, financial, strategy and innovation.

In both, the MIT, the Harvard and the Stanford, the entrepreneurship education is part of the formal curriculum and the business activities are funded by the school. In Brazil, a few universities have this kind of initiatives in Engineering or Computer graduation degree. There are three cases that should be mentioned: (i) Federal University of Pernambuco (UFPE), where the students from bachelor's degree in computer science have the option to choose the Entrepreneurship course besides the optative course available; (ii) Federal University of Minas Gerais (UFMG) and (iii) Federal University of Bahia (UFBA), where it is also offers the optative "Entrepreneurship" course in computer science degree. Even so, these courses offer the entrepreneurship and innovation course as optional in curriculum. At this point the case of UFSCar (Federal University of São Carlos) – Sorocaba is different because it is a required course in the curriculum. This may have influence due to the recent creation of the computer science degree in this university (five years ago) and the young teachers who arrived with desire to change the way education is provided.

Entrepreneueurship and Innovation in CIT

Entrepreneurship is the process to start a new business based on a product or a service. People immersed in this process are driven by the desire to innovate and change the way things are done (status quo). The most common stages of a startup are: thinking in an idea, identifying opportunities and feasibility analysis (i.e. validating hypothesis in the market), defining the resources (i.e. people, tools, strategies, etc.), design, development and acceleration of the idea in the market, collect market feedback, improve the product or service, rapid growth and consequent spin-off from startup to the market [11].

In last years, the scientific and technological innovation has established as one of the most important factors to ensure growth, competitiveness and high profitability businesses. There are several evidences for the importance of this issue and many studies support the view that innovation is the key to survival in competitive environments. New processes and products, new business models, creating new markets, attracting and retaining talent or enhance the image before partners, new customers and investors, represent some of the results of innovation.

Moreover, the Information Technology and Communication (ICT) have contributed to institution (public or private) becoming more agile in its processes. ICT can be considered as a way to the process of technology-based innovation, increasing productivity and competitiveness.

However, for a long time Brazil failed to exploit their potential in entrepreneurship and technological innovation. In part because government policy had started to invest in RD&I (Research, Development & Innovation) late, and partly because the education and culture of the people in this area have never been focused as a priority. Public universities in Brazil, which are considered as the main sources of qualified professionals, have no dynamism in the process of formation their students and curriculum changes. This can be seen by the amount of curriculum that is not updated frequently in several educational institutions of the country.

Teaching Methosology

The Pedagogical Project (PP) of bachelor degree in computer science from UFSCar - Sorocaba was developed considering issues such as sustainability [17], entrepreneurship, innovation and business management. The project was developed in compliance with curriculum guidelines determined by the Brazilian Computer Society [18]. Moreover, the PP agenda determines that the student's education should be based not only on technical elements, allowing to work not only as a developer or technology broadcaster, but also as an agent of change the society.

The PP's is designed considering two disciplines in the area of entrepreneurship: Small Business Management, and Entrepreneurship and Innovation in ICT. The first discipline bringing all the basic knowledge necessary in order to the student have notions of managing any business in its initial phase. The second seeks to instigate the entrepreneurial profile of the students aiming to introduce non-technical concepts as a way to complement the technical courses of the curriculum. Thus, the focus of this paper is related to the experiences of the second discipline, which has been conducted since 2010, and so far, three groups have done it and attended almost 200 students.

[1] http://www.gsb.stanford.edu/

[2] http://www.hbs.edu/

[3] http://mitsloan.mit.edu/

The related work (presented on Section 2), mainly considering the experiences at Stanford, Harvard and MIT – references in the entrepreneurship area around the world – and adding the experience of the author of this paper as a spectator, competitor and judge of several startup competitions in Brazil (Brazil Challenge4, Call to Innovation5, Buscapé Challenge6, I2P7, FGV Latin Moot Corp8, Telefonica Wayra9, RBS Entrepreneurship and Innovation10, IG Startup11 and Startup Weekend12) it could be defined a teaching methodology appropriate to the course. The main idea of the course is to encourage and provide a way to the students create startups during the semester. To do that, it was created a startup competition during the course where it is the main scenario of creation, evolution, feedback, development and implementation of student's ideas. At the end, a panel of judges evaluates the projects and the three best may win some kind of award or receive invitation to participate of an acceleration process in one of our partners.

The teaching methodology was detailed in 4 major steps: Theory, Idea Design, Idea Development and Presentation. Figure 1 shows these 4 major steps and related topics during the course.

The **Theory** step aimed at bringing Entrepreneurship and Innovation concepts in order to the students familiarize themselves with the topic: understand what is a startup, what challenges are relevant in the context of Brazil, the expectations of the market, the competition, what techniques are used for creating a startup, and analysis of cases in order to understand all the processes around a successful startup in the market. The sections of a business plan are explored in order to show what an entrepreneur need to worry, considering several business models on the market as a way to illustrate ways to remunerate the business. After that, Lean Startup concepts [19] are presented and compared with the "old model" of creating startups as a way to show how the creation of "agile startups" – failing fast and learning fast – makes sense today. Finally, the concepts of intellectual property were presented as a way to the students understands their rights under the trademarks, patents and software registration considering Brazilian laws and the difference around the world.

The **Idea Design** step shows a set of market trends for startups, both reputable consultancy (e.g. McKinsey, IBM, Trend Watching, ARC Chart, etc.) as renowned investors / persons around the world (e.g. Steve Blank, Guy Kawazaki, Warren Buffet, Steve Jobs, Romero Rodrigues, etc.); and many speakers / entrepreneur from São Paulo, Campinas, Sorocaba region are invited to speak and tell your experiences in his/her startup creation. With this content all students are encouraged to think about any technological-based idea for projects and do pitch`s in 1 minute for the whole room (usually between 30% - 40% have some idea in the room). After all pitch`s, the students have a time to convince other students about your idea in order to join their project team and create the startup co-founder team (up to 4 students). With startup's team composed, the students begin working on the first presentation of the idea, which is based on Guy Kawazaki[13] guide (reference in the area of investment in the U.S.): 5/5/30 - 5 minutes, 5 slides and 30 points. Once done the presentation, students receive feedback from their ideas as a way to start the development. Some videos of entrepreneurs and / or investors are presented as a way to show the challenges, obstacles, failures and successes issues from startups around the globe.

In the **Idea Development** step, the students looking to understanding better all the details necessary for its startup like merchant, business model, competitors, value proposition, differential competitive, among others. Moreover, the students need to define the hypothesis that should be tested in the market, looking for fail fast and learn fast (one of the main premises of Lean Startup principles [19]). For that, they need understanding more about business model.

According to Osterwalder and Pigneur [20], a business model describes the rationale of how an organization creates, delivers, and captures value. To do that, they created a methodology, called Business Model Canvas (BMC), which was composed of 9 areas in order to help the co-founders to obtain a better knowledge of several important aspects of your startup. The areas are: 1. Customer Segments; 2. Value Proposition; 3. Channels; 4. Customer Relationship; 5. Revenue Streams; 6. Key Resources; 7. Key Activities; 8. Key Partners; and 9. Cost Structure. After developed the BMC, each group presents to the room as a way to gather feedback and learn collectively from all BMC's created in the course.

Additionally, a core component of Lean Startup methodology is the build-measure-learn feedback loop. The first step is figuring out the problem that needs to be solved and then developing a minimum viable product (MVP) to begin the process of learning as quickly as possible. Once the MVP is established, a startup can work on tuning the engine. This will involve measurement and learning and must include actionable metrics that can demonstrate cause and effect question [19]. So, the students must define and develop a MVP in order to validate the market and collect feedback as soon as they can. This will help them evolve the product / service that ara proposed, decreasing the elapsed time and money.

[4] http://www.desafiobr.com.br/

[5] http://www3.fiap.com.br/calltoinnovation/

[6] http://suaideiavale1milhao.com.br/

[7] http://ideatoproductla.org/

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[13] http://www.guykawasaki.com

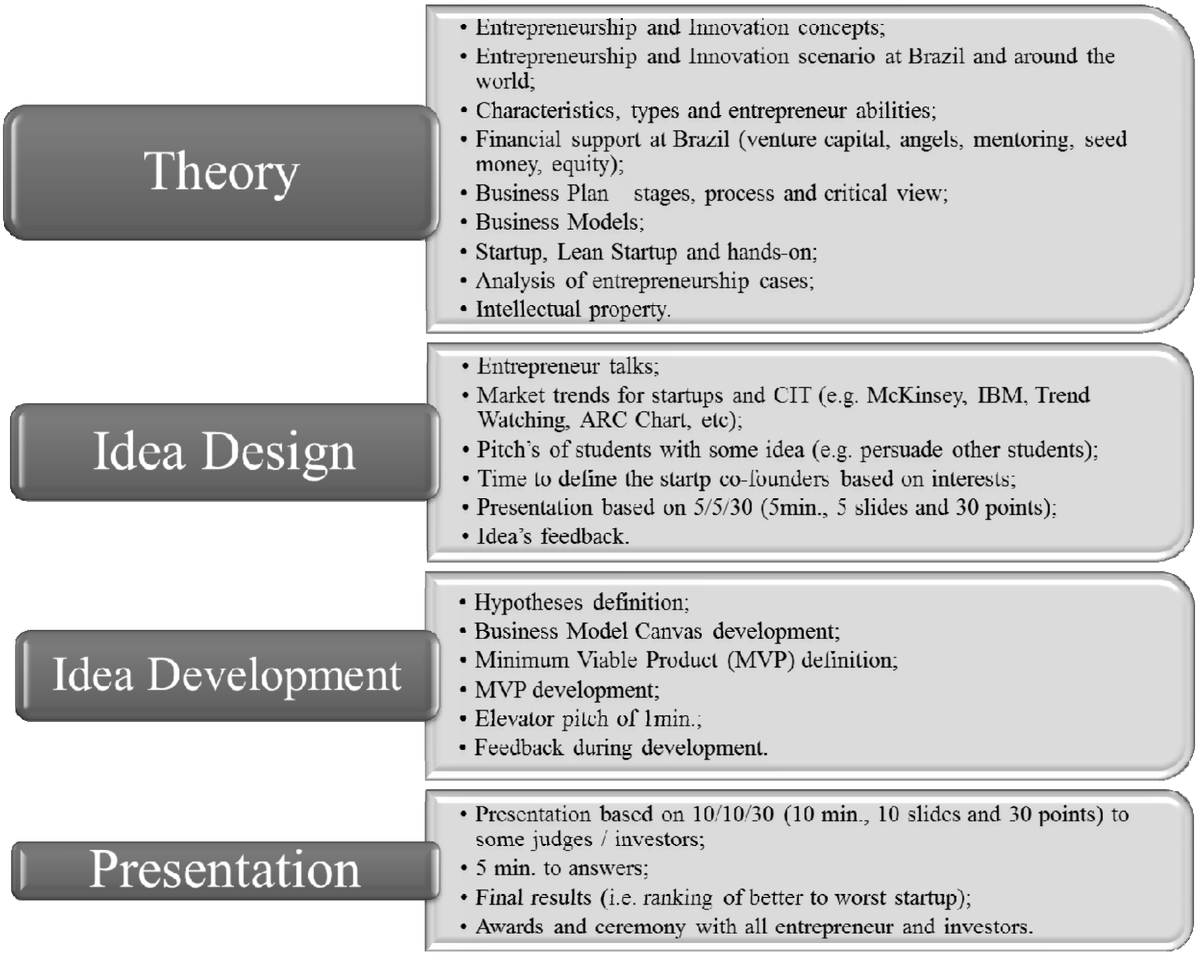

FIGURE 1
TEACHING METHODOLOGY.

At end, the students are encouraged to submit a pitch of only 1 minute; i.e. try to summarize everything they have learned and presents in 1 minute, which is a very difficult and arduous for students however has an impressive result. This video is usually available on Youtube / Vimeo so all students can watch the pitch's in the next classes.

Finally, the **Presentation** step aims to organize a day where all the students will present their projects in 10/10/30 (10 minutes, 10 slides and 30 points) for a panel of judges consisting of up to 6 persons: teacher, one teacher invited from UFSCar – Sorocaba and 4 entrepreneurs and / or investors in the market. The purpose of this day is to assess students regarding your startups to identify those with the greatest opportunity *versus* possibility to leave to the market. So, a ranking of startups is defined and the 3 better are rewarded in some way. In 2010, it was awarded with a pen-drive and digital camera, and in 2011 it was awarded with incubation for 2 months in a partner company and, in 2012 the course finished in February and, probably, the first project will be incubated in Sorocaba city Incubator and the other two will receive an award.

RESULTS AND LESSONS LEARNED

The main expectation of this course, since its inception, was to bring a privileged knowledge to the students of bachelor degree in computer science from UFSCar – Sorocaba, looking for instigate them to create technology-based startups, even if only during the discipline and nothing else. However, some students are more interested in the subject and end up taking the ideas developed during the course forward. In this sense, three ideas extrapolated activities in the discipline and are being developed by students:

- **Brochure:** An iOS app that displays the prices of the products in supermarkets around you (e.g. 20km from you), classifying them by product category. You can get more information of the product and the location of the market. This application was submitted to the Buscapé Challenge "Your Idea Value 1 million." This app was not selected however there was an idea selected that is 90% equal to this in more evolved stage of development[14]. So, the students are developing the

[14] http://www.meucarrinho.com.br

final version of this product in order to put it online to download in Apple Store.

FIGURE 2
BROCHURE PRINT SCREEN.

- **EcoManager**: A web system that intends to perform the solid waste management of a city. This system has to meet the government's determination through the National Policy on Solid Waste, which every city must manage their waste properly until 2014. This project won the Award of Greenpeace Challenge for Smart Cities[15]. Now, the students are finishing its first version in order to put in a city hall of Sorocaba in beta test.

FIGURE 3
ECOMANAGER PRINT SCREEN (*in portuguese*).

- **Flagging**: An android app that manager the "hot points" of a city. The users can check-in a place near his/her (e.g. 10km) and say if it is good or not. Based on that, the point in the map above increase or decrease. So, everyone could identify the hot points (i.e. restaurants, bars, clubs, etc) that are good to go or not to go now.

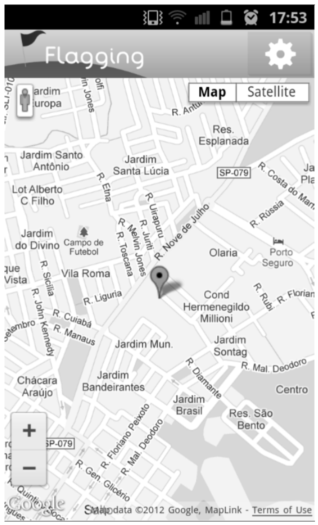

FIGURE 4
FLAGGING PRINT SCREEN.

Still on, a group of four students became interested in the area and initiated the creation of the Junior Company from computer science course at UFSCar – Sorocaba. In the 2nd half of 2011, one of projects of the course was the creation of the Junior Company, creating your business plan, statute and selecting students to operate the startup.

Furthermore, since 2010 it was applied a survey in order to understand the impact of this kind of course into the life of the students. Now it will be presented the composition of the 3 last surveys applied to this course which totally 182 students answered. Additionally, the answers were anonymous which do not intimidate them to answer the survey.

First, it is intends to know what is the knowledgement in entrepreneurship area from the students. Figure 5 show that 59% of the students don't have any knowledge in the begging of the course. Actually, this shows the Brazilian entrepreneurship reality once the entrepreneurship bubble has becoming since 2011/2012 in Brazil and the next courses will be impacted from those experiences acquired in the market by the students.

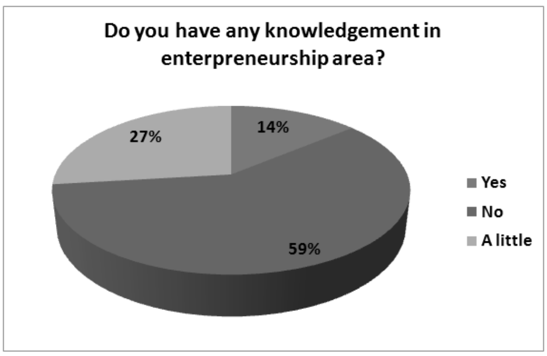

FIGURE 5
KNOWLEDGEMENTE IN ENTERPRENEURSHIP AREA.

[15] http://g1.globo.com/pernambuco/noticia/2012/06/equipe-de-sao-paulo-vence-no-recife-desafio-de-cidades-inteligentes.html (*in portuguese*)

Second, we try to identify what is the expectation of the students during the course. This help us to verify what the intentions of the students in the begging of the course and if there are some changes during the course (related to Figure 8). According Figure 6, 44% answered that would like to be entrepreneur; however 29% were interested only in grade. This should be worked more during the course in order to decrease this interesting of the students. Some insight to do so is try to eliminate the grade from this course and the investor will evaluate the startups and give points to each one; if there are any that do not receive points should doing again the course in the next year.

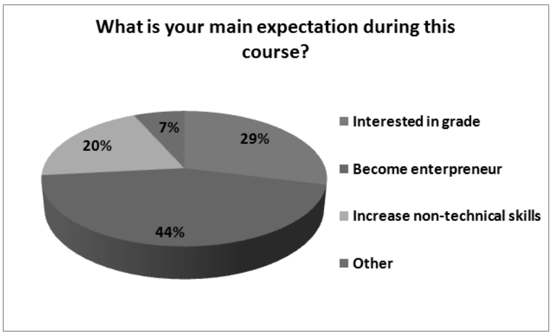

FIGURE 6
EXPECTATION FROM THE STUDENTS.

Third, it is intends to know if this course instigate the entrepreneurial skills in the students. The major answer (Figure 7 shows around 83% from Yes and Substantial) say yes but it is necessary increase this vision of the students in order to demonstrate that the leadership, customer development, business and communication skills are so important to the professional / entrepreneur nowadays. More talks from the market could help this factor and will be increased in the next course.

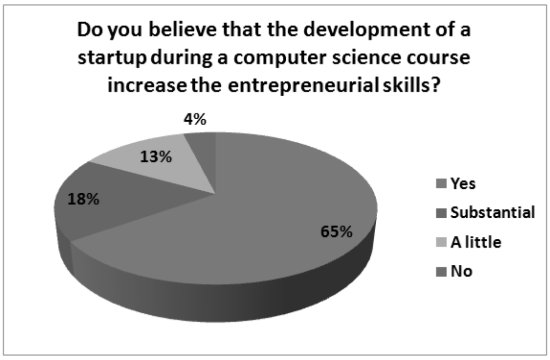

FIGURE 7
ENTERPRENEURIAL SKILLS.

At last, we try to map if the course influenced the students in its carrier decision. According to the Figure 8, 38% intends to create its own business. We believe that this is amazing, considering that the course happened only in the last 3 years. The goal is achieving around 70% in this metric however it should spend more 5 years to achieve that.

Thought these survey we could identify some aspects that should be increased during the course, like show the importance of non-technical skills to computer science students, approximate the students to its customer / market and partnership with investor in order to the projects developed could be really launched to the market. However, the results achieved until now can show the importance of this kind of course to a computing curricula.

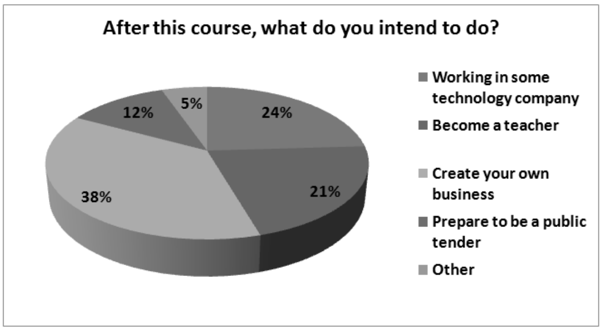

FIGURE 8
INTENTITIONS AFTER FINISHED THE COURSE.

Additionally, several lessons could be learned during the execution of this course. The intention is to learn from what went wrong and seek to improve the course. So, there are some lessons learned:

- Some theoretical basis is critical to engage students in beginning and it is essential hands-on knowledge by the teacher in order to perform a set of dynamics with students;
- Multidisciplinary is very interesting for the entrepreneurship as a way to complement the skills of co-founders. As the discipline happens in the bachelor's degree in computer science, becomes difficult to obtain this multidisciplinary. However, it has been started some partnerships with other courses from UFSCar – Sorocaba (like business administration and economics) which courses that happens in the same semester and have complementarity to technical skills from computer science;
- Networking in the area is essential to attract entrepreneurs, investors and mentors to talk and join the final judge, as well as industry partners as a way to encourage students through a set of awards and acceleration support of the startups;
- The teacher must have previously entrepreneurship education and innovation as well as experience in entrepreneur area (i.e. be entrepreneur), joined in contest startups, talking to investors, made pitch's in the market, know the market, i.e. have the entrepreneurial profile in order to talk the same language of the market with your students; and
- The method of the course should be executed in a systematic ways in order to provide better assessments

and comparisons of the data obtained in the course year after year.

Concluding Remarks and Future Work

Entrepreneurship and innovation education is becoming the future trend of modern higher education reform [21]. Universities must move with the times and develop new ideas, seeking to develop and/or accelerate startups, especially for higher education institutions in a set of areas of computing / business. The universities must be care to the problems existing into the market and work with real problems during the courser and research in order to create solutions that can be very useful to the society. With creation of new business, everyone wins: the society wins with the return of the investment (ROI) (i.e. taxes paid), the university awarded with the generation of applied research and attracting more resources for research, and market gains with the human resource development high capable. Although it looks like normal to do so in some countries, in Brazil it is very difficult to find universities thinking in the future of its university and doing (real) research together with the industry.

Thus the computer courses in Brazil should be more practical. If we are compared to universities in the world, Brazilian universities do not focus so much on courses that develop practical activities together with students. These activities that resemble those performed on a day-to-day life of an entrepreneur and give an adequate view of what are the challenges that these future entrepreneurs will face.

In this way, the UFSCar - Sorocaba has been working hard at introducing entrepreneurship, innovation and intellectual property in order to strengthen and complement the knowledge of both the students of bachelor degree in computer science and society as a whole through the creation of Startup Club[16], where monthly meetings are held (Startup Day) through multidisciplinary partnerships near Sorocaba / São Paulo city.

Acknowledgment

I would like to thanks some partners that inspired / helped me build this course, like Silvio Meira, Augusto Camargo, C.E.S.A.R. (http://www.cesar.org.br) and UFPE (http://www.cin.ufpe.br). Still, this work was partially supported by the FAPESP, grant 2012/10157-1.

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Social Engineering Program – MBA level: Designed for Global Education Demand

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Abstract *— Following the new trend in education, more focused on a global perspective, COPEC - Science and Education Research Council is offering an MBA, online, in Social Engineering for all Countries of CPLP - Portuguese Language Countries Community. The goal is to cover these countries' engineers, which are also seeking for opportunities, as the majority are countries of growing economy based on their very rich resources. The idea of an online program is the possibility of reaching a broader audience and at the same time of enriching the experience of offering and implementing a program that can disseminate ideas and concepts, which fits the needs of the target audience. The Education Research Team of COPEC is convinced that Engineers with proper knowledge and skills can take action in order to solve social problems, as engineers are problem solvers.*

Keywords *— Online education; science and technology; research; public economy; population growth*

I. Introduction

Political environment is full of challenges and crises of deep consequences to society as well as to the environment and it has a strong incidence in terms of decision making in any field. It means that taking decisions is becoming more and more complex and difficult due to the fact that the implications are felt in a faster way and in a larger community. For engineers, the decision process is even more complex once the implications have serious impact not only to the target customers but also to the society as a whole and to the environment. This is an aspect that shows the necessity for engineers to search for the acquisition of an ability to respond to social necessities having in mind the cultural aspects when developing a project.

The effects of this aspect in engineering education imply a different approach providing the future engineers with notions on policy, ethics and social sciences, which are so important to prepare them to the future work market that will require the respect and promotion of society and environment as assets [1].

Most of social groups have ambiguous understanding about science and technology; some understand it as responsible for the environmental deterioration and the voracious capitalism and others as the ones responsible for the better quality of life with the improvement of health systems, agricultural production and other accomplishments. Both perceptions are not far from the reality. In any case, the impacts can be seen along the history and more recently with the sophistication of the so called "information society". This particular "information society" shows how strong the impact of any technology introduced in the society can be. Real time communication and brutal amount of information available have changed drastically how people relate, make business and study [2].

The proposal of COPEC - Science and Education Research Council for the next five years is the offering of MBA by Distance Learning due to the new global education demand. The new programs will be delivered in Portuguese in a first moment, for all Countries of CPLP - Portuguese Language Countries Community. The idea is to cover these countries that also are seeking for opportunities, as the majority of them are growing and are very rich countries. The first group of programs is: MBA in Social Engineering and MBA in International Engineering Educator, both with International Recognition.

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II. THE SOCIAL ENGINEERING PROGRAM – MBA OFFERED BY COPEC

Thanks to technology it is possible to conciliate work and studies once online programs are available for all and in every possible way. It is the era of the so called information society. The design of a project now requires knowledge about the social as well as the environmental impacts, so engineers should be capable of learning how to work close to governments and communities, addressing the results of the projects to solve social problems or at least to prevent new ones[3].

In response to this necessity, COPEC - Science and Education Research Council has developed a MBA in Social Engineering. It is an MBA program offered by distance that fulfills the urban demand of engineers to solve social problems which are outcomes of urbanization and environmental issues in cities.

The program is directed to engineers interested in acting in this field-offering consultancy for construction companies, industrial enterprises, city halls and governmental housing organizations, etc. It is an interdisciplinary program that prepares engineers to work in projects dealing with the social aspects of projects. The program is developed in modules: two modules per semester. The scores and the final project presentation online establish the final approval of a student. An online chat with students provides teaching and guiding for the development of projects in a broader perspective. The MBA is taught almost using case studies—whereby students discuss real dilemmas faced by actual companies. The debates are online and last for three or four days. The professor opens up the debate by asking questions and the students then begin discussing the case [4].

As the target audience is spread over different continents, the cases are discussed in an Internet forum. Students enter the discussion at the time that is best for them. It can be early in the morning before going to work, sometimes in the evening or even late at night. Usually they will be involved for two or three hours every day. The choice of asynchronous learning mode of delivery is due to the fact that so participants access course materials on their own schedule and so it is more flexible [5]. However, there is the possibility of a present module for pertinent seminars and visits to companies and sites with the goal to enhance the acquisition of knowledge and experience in the field.

III. ASSESSMENT

The evaluation of learning is continuous, prioritizing qualitative aspects related to the process of learning and student development observed during the conduct of the proposed activities.

To guide the evaluation process, make it transparent, able to contribute to the promotion and regulation of learning, it is necessary that the performance indicators are defined in terms of teaching, explained and negotiated with students from the beginning of the course, order directing all efforts of the technical staff, teachers and students themselves to achieve the desired performance.

The self-assessment will be fostered and developed through procedures that allow students to monitor their progress, as well as the identification of points to improve, practice deemed essential to learning autonomously [6].

The result of the evaluation process will be expressed in words:

- Optimal: able to play, highlighting the competencies required by the profile professional conclusion;
- Good: able to perform to the satisfaction, the skills required by the professional profile completion;
- Insufficient: still not able to play at least the required skills the professional profile of completion.

The endorsement will be awarded per module, considering the criteria and indicators performance related to the powers provided in each, which integrate professional competencies described in the profile completion below.

IV. ADMISSION REQUIREMENTS

The basic candidate requirement for admission is:

To have a bachelor's degree in civil engineering. However, the program encourages applicants from diverse backgrounds, including (but not limited to) engineering, environmental science, management and economy. Applicants may need to complete prerequisite courses. A faculty advisor will determine the specific requirements on an individual basis depending on the student's educational background and work experience [7].

V. CANDIDATE PROFILE

- Taste for related themes to the sciences of mathematics and physics and technological ones of civil engineering.
- Interest in solving problems in engineering in coastal and estuary environment principally the ones that involves the coast and constructions.
- Capability of questioning.
- Affinity and discipline for the activity of research [8].

VI. EXPECTED OUTCOMES OF THE PROGRAM PROFESSIONAL PROFILE

The engineer with an MBA in social engineering should present some characteristics as a professional. These expected characteristics are:

- Search constant updating and self-development through study and research, to propose innovations, identify and incorporate with criticism, new methods, techniques and technologies to their actions and respond to everyday situations and with unprecedented flexibility, creativity, resourcefulness as well as social and cultural.
- Taking professional attitude consistent with the principles governing the work area, working in multidisciplinary teams and relating appropriately with other professionals, clients and suppliers.

- Manage the career with initiative and in an entrepreneurial way, to provide services or organizations to conduct own business.
- Acting responsibly, committing to the principles of ethics, environmental sustainability, the preservation of health and social development, directing its activities to the values expressed in the professional ethos, which results in quality and commitment with work well done.

These characteristics are important because a social engineer will deal with the aspects of human life that are imperative for the future of young generations. The achievements have a huge impact on how life will develop in a region or community in the years to come. Specialists working in the field of social engineering can make a huge contribution to the overall engineering profession [9].

VII. Objectives of Program

The main objectives of this social engineering graduation program are:

- to prepare engineering researchers and professionals in administrative positions who work in areas related to policy to design and implement in national territory socio-economic systems and to develop the integrated theories and methods of these areas;
- to increase logical thinking, sense of social ethics, social assessment capability;
- to start thinking without any preconceived notions;
- to look for innovative problem solving .

VIII. Final Discussions

At this point some discussions should take place. We start with the definition of science, which states that it is a process of inquiry that involves questioning, hypothesizing, investigating, gathering evidence, organizing data, testing, refining, predicting, explaining and communicating. So the development of science is a long process that requires some personal skills that can be fostered along the education period of the human being. The achievement of knowledge in order to make science respond to human needs results in technology that men use to make life better. Due to the challenging characteristics of scientific knowledge application and development it is possible to say that it is in constant construction. This is what makes science and technology development so interesting and enticing for those professionals who are always seeking for new ways of working, meaning more effectively.

Presently the bachelor diploma is not enough to obtain success in a career. No doubt that a third degree diploma opens some doors. Therefore it means not only the possibility of earning more money but also to reach an upper status, socially speaking. However as the work market is more than ever extremely competitive and mutant life long learning is something that professionals should pursue.

It is a fact that online learning is not for everyone at this point of human development stage. It is very difficult to juggle work, family and study. Plenty of self-discipline is necessary. However, the idea to study at any time any place that suits the students best is very appealing. Another aspect is that it gives an opportunity for bright students in different remote parts of the world to access a top-quality education program, which would otherwise be unavailable to them. Distance-learning students tend to apply what they have learnt immediately in their work, making their studies more practical.

Competitive modern marketplace demands rapid change and innovation, for which distance education programs can act as a catalyst. It is a lifelong learning environment once it provides the students the opportunity to receive equal education regardless of income status, area of residence, gender, race, age, or cost per student. The proposed program delivered by COPEC constitutes another opportunity for engineers to acquire knowledge in their fields of expertise to defeat social problems mainly faced by urban agglomerations derived by the global population growth.

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Critical Support for Upper Division Transfer Students in Engineering and Computer Science

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Abstract – **A Motivated Engineering Transfer Students (METS) Program at Arizona State University (ASU) was established to aid the transition, retention, and graduation of engineering and computer science community college transfer students. The METS Program provides critical support in the form of an Academic Success and Professional Development (ASAP) Class and a METS Center to help provide academic and social support, as well as scholarships. In this paper, we look specifically at the impact of the METS Center for transfer students and the impact on transfer students of the $4K per year scholarship funded by NSF grants.**

The ASAP Class transfer students were surveyed to evaluate the Center and scholarships. The transfer students were asked: "How does the METS Center help you?" and "How did the METS scholarship help you?" The top three identified benefits of the METS Center were: a place to meet/connect with other transfer students, the use of computers and free printing, and the ability to get information about internships.

The top student benefits of the METS scholarship are not having to work as much, not having to take out a loan and, for some students, not having to work. The scholarship benefits did not differ by gender.

Index Terms – Academic Scholarship Program, Professional Development, Scholarships, Transfer Center, Transfer Students.

I. INTRODUCTION

Picture a tiny goldfish jumping from a small fish bowl to a larger and much higher, fishbowl. This is truly a leap of faith. There is not only the fright of being out of water for a short time and the endurance to make the jump, but also the unknown of: being able to land in the bowl or missing it altogether, how supportive the new environment will be, and the nature of the interactions with a whole new school of fish. The new university community college (CC) transfer student in engineering and computer science feels like a freshman all over again, fears the large classes, is aware that the class pace may be much faster, knows that the "easy" classes have been taken, and doesn't know where to find resources. [1]

Much has been written recently about transfer students and their care, especially in engineering and computer science, since President Obama announced in 2001 that there is a critical national demand for more engineers. [2] Henceforth, in this paper, the term "engineering" shall also include computer science. The U.S. Education Department reports that only 60% of students entering four year institutions earn a Bachelor's degree in six years, but only 31 percent of public community college students go on to complete either an associate or a bachelor's degree in six years. [3] This is a large waste of talent.

To solve this problem, there is much for the CCs to do, but there is also work for the CCs and four-year schools to do together, as well as for four-year schools to do after the transfer students arrive: to encourage them to stay in engineering and to graduate. Major steps that CCs in Arizona have taken include adding engineering courses to their curriculum and designing Associate Degrees for engineering so that transfer students can come to the four-year school as a junior in engineering. Articulation agreements are needed between the two-year and the four-year schools to accomplish this. Arizona has complete articulation agreements between the three state universities and the 21 Arizona community colleges.

In this paper we will concentrate on what the four-year school can and should be doing to maximize the graduation rate of transfer students and to be sending them directly on to graduate school. A major reason that most students attend a CC is due to finances and the fact that tuition is much lower at a CC than at a college/university. [1] Therefore, it is obvious that a major need for most transfer students is financial help. [4] Financial help in the forms of scholarships, fellowships, internships, and paid research and intern positions are very important, but financial support alone is not enough.

One study showed that transfer students are less likely to be engaged in the campus life of the receiving four-year institution. The author suggested that "creating social capital for CC transfer students is one way to reestablish the social interest that has been displaced as a result of transferring." Due to their diversity and uniqueness, the author further

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suggested that specifically designed support programs to increase retention, integration, and graduation rates at the four-year school are needed. [5] We have done exactly this.

In Tinto's latest book, "Completing College," he points to four critical areas upon which college completion depends: high expectations, support, assessment with frequent feedback, and involvement. The support that is needed includes academic, social, and, perhaps, financial. [6] Our program is based on these four critical areas.

A Motivated Engineering Transfer Students (METS) Program at Arizona State University (ASU) was begun in 2003 to smooth the transition for engineering and computer science CC students to the university as they take this "leap of faith". Additionally, once they have "landed," the METS Program provides critical support for their retention, graduation, and graduate school attendance. The first Academic Scholarship Program for full-time, upper division engineering and computer science students in the Ira A. Fulton Schools of Engineering at ASU was begun in fall 2002. The next year, a second Academic Scholarship Program was added for transfer students only and the first program continued with non-transfer students. These programs have continued until present with current NSF grants (#1060226 and #0728695, respectively). In 2008, we received an NSF STEP grant (#0856834) to partner with five non-metropolitan CCs in Arizona. Some scholarship money was built into this grant, so we also have these transfer students in our Academic Scholarship Program. For the 2012-2013 year, the ASU Women & Philanthropy group awarded money to ASU to help fund additional scholarships for transfer students.

These Academic Scholarship Programs are open to upper division students who have at least a 3.0 GPA and have unmet financial need as determined by FAFSA. The students must be enrolled full-time in engineering or computer science in the Fulton Schools and be a U.S. citizen, permanent resident, or refugee. An emphasis is placed on diversity and historically at least 60% of the program scholarships have been awarded to women or underrepresented minority students.

The first critical area stated by Tinto as necessary for college student retention was "high expectations." We have high expectations for our transfer students from the time we first see them on a visit to a CC classroom or when they visit at ASU. We tell the students that we expect them to graduate and to go directly on to graduate school.

The second Tinto critical area for college retention success is "support: academic, social, and financial, as needed." Let us first consider the financial support. Over 90% of the CC transfer students to ASU in engineering have unmet financial need. This should not be surprising since a primary reason that students attend a community college is due to the much lower tuition rates and the proximity to their home, saving commuter, board, and room costs. The selected students are given an academic year scholarship of $4,000. This scholarship is renewable until they graduate with a Bachelor's degree and through four semesters of graduate school if they continue their full-time studies in the Ira A. Fulton Schools of Engineering and continue to qualify for the scholarship.

In terms of academic and social support, over the years the author has developed a successful Academic Success and Professional Development Class which has helped to yield high rates for graduation and graduate school enrollment. Scholarship students must enroll in this class each semester they hold the scholarship. The class changed from a one-credit class to a two-credit class in spring 2013. The class credit does not count on a Program of Study, but the grade does count in the GPA. Assignments are given that help the student to acclimate, learn about their professors, to write a resume, and to navigate a career fair, all designed to make them better students and to provide them with information about doing research and going to graduate school. The class also includes time management, speakers from industry with advanced degrees, portfolios, and career planning. The primary help for their academics comes through the time management and the Guaranteed 4.0 Plan by Donna O. Johnson. [7] Through this system the students "learn to learn." The social and networking support is strengthened by holding each of the six 75-minute classes (per semester) six times so that there are no more than 30 students in a meeting and so that there is at least one meeting time that fits with the student's schedule.

In addition to the scholarship students, each semester additional students enroll in the success course. Word-of-mouth has brought both transfer and non-transfer students to enroll to learn about topics that can help them. Students who have taken the course are pleased to see how they can earn better grades in less time. Through two of the NSF grants (#0856834 and #1060226), $300 scholarships are awarded to transfer students and non-transfer students who are qualified to take the course. Each year we receive many more applications from qualified applicants than we have scholarships. We have learned that $300 is enough to entice a student to take the course. The students admit that if they had known ahead of time how valuable the course was, they would have taken it for free. However, since it is impossible to know the course value ahead of time, the students also admit that the $300 was the incentive they needed to actually enroll in the course [7]. Since the class is especially helpful to first semester transfer students, it is interesting to note there were only 84 scholarship students among the 179 students enrolled in the course during fall 2012. More about the programs can be found in additional references [8-12]

The students are given additional support through mentoring by peers in the program, as well as by "informal counselors," successful transfer students who work in the METS Center, the METS Center director, and the PI and co-PIs on the grants. Career Services present to the students in a meeting each year and is also available to help with resumes, interviewing, career fairs, negotiating, and finding an internship.

Our action on Tinto's third point, "assessment with frequent feedback" has already been mentioned. We do this through the class assignments and try to return the assignments within a week.

Tinto's fourth point is "involvement." In order to promote networking, we do an ice breaker at the beginning of each meeting. A typical question would be, "What are your main concerns between now and the end of the semester?" It is comforting for students to learn that they are not the only one struggling with a particular class. We encourage the students to be in a study group for each class. Additionally, networking is encouraged through our METS Center. This Center includes a study room with computers and limited free printing, a reception area for students with desks for the Center workers, a conference room where the Academic Success class is taught, and an office for the METS Center Director. The Center accommodates about 45 students per day and enrolls over 400 students in an academic year. Enrolled students receive a weekly newsletter with information including internships and success tips

The purpose of the METS program for transfer students is to retain and to graduate the participants, to expand their understanding of the engineering profession, and to have the students go right on to graduate school full-time. The program has shown great success: currently 95% of the scholarship students (transfer and non-transfer) are graduating. To understand this success, we note that the graduation rate for upper division transfer students in engineering is 70% for males and 64% for females. In addition, while the national rate of newly-degreed engineers going on to graduate school is less than 20%, during the past three years, 50% of the non-transfer and transfer students have gone directly to graduate school full-time. Less than 15% of upper division transfer students generally go directly to graduate school. Additional students are continuing part-time. In this study, we wished to quantify how the transfer students viewed the METS Center and how the scholarship affected their life.

II. THE SURVEY

An on-line survey was given to the 133 transfer students enrolled in the FSE 394 Academic Success course during fall 2012. A response was given by 119 (89.5%) of the transfer students, 24 females and 95 males. Two of the questions on the survey were focused on the value of the METS Center programs and the effect of the METS scholarships. We will focus on these two questions. We need to note that some of these students were not in this class due to their own interest: some had been told by an advisor to take this course in place of an ASU 101 Orientation Course required of all ASU students. Although these students were generally glad to not have to take a class with freshmen, some were not particularly happy to have to take any such course which did not count in their program of study and which had challenging assignments.

The students were asked "How has the METS Center helped you?" on the survey, to check all reasons on a list that applied to them, and to add any other reasons. Table I gives the METS Center benefits that were listed on the survey. Figures1 and 2 show the breakdown of these benefits as selected by gender.

Table I. METS Center Benefits Listed in FSE 394 Fall 2012 Transfer Student Survey

"How has the METS Center helped you?"	
1	Place to meet other transfer students/connect with other transfer student
2	Networking
3	Computers and free printing
4	Informal mentoring by METS Center staff
5	Staff helpful as resources
6	FSE 394 Academic Success Class
7	Workshops in the METS Center
8	Information about internships
9	Information about jobs
10	Information about research opportunities for undergraduate students
11	Form study groups
12	Have a place to eat lunch
13	Have a place to study
14	Meet for academic scholarship meeting
15	Other: (please list)

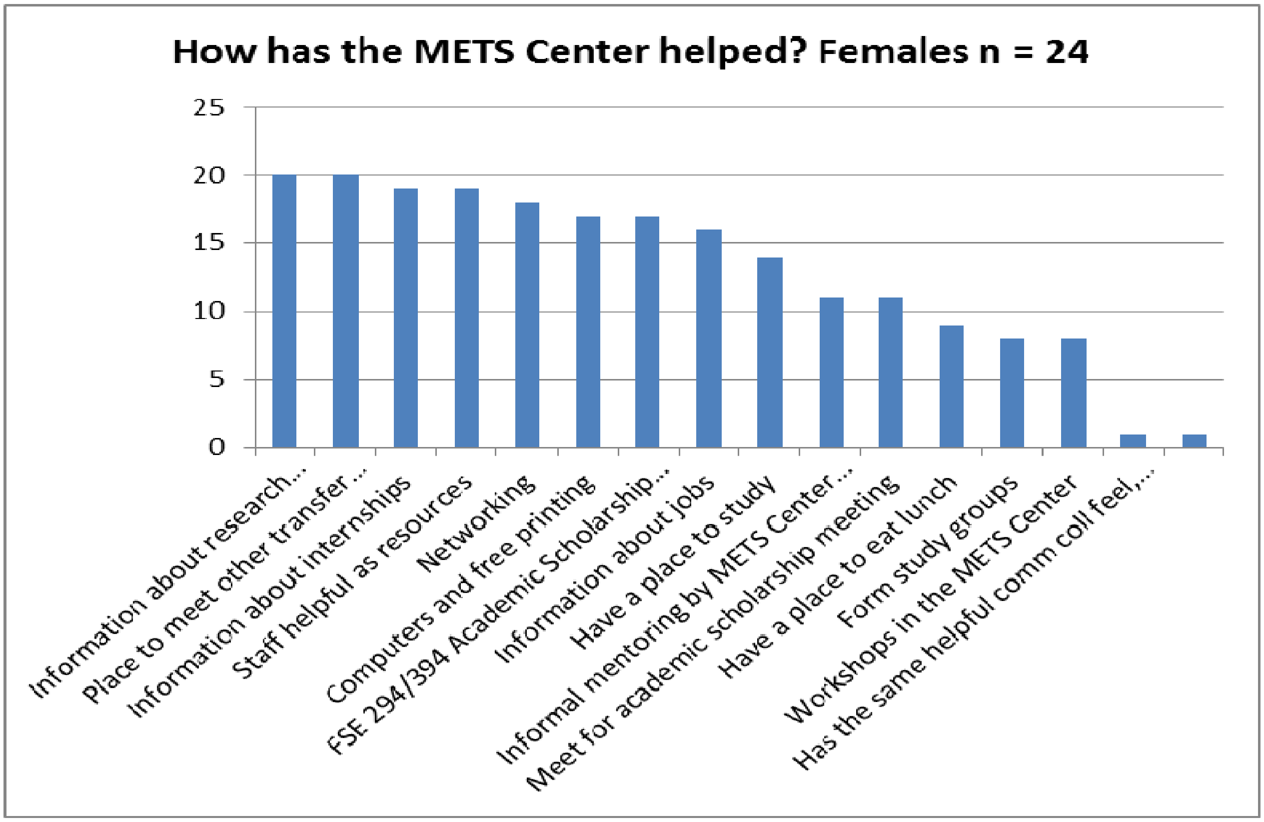

Fig. 1. How the METS Center helped the female transfer students in FSE 394 in Fall 2012.

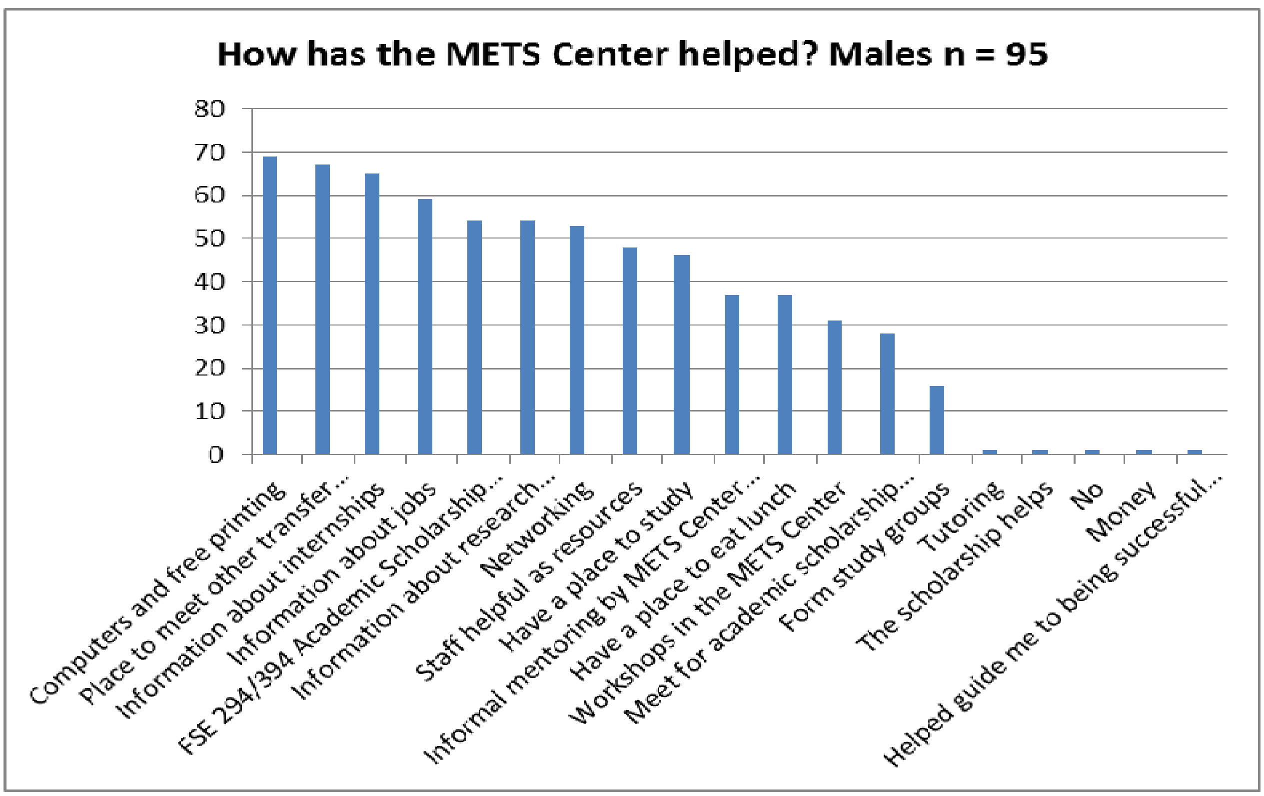

Fig. 2. How the METS Center helped the female transfer students in FSE 394 in Fall 2012.

There were several additional METS Center benefits listed by the survey students. A female transfer student wrote: “has same helpful community college feeling, except for FSE.” It is not clear if FSE, the Academic Success class is mentioned as a positive or negative difference. Another female wrote: “METS is like family...I feel safe...it’s like a home away from home.” There were five additional benefits named by males:” tutoring,” “the scholarship helps,” “none,” “money,” and “helped guide me to being successful at ASU.”

Table II lists the options for the second question: “How did the METS Scholarship help you?” Sixty-nine of the 119 transfer survey students (58%) had scholarships, 15 females and 54 males.

Table II. Scholarship benefits listed in FSE 394 Fall 2012 transfer students survey

“How has the METS Scholarship helped you?”	
1	Did not have to work because of scholarship
2	Did not have to work as much because of scholarship
3	Did not have to take a loan because of the scholarship
4	Scholarship did not help
5	Other: (please list)

The scholarship survey question results by gender are as follows:

Table III. Scholarship benefits identified by FSE 394 Fall 2012 transfer students with scholarship by gender

Benefit	**Females (n=15)**	**Males (n=54)**
Did not have to work as much	12 (80%)	35 (65%)
Did not have to take a loan	9 (60%)	22 (41%)
Did not have to work	2 (13%)	17 (31%)
Other	1 (7%)	5 (9%)

Other reasons included: “Lowers my stress significantly” by a female. Four positive “other” male reasons were: ”Eased overall financial burden,” “Loan not as great,” “Helped me to receive less loans and made me more comfortable without working,” and “Couldn’t have succeeded without scholarship. Full-time work would have been too much with 16 credits.” On the other hand, one male said “Scholarship did not help.”

III. SURVEY ANALYSIS AND RESULTS

It is assumed that when the students ranked these benefits, the METS Center was considered a generic name for both the physical METS Center and the Academic Success and Professional Development Class activities. The percentages and ranks of the METS Center benefits are given by gender in Table IV, along with P-values. The top 9 METS Center benefits that the students identified were the same for females and males, although the individual rankings varied. If we consider the top 5 reasons, which were chosen by 75% or more of the females, there are only two matches to the males’ top 5: a place to meet other transfer students and internship information. Males had computers and free printing as their most important benefit, while females had this ranked tied for sixth and seventh. Job information was in the top 5 for males, while this was ranked eighth by the females.

Table IV. METS Center benefits by gender and p-value: n=24 for females and n=95 for males

Benefit and P-value	**# F**	**%**	**Rank**	**# M**	**%**	**Rank**
***Research information	20	83	1.5	54	57	5.5
Place to meet other transfers	20	83	1.5	67	71	2
Internship information	19	79	3.5	65	68	3
***Staff helpful resource	19	79	3.5	48	51	8
**Networking	18	75	5	53	56	7
Computers and free printing	17	71	6.5	69	73	1
Academic Scholarship Class	17	71	6.5	54	57	5.5
Job information	16	67	8	59	62	4
Have a place to study	14	58	9	46	48	9
Informal mentoring	11	46	10.5	37	39	10.5
*Academic Success meeting	11	46	10.5	28	30	13
Have a place to eat lunch	9	37	12	37	39	10.5
*Form study groups	8	33	13.5	16	17	14
Workshops in METS Center	8	33	13.5	31	33	12

*** p-value < .02; ** .05 ≤ p-value < .11; * .11 ≤ p-value ≤ .15

Over half of the females appreciated the top 9 benefits including information about research, a place to meet other transfers, internship information, the staff as resources, the networking, computers and free printing, the Academic Scholarship class, information about jobs, and a place to study On the other hand, over half of the males only appreciated eight benefits, although 46% appreciated the METS Center as a place to study as their ninth most valuable benefit.

Table V clarifies the p-value differences between females and males relative to METS Center Benefits

Table V. P-values with normal approximation and Fisher’s exact test for significant gender differences and trends in METS Center benefits

Benefit	**P-value Normal approx**	**P-value Fisher’s exact**
***Staff as helpful resources	.003	.012
***Research information	.004	.019
**Networking	.060	.106
*Form study groups	.111	.089
*Academic Success meetings	.144	.148

In all of the cases worth noting where there is a difference between the percentage of females and the percentage of males selecting a benefit, the percentage of females is higher. From Table IV we can see that females (79%) considered the helpful resources given by the METS staff in a statistically significant higher percentage than did the males (51%). Similarly, a higher percentage of females (83%) considered gaining research information from the METS Center as a benefit than did males (57%). Another difference, although not as significant, is networking (valued by 75% of the females and only 56% of the males). Two other categories that may be noted as possible trends are the formation of study groups (valued by 33% of females and only 17% of males) and Academic Success meetings (valued by 46% of females and only 30% of males). This last category should be clarified in any future surveys to distinguish between if the benefit is from the Academic class itself or that the meetings of the Academic class are conveniently held in the METS Center.

The scholarship benefits were ranked in the same order by both genders. The largest benefit was that the students did not have to work as much because of the scholarship. This was true for 47 (68.1%) of the students. Thirty-one students (44.9%) did not have to take a loan because of the scholarship. Nineteen students (27.5%) reported that they did not have to work because of the scholarship. One male student said that the scholarship did not help. It is assumed this implies that the scholarship was not enough to cover all costs and the student still struggled financially. One female added that having the scholarship lowered her stress significantly. We assume that part of this was due to the fact that the student knew the scholarship would continue as long as she did well in school. This would be a good benefit to add to future surveys.

Table VI displays the scholarship benefits by gender and the p-values for significant differences in the benefits by gender.

Table VI. Scholarship Benefits by Gender and P-value: n=15 for females and n=54 for males

Benefit and P-value	# F	%	Rank	# M	%	Rank
Did not have to work as much	12	80	1	35	65	1
Did not have to take a loan	9	65	2	22	41	2
*Did not have to work	2	13	3	17	31	3
Other: less stress	1	7	4	3	6	4
Smaller loan				2		
Did not help				1		

*p-value = .093 (normal approximation), .206 (Fisher's exact test)

The only hint of a statistical difference in the scholarship effect by gender is in the percentage of females (13%) and males (31%) who did not have to work after receiving the METS scholarship. The p-value is .093 if we use the common normal approximation test, but only .206 if we use Fisher's exact test because the one sample is rather small. This could be considered a trend and something to watch in the future.

It appears that the students appreciate the benefits of the METS Center and programs. There was not much difference between females and males. Over half of the females noted 9 benefits of help to them, while only 8 benefits were named by over 50% of the males. The benefit noted by over half of the females and not by over half of the males (46%) was "having a place to study."

It was satisfying to note that 30% of the scholarship holders did not have to work. We have found that working too many hours is the primary reason that transfer students do not do well academically. Part-time jobs that are initially limited to 20 hours per week can suddenly demand 30 or more hours to the academic detriment of the student. Over 68% of the scholarship students did not have to work as much because of the scholarship. This is good. The scholarships also prevented 45% of the scholarship holders from taking out a loan. It appears that the scholarships are being used well.

IV. CONCLUSIONS AND FUTURE WORK

These survey items helped to verify that the METS Center and its program are doing well with the students. There was also an opportunity for the students to give suggestions on how the METS programs could be improved. This data has not yet been analyzed, but will be in light of the two questions in this paper. It would be interesting to break this data down further to see if the satisfaction by scholarship holders was higher than that for students without a scholarship and for students who were required to take the course as a substitute orientation course. We will also look to see if there are any differences between the results of underrepresented minority students and non-minorities. We know from past experience that it sometimes takes two semesters for students to buy in to approaching learning as a system (a central theme for the Academic Success class) and to use the 4.0 Plan to their advantage.

The response of the scholarship students was very gratifying. The $4,000 scholarships toward a tuition of $10,000 is doing what it is supposed to do. In future surveys the stress reduction caused by a scholarship and the other benefits named by the students will be included as possible benefits. The biggest challenge for the program going forward is scholarship money. Not only are we receiving more scholarship applications each year from capable, qualified students, but the NSF S-STEM grant for transfer students ends summer 2013. We are seeking additional sources for scholarship support.

Special thanks go to Mr. Carlos Flores, graduate assistant, who put the survey on-line, sorted data, and prepared the histograms.

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Improving Student Results in a Statics Course using a Computer-based Training and Assessment System

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Abstract: **One of the main causes of desertion in engineering programs is the poor student academic performance in basic courses. One of these courses is Statics, which is taught at the undergraduate level. Between 2009 and 2011 about 30% of students did not get a satisfactory grade to pass the course and a high percentage of these students deserted from their engineering program at EAFIT University.**

The evolution of computer systems and the Internet progress have enabled educators to develop software to support teaching and learning processes. For instance, educational software like E-learning platforms now allow teachers and students to interact through collaborative and friendly environments that can result in improvement on student learning outcomes and therefore improvement in their final results. Various learning tools based on problem-based learning approaches have been developed for the Statics area. These systems usually pose problems for students to solve; however, the problems usually used to evaluate and certify student knowledge are different from those used by the students during their training process. This is aimed at focusing students' attention to the use of analytical skills instead of memorizing processes.

This paper describes the results of using a computer system to support training and assessment processes to convey concepts related to a Statics course using an existing open source tool and implementing a dynamic assessment generation scheme (i.e., generation of multiple versions of the same problem using algorithms with variables). This system has been used in the Statics courses during two academic periods in 2012 involving the participation of 400 students. The results of this experiment are compared with performance results of students from previous years who used traditional practice and assessment methods such as solving tasks in conventional paper and pencil tests. Results have had a positive impact in student grades and retention.

Keywords: computer systems, desertion, engineering, reprobation, training and assessment processes

I. Introduction

One of the main causes of desertion in engineering programs at universities is the poor performance of students in basic courses [1, 2, 3]. One of these courses is Statics, which is taught in the following undergraduate programs at EAFIT University: Mechanical, Civil and Production Engineering. From 2009 to 2011, about 30% of students did not get a satisfactory grade at the end of the Statics course and a high percentage of these students deserted from their engineering program.

Researchers [2, 3, 4, 5] have identified and discussed some causes of learning difficulty in some basic courses such as Statics and various solutions have been proposed to make the learning process more effective and motivating. One of the causes for students' failure and subsequent drop out is attributed to the misalignment between the elements involved in the process of training and evaluation systems; these elements are organized differently by teachers and students [6]. From the point of view of the teacher, first (s)he defines the learning objectives and then (s)he defines the process of planning instruction, selecting resources and activities and finally planning the evaluation. From the point of view of students, the assessment is the starting point of learning process and according to their beliefs, they plan their learning activities.

An alternative to achieve align training processes and assessment processes consists of linking both processes so the students find useful to make training efforts to achieve good results in the evaluation. This can be supported by the use of computerized assessment systems that help students in their preparation while measuring their level of knowledge on the subject.

This paper describes the result of using an online assessment system [7] to support training and evaluation processes. This system was implemented using open source tools. It implements a dynamic schema of assessment generation. The rest of this paper is organized as follows: section 2 defines the process of training and evaluation implemented in the system, section 3 describes computer evaluation systems, section 4 presents the implementation of an automatic task generation system, section 5 describes the

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study, section 6 reports of the results. Conclusions are presented in section 7.

II. Training and Evaluation Processes

The subject of Statics has a wide variety of text books [8, 9, 10, 11] which are the main tools that teachers use in preparing lessons and assessments, and for the students in preparing their learning plans.

A number of workshops have been designed to help student focus on learning the concepts rather than memorizing solutions to particular problems. However, sometimes there is no a good alignment between the assessments designed by the teacher and the activities the students do to get prepared for these assessments, which results in high course failure rates. This problem can be addressed by implementing a dynamic assessment approach [12, 13].

A dynamic assessment system that implements automatic generation of tasks has been implemented to help students to improve their performance on the Statics course [7]. This system offers tasks on relevant topics to be used for students in their preparation. These practice tasks have equivalent difficulty levels but with different contexts and variables those tasks are included in the teacher designed tests. This way students can be assigned different types of problems for a particular test.

By changing task parameters, the system can generate countless tests for students to practice. Thus, students have more opportunities to improve their conceptual and procedural knowledge on the subject.

III. Computer-based Evaluation systems

Computer automated assessment (e-assessment) [14] has been used in contexts such as professional certifications [15], certification tests of general knowledge [16], language testing [17], online courses [18], among others. These assessments can be administered by E-learning platforms [19], which are computer systems that have modules for managing administrative and academic tracking [20]. E-Learning platforms allow user interaction with Internet content. Platforms such as Moodle, Dokeos, Blackboard, Chamilo [21, 22, 23, 24] among other have transformed educational practices energizing the teaching-learning processes and supporting distance education schemes. The assessment modules on E-Learning platforms are implemented in standard formats that allow interoperability of assessments [25, 26]. Currently, great efforts are made to implement these systems in web-based schemes using technologies such as Cloud Computing [27].

The individualization of the assessments, which consists in assigning a different test to each student, has been implemented using computer systems. An example of this is Calculated Question Type [28], which includes variables that take different values each time the test is generated.

IV. Implementation of an automatic generation task system.

The system developed allows students to practice the concepts of the course by solving problems. The system generates a variety of problems modeled for each course topic using algorithms that generate different versions of these problems and deliver them to students using an E-learning platform. Students interact with the questions as part of workshops and teachers also use the system to assess student outcomes and track all interactions in the system.

The system generates questions automatically by assigning different values to variables involved, varying situations and solution strategies. The system also has an automatic plotter that creates images for particular problems.

The proposed evaluation system was designed to be used in different e-learning platforms. In the Statics course the system has been used with two E-learning platforms: Chamilo and Moodle.

Initially the system was designed to be used as an independent system. The generator produces the questions for tests; teachers import them into a bank of questions to be used in an LMS platform (see Figure 1). Currently a plugin that will automatically perform some of these test configuration processes is under development.

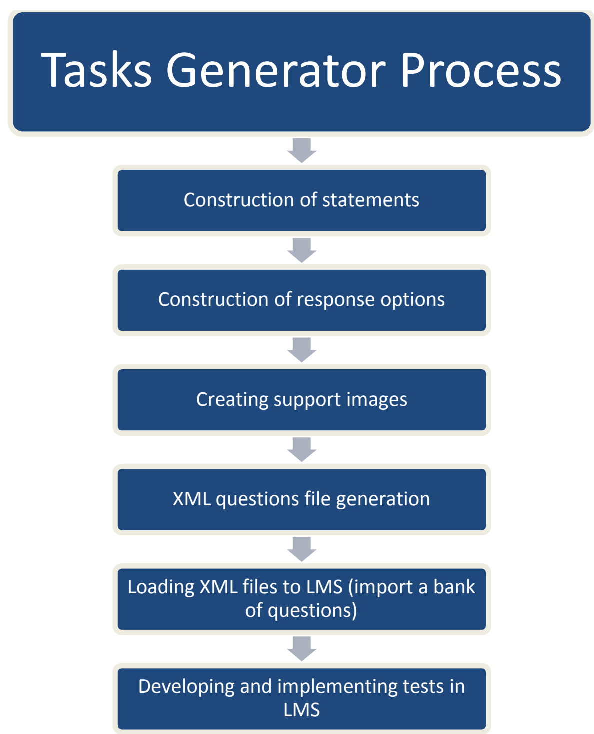

Fig. 1. Process of creation of a new test

Users are classified in three different groups: teachers, coordinators and students. Teachers are involved in various stages of the process, first the construction of the engine by providing input to the development team to design and implement problem solving algorithms, and also in the administration of test results submitted by the students through the system (see Figure 2).

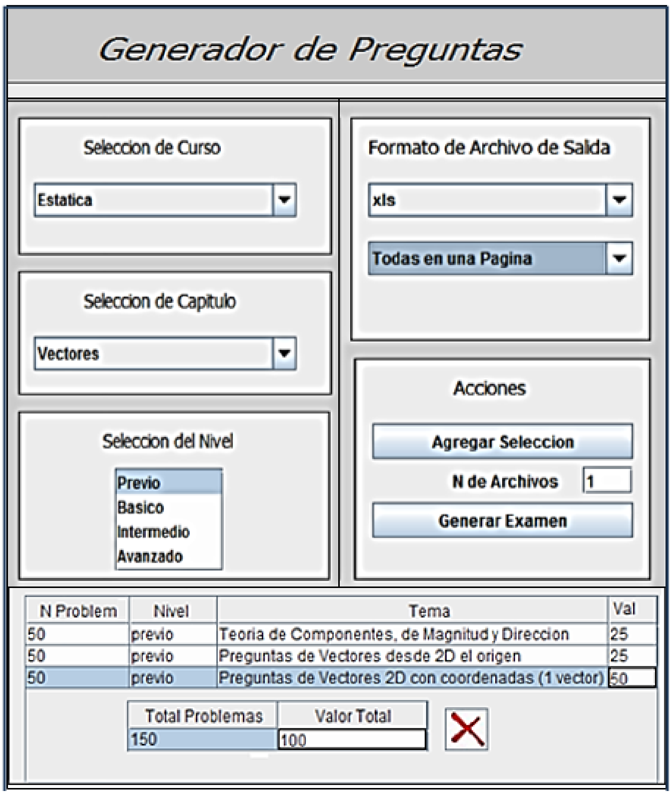

Fig. 2. Interfaces for coordinators and teachers to create a test.

Coordinators, with the help of teachers of the course, are responsible for pre-set tests; this means that they can change the parameters of an evaluation. Parameters available include: subjects, duration, date, difficulty level, and number of attempts (see Figure 3).

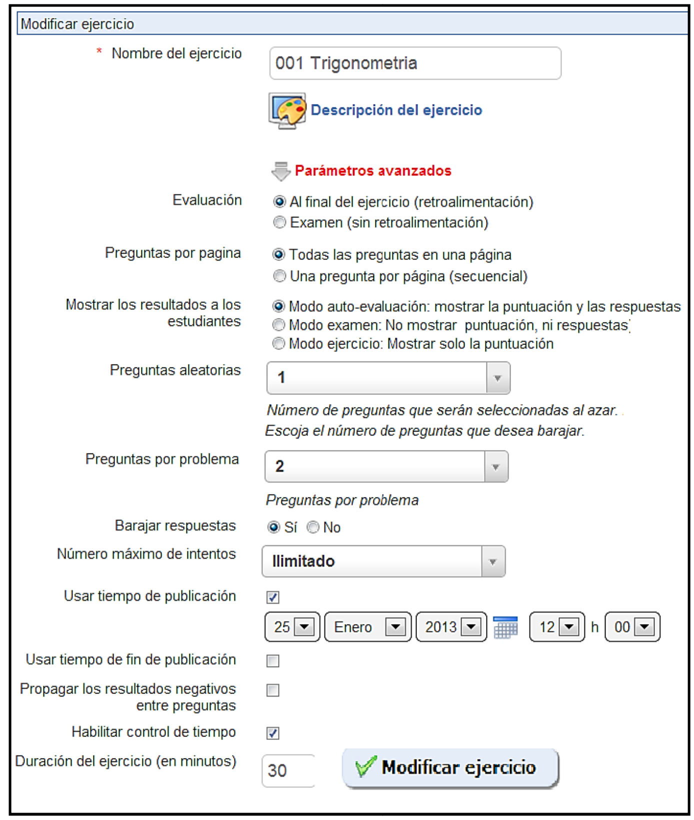

Fig. 3. Interfaces for coordinators and teachers to configure a test.

Students can interact with the system in two different ways. The first way is called training mode where students can select the topic and problem type therefore the system generates a test to practice. The second way is called evaluation mode, in which students answer previously configured tests created by coordinators and teachers (see Figure 4).

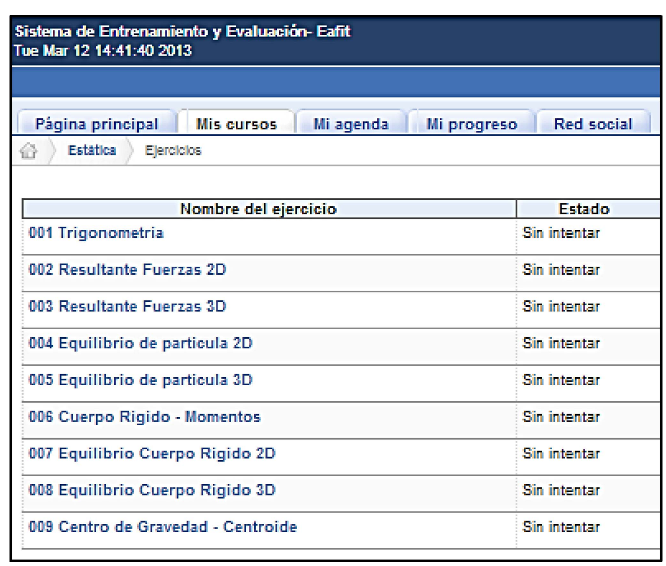

Fig. 4. Interface for students to select a test.

Processes of automatic generation of tasks was designed for being used in the web and implemented in Java language [29]. The generator algorithm produces various versions of the task by modifying the variables previously defined using random values within particular ranges. The variation includes also graphs and text that accompany the tasks generated.

According to the question format (i.e., multiple choice, matching, true or false and open written response) the correct solution must be programmed. Incorrect options are also programmed based on students' most common errors. This helps identify student misconceptions (see Figure 5). Data of students' wrong responses is not used, but all of this information is stored in the results database.

The program output is a file in one of the following formats: txt, xls, pdf and XML [30]. The XML formats like XmlMoodle [25] and QTI2 [26] are powerful and useful to transfer question and complete tests between different platforms. QTI2 is supported by many E-learning platforms.

Some instructional systems include: simulation tools (myphysicslab [31]), online courses platforms (WileyPlus [32], Connect Mcgraw Hill [33], and Courseconnect Pearson [34]). Most of these systems are commercial products which cannot be easily changed or adapted. Instead the approach presented here is flexible and affordable.

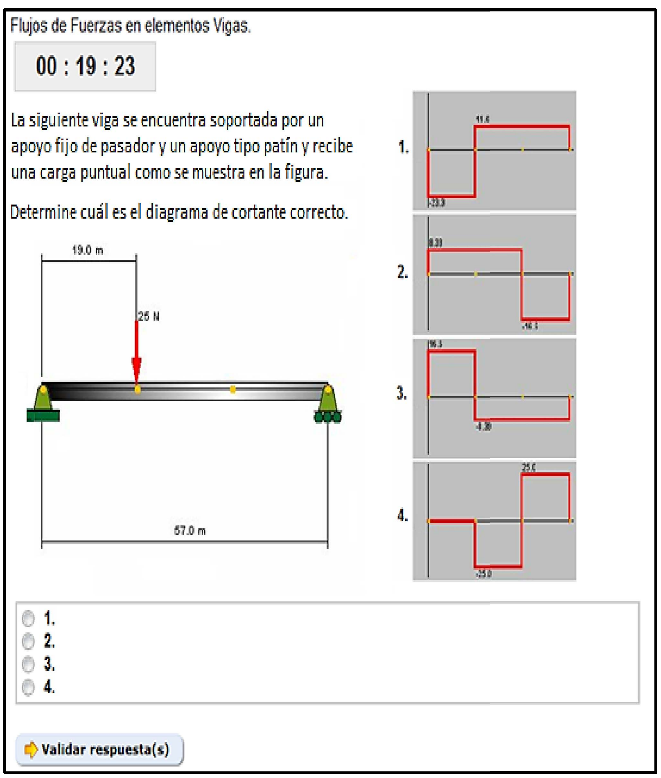

Fig.5. Example of a generated problem (response options correspond to the figures on the right).

V. DESCRIPTION OF THE STUDY

The subject of Statics and other engineering basic courses have high levels of student failure [1], with percentages close to 30%. The course is offered at the EAFIT University to about 200 students each semester in three different engineering programs. Success on the course objectives is determined by students' performance on various tests administered by the courses coordinators. Students pass the course when they achieve a success rate of 60% (a score of 3.0 on an absolute scale from 0 to 5.0).

In 2011, the Mechanical Engineering Department at EAFIT University took the initiative to change some aspects of the course through the implementation of a system for training and evaluation. The objectives were to provide a tool to improve the acquisition of knowledge and consequently improving the performance of students in the class of Statics. Further it stimulates the uptake of Information and Communication Technologies in the institution.

This system has been used in Statics courses during the 2 semesters of 2012, with the participation of 384 students from 12 different groups. The results of this experiment are compared with the results of other students from previous years who were evaluated without using the system for training and evaluation that uses the automatic task generation engine [12].

The system was introduced in 2012. It was used by students as a practice system. Student performance accounted for 20% of the final grade. On average each student solved 40 questions on each topic.

Data for this study includes result of tests of students from 2006 to 2012. The first 5 years (2006-2010) correspond to students who did not use the proposed evaluation system, 2011 students used a preliminary version of the system and 2012 includes data from students who used the system. The scores averages per year for all students are shown in Figure 6.

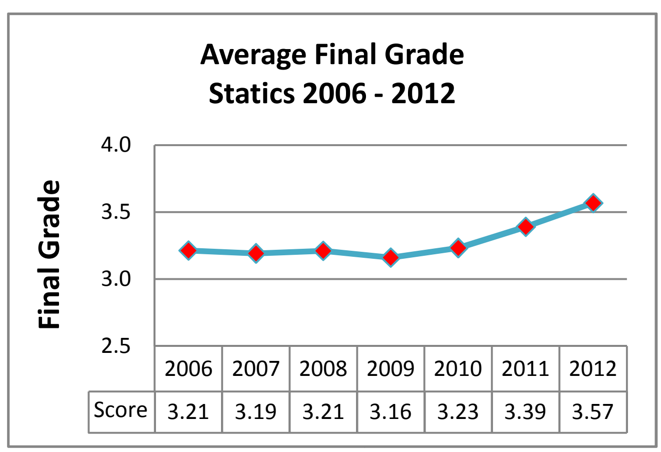

Fig. 6. Average Statics grade for 2006 to 2012.

The failure rate for a group IR in an academic period is calculated by the formula: IR = (RA / TA) x100 where (RA) is the number of students who did not get the minimum score and (TA) is the number of students formally enrolled in the course. The figure 7 shows the percentage by year of the students that failed the class in (2006-2012).

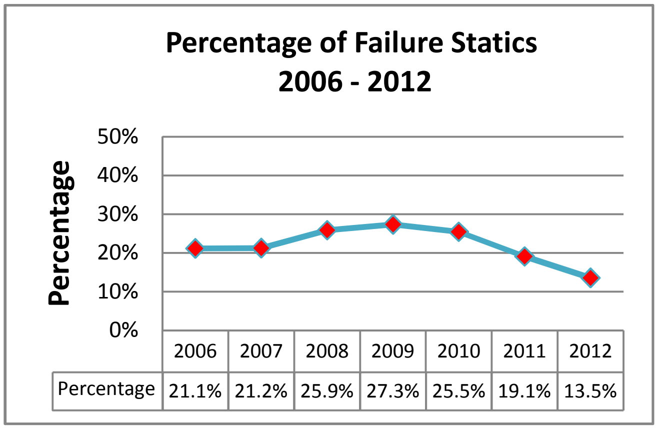

Fig. 7. Static fail rates for each year from 2006 to 2012.

Between 2006 and 2010 the students were evaluated with paper and pencil tests. During 2011 and 2012 students were evaluated with a combination of paper and pencil tests taken from the guide books, and computerized tests created by the automatic task generation system.

For the analysis two samples have been selected. The first sample (sample 1) includes the results of 1290 students, who were the total enrolled in the course between years 2006 and 2010, and the second (sample 2) includes 384 student, who were the total enrolled in the course in 2012.

2011 students were not included in the analysis of the results because that year the system was in a building phase and students used a preliminary version of the system. A comparison of the results was made to measure the changes in students' scores averages of the e-learning evaluation platform on the subject.

Finally a statistical analysis was performed and it includes tests to see if the data of the two samples follows a normal distribution, medians comparison, average analysis, and effect size test were made.

It is important to mention that the final course test is a pencil and paper test and its difficulty level has been kept the same throughout the years.

VI. Results

The figures 8 and 9 show the frequency histogram and the normal distribution fit for the sample 1 and sample 2.

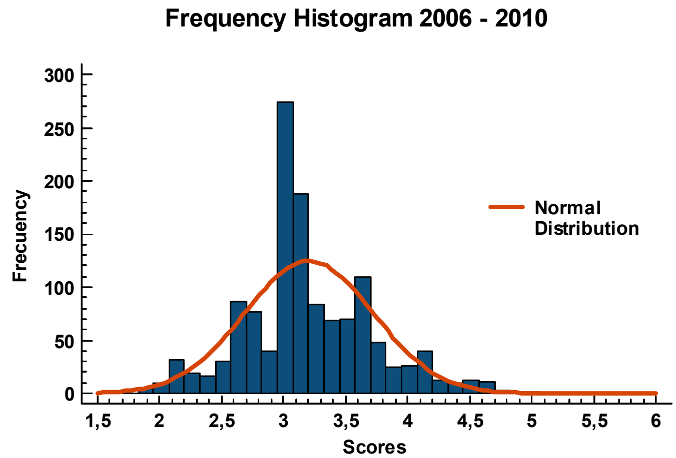

Fig. 8. Frecuency Histogram for sample 1.

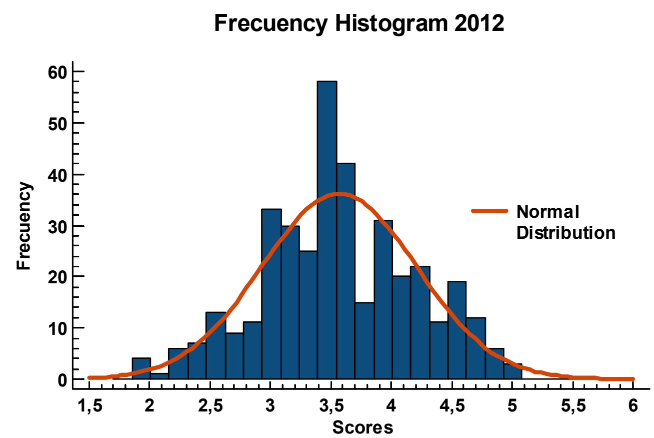

Fig. 9. Frecuency Histogram for sample 2

Table I shows the results of the Goodness of fit test (Kolmogorov–Smirnov) [35], which check the normality of samples.

TABLE I. Results of Goodness of fit test

	Sample 1	Sample 2
D max	0,107	0,063
D min	0,104	0,054
DN	0,107	0,063
Value-P	0,0	0,099

The P-value of sample 1 is less than 0.05, because of this the hypothesis that sample 1 data comes from a normal distribution should be rejected with 95% confidence. For sample 2 the P-value is greater than or equal to 0.05, the hypotheses cannot be rejected then sample 2 data comes from a normal distribution with 95% confidence.

Since the goodness of fit test for sample 1 did not fit a normal distribution, an average comparison between each sample cannot be done, then a comparison of medians test through Mann-Whitney (Wilcoxon) [36] was done. The results of this test are shown in Table II.

- Null hypothesis (1):

$$\text{Median sample } 1 = \text{Median sample } 2 \quad (1)$$

- Alternative hypothesis (2):

$$\text{Median sample } 1 \neq \text{Median sample } 2 \quad (2)$$

TABLE II. RESULTS OF MANN-WHITNEY (WILCOXON) TEST

Median Comparison	Sample 1	Sample 2
Median	3,1	3,5
Average Range	770,67	1066,62
W	331551	
P-value	0	

As the P-value is less than 0.05, then the Null hypothesis can be rejected with alpha = 0.05. There is a statistically significant difference between the medians with a confidence of 95.0%.

Finally to determine how significant the difference between the samples averages is, the effect size is calculated in (3).

$$d = \frac{\bar{x}_1 - \bar{x}_2}{s} \quad (3)$$

Where x1 and x2 are the averages of samples and “S” is the control standard deviation. The results of this test are shown in Table III.

TABLE III RESULTS OF COHEN EFFECT SIZE TEST

	Sample 1	Sample 2
Average	3.20	3.56
S	0.52	0.64
effect size	0.62	

It was found that the sample effect size is equal to 0.62, which is a moderate effect size.

After validate statically the reliability of data, the results of the differences between the averages scores and between the failure rates for two samples are shown in the Figures 10 and 11.

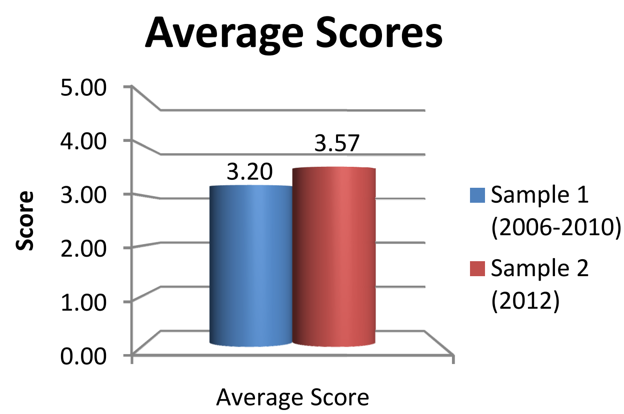

Fig. 10. Average scores for two samples.

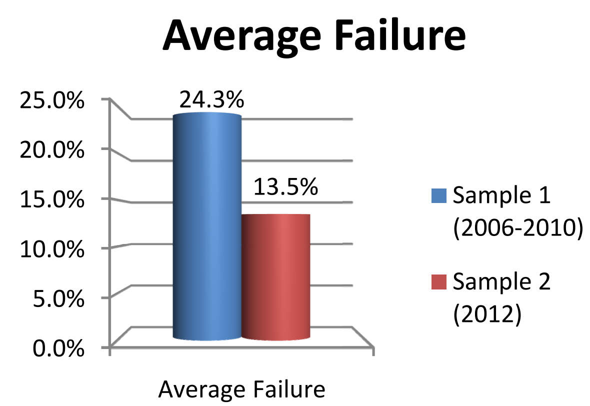

Fig. 11. Average Failure for two samples.

VII. CONCLUSIONS AND FUTURE WORK

The Statics grades for 2012 increased about 8% compared to those from 2006-2010. In addition, the percentage of failure has considerable decreased in 2011 and 2012 about 11% compared to those from 2006-2010. This is expected to have an influence in reducing dropout rates of engineering programs Mechanical, Civil and Production engineering. However, more information is needed to measure the impact of the system on dropout rates (e.g., other information on student progress, instructional changes in other classes, and teacher effects).

It should be noted that the subject of Statics is not the only subject that has high levels of failure. Also, other non-academic aspects influence desertion of academic programs.

Some students did not use the system for continuous assessment. More research needs to be done to find out why these students did not take full advantage of the system.

Part of the success of the system can be attributed to an increase in student motivation generated by the system.

Students appreciated the opportunity to use the system in other places outside the University. The LMS platform logs shows that a high percentage of the connections comes from outside the university

The development of the tool has generated interest from other academic departments and studies are in progress to adapt the system in other core subjects.

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Search Engine for Engineering Education Assessment Instruments

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***Abstract*—Adoption research has guided the development of a classification and rating system for assessment instruments valuable to the engineering education community. The ASSESS website enables users to search for instruments that measure outcomes of interest and that possess desired characteristics. The website classifies instruments by outcomes assessed, technical features, instrument format, and administration parameters. Instrument descriptions and ratings are displayed in forms useful to both experienced and inexperienced users seeking instruments for specific needs. The user community contributes to ASSESS by rating instruments and suggesting others for development or inclusion. ASSESS developers invite user input to make ASSESS highly valuable to the engineering education community.**

Keywords—assessment; engineering education; assessment instruments; outcomes

I. Introduction

The engineering education community increasingly faces the need to assess outcomes of instructional practices or to assess impacts of student characteristics, institutional culture, or educational innovations on student learning and retention. Importantly, institutional and program accreditation require assessment of student outcomes, and many grant proposals require assessment of student learning outcomes. However, the typical engineering faculty member lacks training in assessment of educational outcomes and is unaware of instruments available for assessing these outcomes.

This work-in-progress paper describes how results of adoption research are used to create a practical tool enabling the engineering education community to identify assessment instruments meeting their needs. Adoption research focused on a prototype of ASSESS[1], a web-based assessment instrument information system, to define requirements for a completed system attractive to the engineering education community. The paper summarizes needs defined by the community, describes the system designed to meet these needs, and invites readers to contribute to the refinement and adoption of the completed web-based ASSESS system.

II. Research Goals

The goal of the ASSESS project is to create an online repository of engineering education assessment instrument information that helps users identify assessment instruments meeting their needs and grows the evaluation capacity of the engineering education community. The development of the ASSESS online repository was guided by adoption research, which studied the perspectives of potential users of ASSESS. Diffusion of Innovations (DI) theory was used as a framework for this study, seeking to:

- Capture multiple perspectives of the innovation during the development phase to develop and refine ASSESS.
- Determine the relative importance of DI characteristics in technological educational innovations.

III. Methodology

A. Theoretical Framework

Adoption research was conducted using Roger's Diffusion of Innovations theory as a framework for interviews and surveys used to define needs of users [1][2][3]. Therefore, questions probed information needs and functionality desired by users in categories of:

- *Relative advantage*. Providing advantages over existing methods of finding assessment instruments.
- *Compatibility*. Matching needs, experiences, and views of users.
- *Complexity*. Giving users' perceptions of simple system operation and understandable results.
- *Trialability*. Providing new users opportunities to try the system at low cost before committing to greater use.
- *Observability*. Making results of using the system immediately visible to users.

B. Adoption Research Data Collection

Engineering educators, researchers, and evaluators (all potential users of ASSESS) were included in participant groups

[1] Appraisal System for Superior Engineering Education Evaluation-instrument Sharing and Scholarship

(PG) for the adoption research. (See Table I.) The first group had participated in a 2009 workshop of the *Inventory of Evaluation Tools for Engineering Education Projects (NSF DUE grant 0839898)* focused on defining the need for and content of a database for engineering education evaluation instruments. Of nine participants, all had already been exposed to the idea of ASSESS, but not to the website itself.

TABLE I. ADOPTION RESEARCH PARTICIPANTS AND SETTING

PG	Descriptions of Adoption Research Conditions		
	Participant Description	***No.***	***Website Status***
1	Previous workshop attendees who contributed to initial concept of ASSESS	9	Initial prototype site with basic functionality and detailed information on 10 instruments
2	ASEE-ERM Division members with possible exposure to ASSESS through conferences	10	Prototype site with additional search features and outlines of pages for rating and learning
3	ASEE-ERM Division members with possible exposure to ASSESS through conferences	4	Prototype site with additional instruments, improved search features, added content

Participant groups 2 and 3, with ten and four individuals, respectively, were selected from the Educational Research and Methods (ERM) Division of the American Society for Engineering Education (ASEE). These individuals may have had exposure to ASSESS through conference presentations.

The three participant groups were asked to view and provide feedback on the ASSESS development website at three different stages in its development. PG 1 viewed the prototype website when it had basic functionality to display instrument information and conduct searches for instruments with only 10 instruments fully described. PG 2 and PG 3 viewed the website later with increased functionality and some additional content.

Participant groups were interviewed via individual recorded telephone conversations for 10 to 20 minutes using questions derived from the five DI characteristics— multiple questions associated with each characteristic. In addition, general questions were used to determine the interviewee's background with assessment instruments.

C. Data Analysis Methods

Interviews were recorded, transcribed, and analyzed using Atlas TI software [4]. Because participant responses were similar across the three sets of interviews, data from all three groups were analyzed together. Data analysis was done in a series of steps with increasing depth as described by Krathwohl [5]:

- Transcriptions were first read to understand overall responses and initial (descriptive) coding was done.
- Data were coded for responses that mapped to one of five DI characteristics.
- Data were recoded at an interpretive level– good or bad.
- Data were analyzed to identify code patterns of activities, themes, and causal links.
- Responses were categorized with tags for reasoning behind categorization (e.g., complexity-good-simple).
- Responses were grouped using interviewee's language to better guide website development.
- For each category and corresponding DI characteristic, a "high" or "medium" or "low" ranking was used to indicate the importance of the responses.

IV. RESULTS AND DISCUSSION

A. Adoption Research Results

Results of data analysis were grouped into six categories using interviewees' terminology: *expectations of instrument inclusion*, *available information*, c*ommunity features*, *use as an alternative*, *searchability*, and *functionality of design*. Table II summarizes data that indicate for these six groups and for the DI categories: (a) whether summed responses were positive (+) or negative (-) and (b) if the resulting numbers, as a percentage, occurred in categories at low (<25%), medium (25 to 75%), or high (>75%) frequencies.

TABLE II. INTERVIEWEE FEEDBACK ON ASSESS

Group	DI Categories				
	Relative Adv.	***Compat -ibility***	***Complex -ity***	***Trial-ability***	***Observ-ability***
Expectations of Inclusion	- High	- Low			
Available Information	+ Med	+ Med	- High		
Community Features	+ Med	+ Low			+ Low
Use as an Alternative	+ High	+ Med		+ High	+ High
Searchability		+ Med	+ Low	- Low	
Functionality of Design	+ Med	- Low	+ Med	+ Low	- Med

High rating for *expectations of instrument inclusion* (and *relative advantage*) indicated the importance that ASSESS include instruments of the types desired by the user. The negative ranking resulted from the small number of instruments and lack of qualitative instruments in ASSESS when viewed during the study.

Positive ratings for *available information* indicated that users were pleased with the range of information provided for an instrument, and they felt they could learn from this information. Several respondents felt that some information and terminology was confusing and would need better explanation (negative *complexity*).

Community features were mentioned infrequently but positively. Respondents were pleased with the features allowing them to suggest instruments and to provide reviews on instruments. People desire to know if others are using an instrument successfully.

High positive rankings for *use as an alternative* indicate that users saw distinct advantages to ASSESS over other methods for finding assessment instruments. They especially like the idea of going to one place to find information on a range of available instruments. Many liked ASSESS's *trialability*, being able to use it without subscriptions or login. Some respondents see advantages in the ease with which one can direct others to the ASSESS website.

Searchability received generally positive rankings. Users found the keyword and category searches familiar. Some were disappointed in not finding instruments specifically for their disciplines. Some encountered difficulties when modifying searches. One concern was that *searchability* would decrease as the number of instruments increased.

Functionality of design received mixed but generally positive rankings. Users liked that website functionality followed familiar conventions. Concerns included how users could find the site and that the site contains information about instruments but not the instruments themselves.

It is noted that *relative advantage*, *compatibility*, and *complexity* received the most user responses or the most negative responses, indicating that these characteristics are most important to ASSESS's adoption.

V. Research Transfer

The ASSESS development team used the adoption research results to guide refinement and enhancements of the website illustrated in Figure 1. Major changes implemented in ASSESS with guidance from adoption research are described below.

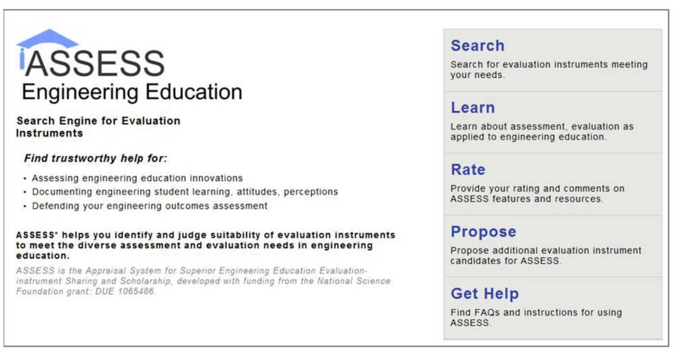

Fig. 1. ASSESS website home page.

A. Relative Advantage

The most important *relative advantage* of ASSESS over other methods is its offering helpful information on many instruments at one site. Subsequent to receiving adoption research results, the development team added new instruments (now nearly 150 total), provided more information on instruments in ASSESS, and developed procedures that yield instrument ratings with high inter-rater reliability. The team invited members of ASEE-ERM to suggest instruments for inclusion, and other potential users are being contacted to suggest new instruments. Information on an instrument will be checked for accuracy by inviting instrument owners or authors to provide missing information or correct errors in ASSESS website information. The website now contains a feature by which users can suggest instruments to add to ASSESS.

B. Compatibility

The development team addressed concerns about ASSESS *compatibility* through solicitation of a broader set of instruments. The team will now go directly to contacts in engineering education and in disciplinary engineering fields to request instruments useful to them, including qualitative and quantitative instruments. These instruments will address specific needs of educational researchers and engineering faculty who need to assess learning in their disciplines.

C. Complexity

The development team addressed *complexity* of ASSESS by refining search and rating features. Searches may be done by keywords or by advanced searches that allow selection of multiple characteristics of instruments. Search results are sortable by amount of evidence found for uses in engineering, reliability, or validity. Users may also easily provide ratings for instrument usability and site feedback. Simplified website language and a glossary will minimize user confusion.

VI. Conclusions

The adoption research conducted to determine potential user perceptions of ASSESS identified characteristics of this type of technology most important to its adoption by the engineering education community: *relative advantage*, *compatibility*, and *complexity*. This research has enabled the ASSESS project developers to address issues important to users so that the website, when made public, is found attractive for adoption by the community. Because the website empowers the community to contribute and shape it, ASSESS has potential to gain broad support needed for sustainability. Interested users are encouraged to contact the authors of this paper or visit the site and provide input at: http://assess.tidee.org.

Acknowledgment

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A Methodology to Teach Exemplary Coding Style Considering Students' Coding Style Feature Contains Fluctuations

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***Abstract*—Readable source code should contain a relatively small amount of latent bugs and should be easy to maintain. However, it is difficult for a teacher to teach all students to write code in accordance with a certain coding style because each of them naturally has his/her own different coding styles, and the teacher needs to advise them considering their original coding styles. To deal with this issue, the CM algorithm is introduced, which was originally developed to detect source code plagiarism in Java programming classes. It quantifies a student's coding style feature by using a set of hidden Markov models called coding models. Coding models quantify a person's code writing style as that person's coding style feature. In this paper, an attempt to apply the CM algorithm for facilitating coding style instruction is reported. Experimental results showed that the coding models provided information that was useful for teaching coding styles.**

I. Introduction

A primary objective of programming classes is to teach students to write source code by following the grammar and syntax of a programming language. Currently, students can write code without learning coding styles; however, to be good programmers, it is essential that they be knowledgeable about coding styles and write readable code. Readable source codes are easier to maintain: they should not contain latent bugs that cause errors or are difficult to detect. Ambler [1] noted that beginners can increase their Java programming skill very significantly by following the coding standards and investing a lot of time in writing high-quality source codes from the beginning of their learning experience. Thus, in terms of improving students' programming skills, writing such code without using the auto-formatters is as effective as learning programming grammar, syntax, and algorithms.

However, it is often difficult to teach students proper coding styles because they write their source codes in their own way. As a result, unless they are very skilled programmers, students find it difficult to follow strictly a coding style guide or a style produced by an auto-formatter; this, in turn, may cause them to take a longer time to write source code.

In this paper, a teaching method that uses the quantified features of the individual code writing style of a student as obtained by applying the *CM algorithm* [2] is proposed. In Section II, the definition and procedure of the proposed method is explained. In Section III, the experimental results are presented. Finally, in Section IV, the conclusions are given.

II. About Proposed Method

A. Application of CM Algorithm

The CM algorithm was originally developed to detect plagiarism in programming classes. It simulates the process of visually searching for a certain pattern of token sequences that commonly occur in the same author's source code to check whether the given source codes are produced by the same author. It quantifies the programmer's *coding style feature* instead of the content feature of a source code. This unique approach enables a teacher to grasp the perspective and the gist of a student's coding style visually and to compare it with other students' coding style or an exemplar coding style. In addition, a stochastic model is suitable for representing features that appear in common among token sequences where the occurrence pattern of the tokens shows fluctuation.

B. Definition and Procedure of the Method

A source code consists of tokens o_t, each of which is categorized into one of three groups as shown in Table I. The tokens used in most Java source codes, such as "{," are treated as one of 14 *basing-point tokens* $o^b_{n_b}(1 \leq n_b \leq 14)$. The adjacent tokens of $o^b_{n_b}$, such as 1-letter spaces are categorized as *identification tokens* $o^i_{n_i}(1 \leq n_i \leq 6)$, and the remainder are *other tokens* $o^o_{n_o}(n_o = 1)$. A *coding style feature* of an author A_α is defined as the occurrence pattern of $o^i_{n_i}$ before or after each one of $o^b_{n_b}$ in token subsequences generated from a normalized source code by using $o^o_{n_o}$ as delimiters.

The coding style feature of A_α is represented by parameters of a set of *coding models* M_α consisting of 14 forward coding models M^α_F and 14 backward coding models M^α_B [2] as

$$M_\alpha = \left\{M^\alpha_p | p = \{F, B\}\right\} \quad (1)$$

$$M^\alpha_p = \left\{M^\alpha_{p,n_b} | 1 \leq n_b \leq 14\right\} \quad (2)$$

where p indicates the forward or backward coding model.

M^α_{p,n_b} consists of three states, $s_i(1 \leq i \leq 3)$, and has the three parameters: *initial probability* π_i, *transition probability* $a_{i,j}(i < j \leq 3)$, and *observation probability* $b_i(o_t)$, where $o_t = \left\{o^i_{n_i}, o^b_{n_b}, o^o_{n_o}\right\}$ and $0.0 \leq \pi_i, a_{i,j}, b_i(o_t) \leq 1.0$.

Figures 1 and 2 show the forward and backward coding models that represent parts of the coding style feature of A_α corresponding to the basing-point token o^b_1 ("{"). As shown in Figure 1, $o^i_{n_i}$ in Table I such as o^i_1 can be observed in s_2

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TABLE I
THREE CATEGORIES OF TOKENS

Categories o_t	No.	Tokens
Identification tokens $o^i_{n_i}$	1	o^i_1: 1-letter space
	2	o^i_2: 2-letter space
	3	o^i_3: 3-letter space
	4	o^i_4: 4-letter space
	5	o^i_5: tab
	6	o^i_6: linefeed
Basing-point tokens $o^b_{n_b}$	1	o^b_1: opening brace (e.g., "{")
	2	o^b_2: closing brace (e.g., "}")
	3	o^b_3: opening round bracket (e.g., "(")
	4	o^b_4: closing round bracket (e.g., ")")
	5	o^b_5: opening square bracket (e.g., "[")
	6	o^b_6: closing square bracket (e.g., "]")
	7	o^b_7: arithmetic operators (e.g., "+")
	8	o^b_8: assignment operators (e.g., "=")
	9	o^b_9: comparative operators (e.g., "<")
	10	o^b_{10}: logical and bit-wise operators (e.g., "!")
	11	o^b_{11}: comments
	12	o^b_{12}: colon (e.g., ":")
	13	o^b_{13}: comma (e.g., ",")
	14	o^b_{14}: semicolon (e.g., ";")
Other tokens $o^o_{n_o}$	1	o^o_1: reserved words, identifiers, delimiters, etc.

and o^b_1 can be observed in s_3 whereas only o^o_1 is observed in s_1. Figure 2 shows that o^b_1 in s_1, $o^i_{n_i}$ in s_2, and only o^o_1 in s_3 are observable in M^α_B. π_1 is always 1.0 in both M^α_F and M^α_B.

Each of the coding models is small-scaled and represents only a simplified token occurrence tendency corresponding to one of the 14 basing-point tokens as a part of a programmer's complex coding style. $M^\alpha_{F,1}$ shown in Figure 1 represent only which one or which combinations of the tokens out of six kinds of $o^i_{n_i}$ are observed between o^o_1 and o^b_1, and $M^\alpha_{F,2}$ in Figure 2 represents which one or which combinations of $o^i_{n_i}$ are observed between o^b_1 and o^o_1. There are 13 other pairs of M^α_{F,n_b} and M^α_{B,n_b} to represent 13 other kinds of coding styles regarding the 13 other $o^b_{n_b}$. In this way, the partial and overall features of A_α's complex coding style are represented.

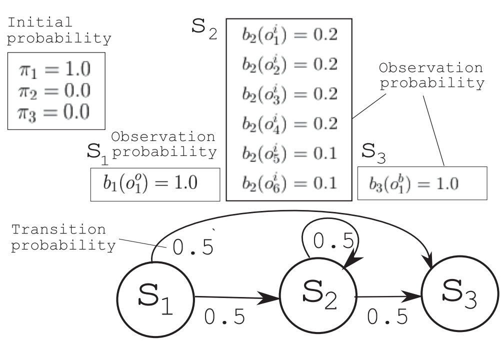

Fig. 1. One of the forward coding models $M^\alpha_{F,1}$

The following process to generate the learning data to train M_α is conducted. We tokenize the n-th source code of A_α to generate a token sequence D^α_n and apply 14 different normalizations to generate D^α_{n,n_b} consisting of $o^i_{n_i}, o^b_{n_b}$, and $o^o_{n_o}$. Then, we clip out a number of token subsequences $d^{\alpha,p}_{n,n_b,n_s}$ from D^α_{n,n_b}. When generating learning data for $M^\alpha_{p,1}$, $o^b_{n_b}$, except for o^b_1, such as o^b_2, are all treated as o^o_1.

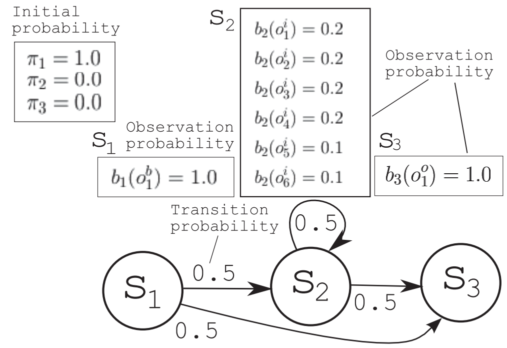

Fig. 2. One of the backward coding models $M^\alpha_{B,1}$

$$D^\alpha_n = \left\{D^\alpha_{n,n_b} \mid 1 \le n_b \le 14\right\} \quad (3)$$

$$D^\alpha_{n,n_b} = \left\{d^{\alpha,p}_{n,n_b,n_s} \mid n_s = \text{ \# of subsequences}\right\} \quad (4)$$

$$d^{\alpha,p}_{n,n_b,n_s} = \left\{o_t \mid 1 \le t \le l_{n_s}\right\} \quad (5)$$

where l_{n_s} is a length of the n_s-th subsequence.

The procedure of generating learning data $d^{\alpha,p}_{n,n_b,n_s}$ for $M^\alpha_{F,1}$ is as follows. (1) Choose o^b_1 out of 14 $o^b_{n_b}$ as a *current basing-point token*, (2) apply normalization by transforming all $o^b_{n_b}$ besides o^b_1 into o^o_1, (3) search for o^b_1 from the beginning of D^α_{n,n_b}. (4) After finding o^b_1, step back until o^o_1 is reached. Here, o^o_1 is treated as a delimiter and a line of o^o_1 are treated as a single appearance of o^o_1. (5) Then, start collecting tokens after o^o_1 until o^b_1 is reached. For example, in Figure 3, the token before "{" is ")," which should be represented as o^o_1 when the current basing-point token is o^b_1. Therefore, one of the subsequences $d^{\alpha,F}_{n,1,n_s}$ to be used as input data for $M^\alpha_{F,1}$ is "o^o_1, o^b_1". As another example, the tokens after o^b_1 are, in sequence, o^i_1, o^i_6, and o^i_5, before reaching o^o_1 ("int"). Therefore, the input data for $M^\alpha_{B,1}$ is "o^b_1, o^i_1, o^i_6, o^i_5, o^o_1."

The processes is continued to clip $d^{\alpha,p}_{n,1,n_s}$ in parallel until the end of $D^\alpha_{n,1}$ is reached. Then, the current basing-point token is changed to o^b_2, and the above process from the beginning of $D^\alpha_{n,2}$ is repeated to collect $d^{\alpha,p}_{n,2,n_s}$ as the learning data of $M^\alpha_{p,2}$. M_α is trained the corresponding parts of the coding style features of A_α, by inputting $d^{\alpha,p}_{n,n_b,n_s}$ and updating its parameters according to the learning algorithm of hidden Markov models [2][3]. In this method, the parameters of M^α_{p,n_b} and $M^{\alpha'}_{p,n_b}$ are compared to check the difference between a student's coding style feature and an exemplar coding style feature. Thus, a teacher can provide instructions about coding styles according to each student's original coding style feature.

III. EXPERIMENT

A. Settings

12 students $A_\alpha (1 \le \alpha \le 12)$ were provided with 10 basic Java exercises, and were required to produce 12 sets of 10 Java source codes $D^\alpha_n (1 \le n \le 10)$ under supervision to ensure that each set of source codes would be written in each of the students' own coding styles. First, copies of D^α_n were made and formatted according to *Eclipse 2.1 format* by using

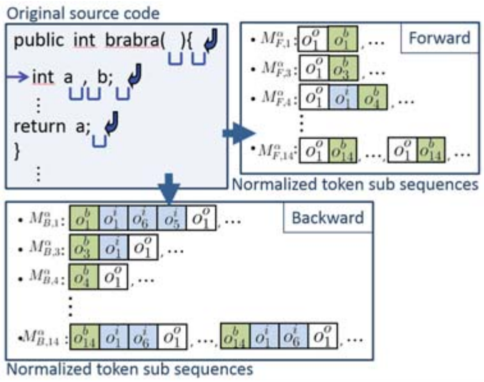

Fig. 3. How to generate input data for each of the 28 coding models

the formatting capability of Eclipse IDE [4]; some additional formatting such as inserting a single space before ")" and after "=" was also applied to generate a set of exemplar source codes $D_n^{\alpha'}$. We trained M_α and $M_{\alpha'}$ by inputting D_n^α and $D_n^{\alpha'}$, and compared the parameters of M_{p,n_b}^α and $M_{p,n_b}^{\alpha'}$.

B. Results

Figure 4 shows the parameters of $M_{F,1}^1$, $M_{F,1}^5$, and $M_{F,1}^{10}$ (red bars) and $M_{F,1}^{1'}$, $M_{F,1}^{5'}$, and $M_{F,1}^{10'}$ (blue bars), respectively. Figure 5 shows the parameters of $M_{B,1}^1$, $M_{B,1}^5$, and $M_{B,1}^{10}$ (red) and $M_{B,1}^{1'}$, $M_{B,1}^{5'}$, and $M_{B,1}^{10'}$ (blue). The types of parameters are shown on the x-axes and their values are shown on the y-axes of the graphs. π_i, b_1, and b_3 are not used, because the values are always the same.

From the graphs, the partial similarity and difference between the coding style feature of A_α and $A_{\alpha'}$ can easily be read. For example, the forward coding style of A_1 and A_5 are similar to each other and quite different from their exemplar coding styles $A_{1'}$ and $A_{5'}$, whereas A_{10} is different from A_1 and A_5 but similar to $A_{10'}$. A_5 and A_{10} occasionally insert no $o_{n_i}^i$ before o_1^b and at other times insert o_1^i, whereas the exemplar always inserts o_1^i, o_4^i, o_5^i, or o_6^i. The parameters of M_5 and $M_{5'}$ in Figure 5 indicate that the part of the coding style feature of A_5 regarding o_1^b is quite similar to the exemplar coding style feature, except that the student sometimes inserts o_1^i, o_2^i, o_3^i, or o_4^i, which does not occur in the exemplar coding style. Overall, there are very small differences among the backward coding styles of A_1, A_5, and A_{10}, and they are all also quite similar to the exemplar coding style.

The graph representations of the coding style help a teacher to provide instructions to students according to their features. D_n^α and $D_n^{\alpha'}$ were inspected visually and it was confirmed that the same difference between the coding style features of A_α and the exemplar exists as represented by the graphs.

IV. Conclusion

In this study, a method that measures a similarity between a student's and exemplar coding style features which can be used to improve a student's coding style is developed and tested.

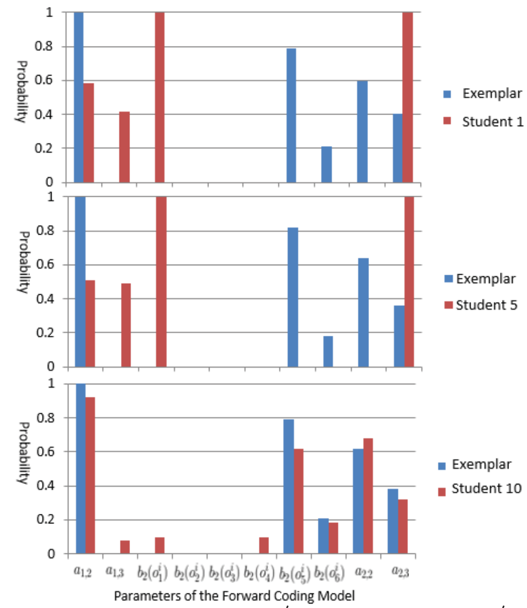

Fig. 4. Parameters of $M_{F,1}^1$ and $M_{F,1}^{1'}$ (top), $M_{F,1}^5$ and $M_{F,1}^{5'}$ (middle), and $M_{F,1}^{10}$ and $M_{F,1}^{10'}$ (bottom), respectively

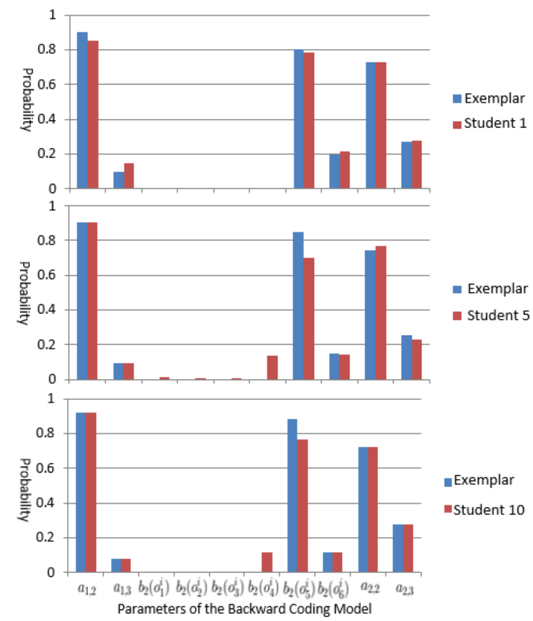

Fig. 5. Parameters of $M_{B,1}^1$ and $M_{B,1}^{1'}$ (top), $M_{B,1}^5$ and $M_{B,1}^{5'}$ (middle), and $M_{B,1}^{10}$ and $M_{B,1}^{10'}$ (bottom), respectively

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Teaching an Introductory Programming Course Using Hybrid e-learning Approach

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***Abstract* - The usefulness of hybrid delivery in education has long been realized, and with the advancement of computer and communication technologies and the introduction of Web-based authoring tools, its effectiveness has been further extended. In this regard, it has affected traditional distance learning by transforming the learning experience from a static videotape delivery to a more dynamic format by adding/substituting the web as the delivery media. In this paper, we report our initial results based on offering an introductory computer programming course for engineers using Matlab; via hybrid e-learning including virtual face-to-face, for distance course delivery. We present the challenges that teaching a programming course brings about using a hybrid methodology with synchronous online delivery component. Details of this work, including design and delivery issues, student and course assessment, and required technology, as applied to a computer programming course, are included in the paper.**

***Keywords - distance learning, e-learning, virtual delivery, hybrid delivery*.**

I. INTRODUCTION

In our previous work [1], we reported our proposed hybrid e-learning approach to enhance distance learning and address some of the difficulties that have been reported with web-based deliveries. In this work, we report our initial findings and describe our next development plan. We first start with brief background information. The Internet "revolution" has formed an efficient and convenient way of managing many aspects of our lives, among them a new media for teaching and learning. Online learning has affected the traditional distance-learning format by transforming it from a static paper or videotape-based delivery to a more dynamic format by adding/substituting the web as the delivery media. While some studies reported high levels of student satisfaction with web-based course delivery [2]-[5], others found that students preferred the more familiar classroom-based environment [6]-[7]. Some of the difficulties associated with web-based learning, as reported by students going back a decade ago, still exist. They include: the feeling of isolation due to a lack of interaction with peers or faculty; lack of prompt feedback about processes and progress in the course; and a need for students to better manage their time in order keep abreast of the course requirements [8]-[9]. This project partially initiated based on our belief that by using a "hybrid" or "blended" e-learning approach, we would be able to address some of these concerns. Our approach could be considered enhanced distance education, with some distinct differences/requirements and added features. It is worth pointing out that among the published studies in this area, some define "hybrid" as a combination of "face-to-face" and "asynchronous" [10]-[11] and some like ours, taking a more general approach, as "synchronous" and "asynchronous" [12]-[13].

As was pointed out in [1], the initial idea for this project originated from trying to find a cost effective model/solution to the problem of under-enrolled engineering courses across Commonwealth Campuses at Penn State University. The idea of offering cross-campus courses has been entertained several times before by using Pic-Tel video technology, where students were able to watch an instructor deliver a lecture on a television set, or its updated delivery version called Video Learning Network (VLN). The major problem with these approaches is that the necessary interaction during the programming process, vital to student success in a computer-programming course, is difficult to achieve, as these systems are not designed for such requirements.

II. IMPLEMENTATION PLAN

This section focuses on the modifications that we have made, to the original approach as described in [1], for the second delivery attempt or planning to make in the next scheduled offering. For clarity, brief descriptions of the sections that have remained intact are included.

A. Course Selection

As described in [1], the project was designed to deliver CMPSC 200 (programming with Matlab), which is a required course for mechanical, and bioengineering students, and is recommended/accepted by civil, industrial, and biological engineering departments. Due to under-enrolled expectation, for this course, at Commonwealth Campuses of Penn State, it has not been available to some students and is only offered at the main campus, University Park. The main objective of this project is to improve student access to academic specialties across the college by using a cost effective model.

B. Hardware-Software Requirements

The hardware and software requirements/recommendations included the Adobe Connect [14] platform for virtual face-to-face delivery. We required web cameras and headsets for students. The instructor's computer included a dual screen for better control and delivery of the course. As anticipated, the quality of the Internet connection (available bandwidth) played an important role.

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C. Design and Delivery

The following includes points that are relevant to our current discussions, for more details on design and delivery considerations please refer to [1].

- Fourteen students from three campuses enrolled in the course during the first two delivery attempts.
- Students enrolled in the course were informed about course delivery methodology and the requirements for student participation, via email two weeks before the beginning of the semester.
- Support for online delivery classes was obtained. An e-learning specialist was assigned to help the instructor with design and delivery of the course.
- A short training video on how to use Adobe Connect was made for students. During the first online session, basic points were reviewed and practiced.
- Course syllabus included the number of synchronous class teachings/discussion, the amount of expected asynchronous learning by students, expected conduct during the synchronous delivery, and grading and attendance policies.
- Course delivery was through Penn State's E-learning cooperative and we have committed to a three-year delivery of this course.
- A programming team project using Matlab's GUI was added to the course design described in [1].
- Peer evaluation, using VoiceThread [15], for the team project was added to the design describe in [1].
- Students were encouraged to post their programming questions using ScreenR [16]. This was added to the design described in [1].

D. Teaching Process and Resources

Only the points relevant to our current discussion are included in this section for more details please refer to [1].

- The course included a textbook for reference and homework assignments [17].
- Pre-recorded short-lecture weekly videos were made available to students.
- Students were asked to watch the videos, read the textbook, and take a readiness assessment before the beginning of each synchronous lecture (to measure the learning level from the asynchronous portion). The readiness assessment questions changed from concept questions to short programming questions from first delivery to the second delivery.
- The synchronous delivery portions were designed to cover the topics that needed to be emphasized based on the questions that were missed by a 40% percentage of students during the first delivery and focused mostly on problem solving/programming rather than lecture delivery during the second delivery.
- Students were required to take a post assessment questionnaire that included short programs, a day after the synchronous meeting. The result of this assessment was used by the instructor to evaluate the effectiveness of the on-line segment.
- Weekly online programming quizzes (asynchronous) were included in the course.
- Exams included programming and concept type questions.
- ANGEL [18] (A New Global Environment for Learning) was used as the CMS tool for this course.

In our previous work, we indicated that the synchronous portion should be designed and conducted as a discussion and problem solving session and not on information delivery. The information delivery portion is expected to be handled by the e-lectures, recorded videos, and tested by online quizzes and activities during the asynchronous part.

III. Student and Course Assessments

The following integrated, but separately assessable components were used in the assessment process:

- Class participation and student contribution during the synchronous delivery mode (bonus point: up to 4% added)
- Homework assignments (13.7% of the final grade)
- Course GUI Project (9% of the grade)
- Project Presentation at a campus event and/or symposium (bonus point: up to 1.8%)
- Readiness- and post-assessments (13.7% of the final grade)
- Examinations and on-line quizzes (63.6% of the final grade)

IV. Remarks and Conclusions

The online synchronous delivery segment was modified, due to the assessment at the end of the first delivery, from review/short lecture to review/programming practice. The main reasons for this modification is presented below:

1. The underlying assumption for the proposed methodology was that students would review/study the posted/pre-recorded lecture material, and the online synchronous sessions would be used to answer their questions. After a few weeks during the first delivery, we found out that this was not the case. Consequently, due to the overwhelming request by students, the synchronous sessions changed to lecture delivery meetings, which was not our intent.
2. Unfamiliarity of the enrolled students with expected study plans for "online" courses and their approach to the class like a traditional face-to-face course.

We need to point out that CMPSC 200 is a programming course that is taken by third semester undergraduate students, and most students did not have any experience with online course offerings. Their approach to studying and preparations for this course was reflective of their college level experience. Based on exit interviews, we modified the synchronous delivery modules after the first delivery and we are planning to introduce/expand the following changes during the upcoming delivery:

- Provide an in-depth discussion with students regarding how to study for an online programming course. Students would be required to acknowledge the requirements and learning process.
- Produce several "dynamically worked-out problems" based on a model that we developed before [19].
- Change the online sessions from once to twice per week, focusing on problem solving. Students are expected to post/email their questions 24 hours before the meetings. These meetings will be recorded and would be available to all students. Attending at least one of the sessions is mandatory.
- Host a brief online meeting with each student every three weeks, going over his/her progress.

ACKNOWLEDGMENT

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An online e-Learning authoring tool to create interactive multi-device learning objects using e-Infrastructure resources

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Abstract— **Education can take advantage of e-Infrastructures to provide teachers with new opportunities to increase students' motivation and engagement while they learn. Nevertheless, teachers need to find, integrate and customize the resources provided by e-Infrastructures in an easy way. This paper presents ViSH Editor, an innovative web-based e-Learning authoring tool that aims to allow teachers to create new learning objects using e-Infrastructure resources. These new learning objects are called Virtual Excursions and are created as reusable, granular and interoperable learning objects. This way they can be reused to build new ones and they can be integrated in websites or Learning Management Systems. Details about the design, development and the tool itself are explained in this paper as well as the concept, structure and metadata of the new learning objects. Lastly, some real examples of how to enrich learning using Virtual Excursions are exposed.**

Keywords— authoring tool; learning objects; e-Infrastructures

I. INTRODUCTION

The European Commission considers that e-Infrastructures are essential to foster scientific excellence and stimulate the development of high-quality human capital and therefore they must have a place in education and training [1]. According to [2] an e-Infrastructure consists of computational systems, data management, advanced instruments, visualization environments and people, all linked together by software and advanced networks to improve scholarly productivity and enable knowledge breakthroughs and discoveries not otherwise possible. In education, e-Infrastructures can be used to provide unprecedented access to educational resources including experts, online activities, games and virtual environments [3]. Therefore, e-Infrastructures can greatly expand learning and teaching opportunities for students and teachers [4]. For instance, they can allow interacting in real time with resources such as microscopes, virtual laboratories, webcams or tools of professional science like simulations, data sets or remote equipment. Teachers can combine virtual resources like these and traditional F2F (Face to Face) teaching in order to enrich the learning experience in an effective way taking advantage of technology without renouncing to the benefits of in-person teaching [5]. Hence, e-Infrastructures can be used in blended learning, supplementing traditional classroom activities and providing enhanced learning materials. According to [6], this is especially useful for science, technology, engineering and mathematics (STEM) disciplines as the best way to provide this kind of education is to use a blended approach.

Nevertheless, it is difficult to find accessible educational e-Infrastructure resources. Moreover, although sometimes teachers can find an appropriate one, they need to customize and link it with other educational contents (e.g. text, images or videos) in order to make it more pedagogical and to adapt it to different knowledge levels and requirements of different classes. Additionally, if teachers want to improve the quality of their own teaching materials by using e-Infrastructure resources, they should integrate both. Therefore in spite of all e-Infrastructure benefits in education, teachers usually end up using classical resources, which provide less engaging experiences, or generating their own resources from scratch.

Taking all this into account, providing e-Infrastructure resources as content units that can be individually adapted and integrated into existing teaching materials and curricula of teachers was identified as the main challenge when the GLOBAL excursion (Extended Curriculum for Science Infrastructure Online) project started. GLOBAL excursion is a European project which main aim is to enrich science teaching in European schools. Via a central web portal, called Virtual Science Hub (ViSH), we provide scientists, teachers and their pupils a package of activities, materials and tools for enabling the integration of e-Infrastructures into school curricula.

In order to allow teachers to create enhanced learning materials through integrating e-Infrastructure resources we have developed an e-Learning authoring tool called ViSH Editor. This tool will be presented in this paper. The content generated by this authoring tool is a new learning object called Virtual Excursion which will be also explained.

The rest of the paper is organized as follows. The next section reviews related work of authoring tools as well as learning objects. Section 3 introduces the GLOBAL excursion project. Section 4 shows an overview of the ViSH platform. Section 5 and 6 explain the generated learning object and the ViSH Editor authoring tool. The last section finishes with some concluding remarks together with an outlook on future work.

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II. RELATED WORK

Before content can be accessed, shared or reused, it must be created. Authoring tools aim to enable authors to create this content. An authoring tool can be defined as a software application that allows authors to create their own content and deliver it to the end users. As a general rule in the case of an e-Learning authoring tool, the authors are teachers, the end users are students and the content is a learning resource created following a learning object content model. An official definition of learning object (hereafter LO) can be found in the learning object metadata (LOM) standard [7], which defines a LO as "any entity, digital or non digital that may be used for learning, education or training". However, this is not an universal definition since LO definitions and specifications considerably vary depending on the content model [8]. The primary purpose for creating these resources as LOs is to facilitate reuse [9]. The major benefit of reusing LOs is to reduce time and to enable cost-effective development by reusing learning materials instead of repeatedly authoring them. Moreover, digital LOs may even enhance the quality in comparison with those developed from scratch [10]. The potential of a LO for reuse increases as its size or granularity decreases [11]. Thereby learning resources should be sufficiently large to be of educational value but also be small enough to be effectively reused [12]. LOs can be combined among them to build more complex ones forming a hierarchy. For instance, a slideshow can be created by linking single slides together. Furthermore, each of these slides can be created at the same time by linking other LOs such as a paragraph of text, a picture or a video. This creation process can be referred to as authoring by aggregation [11]. Also, these LOs are known as granular LOs and the different hierarchy levels are called aggregation or granularity levels. Learning object models define these levels of granularity and specify how the components can be aggregated as well as the properties of these components [13]. One very important aspect of LOs is metadata, where a description of the content is included in order to improve their reusability, discoverability and interoperability. Standards also play an essential role for an authoring tool to achieve the interoperability of the resulting LOs. For this reason, the learning resources created by most authoring tools can be exported or are built conforming to some e-Learning standard such as SCORM (Sharable Content Object Reference Model) [14] or AICC (Aviation Industry Computer-Based Training Committee). However, there also exist some e-Learning authoring tools that do not include support for e-learning standards. Since authoring tools offer a diverse variety of features, the process of selecting one to create the LOs might be hard. As [15] points out, the criteria for choosing the most suitable authoring tool should be based on the particular needs of the end users, taking into account capabilities such as automated programming, interoperability, standards, question types and media and file support. This is especially important in low-tech teaching contexts, where teachers are not computer specialists and also have poor IT (Information Technology) support. Under these conditions, it is still possible to get excellent results by using the appropriate models and authoring tools [16]. An authoring tool can provide a differentiating value not only adapting to their target users' needs but also by integrating novel learning resources such as e-Infrastructures.

Several e-Infrastructures (e.g. DEISA [17], EGI [18], OSG [19], XSEDE [20]) exist nowadays with the foremost aim of sharing computing resources and data between scientists. However, the potential impact of e-Infrastructures in education is at least as significant as that in other disciplines [4], and hence, as time goes by, more projects [21] [22] are carried out to provide more e-Infrastructures for education. Finally, bearing in mind that a LO can be formed by aggregation, these e-Infrastructure resources can be linked with other LOs through authoring tools to increase their educational value.

III. GLOBAL EXCURSION PROJECT

The European Commission has defined the advancement of STEM related skills as one of the priorities for the period 2014-2020 [23]. Furthermore, it has shown in several reports its concern about the way science teaching is currently being performed [1]. Bearing all this in mind, and considering that e-Infrastructures are recognized by the European Commission as a key to a knowledge-based economy and social cohesion that need to have a place in education, the GLOBAL excursion project (http://www.globalexcursion-project.eu) was proposed and approved.

Together with end users, GLOBAL excursion develops a common understanding, teaching use cases, as well as pedagogical and technical artifacts. The aim of this project is to provide students and their educators (teachers, parents, etc.) across Europe with a range of e-Infrastructures and access to expert knowledge on its usage for a joyful exploration of e-Science. Another goal of the project is to improve science curricula by enriching school's existing teaching and learning materials.

The e-Infrastructure providers participating in the project were initially three, the Institute for Biocomputation and Physics of Complex Systems (BIFI) from Spain, the Nanoscience Centre from the University of Cambridge (UCAM) from the United Kingdom and the Computer and Automation Research Institute (SZTAKI) from Hungary. Other scientific centers are expected to participate in the near future. The materials currently provided by these partners are based on the following topics: biotechnology and biology from BIFI, grid computing and volunteer computing from STZAKI and nanoscience from UCAM.

IV. VIRTUAL SCIENCE HUB

Virtual Science Hub, or ViSH in short form, is a social collaborative e-Learning platform in which all GLOBAL excursion activities take place. It provides a social network where teachers and scientists can share their resources, know each other and collaborate. The other main aim of the ViSH platform is to create and share enhanced LOs taking advantage of e-Infrastructures for education, providing this way more engaging experiences to students. These new LOs, which we have called Virtual Excursions, are created using the ViSH Editor authoring tool. Fig. 1 represents the different actions that are carried out to create a Virtual Excursion.

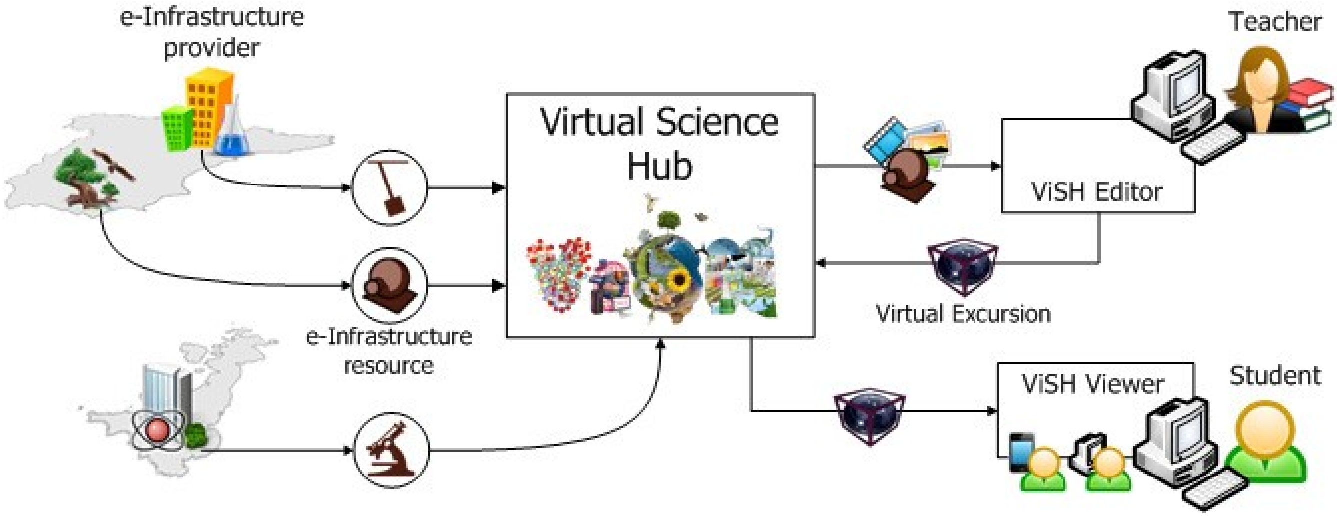

Fig. 1. Virtual Excursion generation

Besides providing the social network and the authoring tool, ViSH also provides a learning object repository (LOR) that stores both LOs and their metadata. The e-Infrastructure providers use this LOR to upload their resources. Once the e-Infrastructure resources have been stored in the LOR, they are available to be used in any Virtual Excursion. Teachers can create a Virtual Excursion online using the ViSH Editor web-based authoring tool. They can add any resource of the LOR as well as resources from external services like Flickr or YouTube to compose the excursion. When teachers finish the creation task, they can publish the excursion into the ViSH or save it as a draft for keeping it private and finishing it later. Anyway, the excursion created is stored in the ViSH LOR with the rest of the LOs. From the moment an excursion is published, it can be accessed by anyone, even without being registered in the platform. The published Virtual Excursions can also be cloned by other registered users, and of course, they can be edited or removed by their owners at any time.

To explore a Virtual Excursion users just have to load a lightweight web application called ViSH Viewer [24]. ViSH Viewer is a module of ViSH Editor used for previewing the Virtual Excursions while they are being created, but it can also work standalone. It allows users to view and interact with the Virtual Excursions (or with any other LO generated via ViSH Editor) from any device using only a web browser without any installation or previous configuration being needed. For this reason, we can also refer to the LOs generated by ViSH Editor as multi-device LOs. Using a lightweight web application is especially important for handled devices which usually have lower power processing.

ViSH has been completely designed by the project members following a participatory design process [25] whereby the user requirements were identified. It is open source and has been developed using the latest technologies on top of the social network framework Social Stream [26], which is also open source and provides common social network features such as contacts, walls, posts, comments, documents, privacy and permissions management, private and instant messaging, groups and so on.

ViSH is currently in production at http://vishub.org. It is free for end users to register, enter the community and enjoy the experience.

V. The Virtual Excursions

A. Definition

Conceptually, a Virtual Excursion is defined as a tour through some digital context by teachers and pupils on a given topic that is attractive and has an educational purpose [27]. A Virtual Excursion provides a new way to explore science in class allowing students and teachers to access and control experimental equipment of research laboratories at remote sites, explore natural parks, museums or any other infrastructure with educational or cultural interest which would be too expensive or non-viable to visit in person [24]. In practice, Virtual Excursions are created by teachers or scientific organizations using the ViSH Editor authoring tool as reusable, granular and interoperable LOs.

B. Structure

LOs can be combined among them to build more complex ones forming a hierarchy. Regarding the aggregation levels (i.e. hierarchy levels) to which a LO belongs we can differentiate between coarse-grained and fine-grained or granular LOs [28]. Thereby, granular or fine-grained LOs are those that belong to the most granular or atomic aggregation level. The LOM [7] standard contemplates four aggregation levels to describe LO granularity.

The Virtual Excursion LO is defining conforming to its own learning object model. This model defines four levels of granularity based on the LOM standard with small differences according to the scheme of Fig. 2:

- The first level, which corresponds to the most granular or atomic level, includes raw media files like text, images, videos or flash objects and single elements like a website, a document or a 3D object. More sophisticated

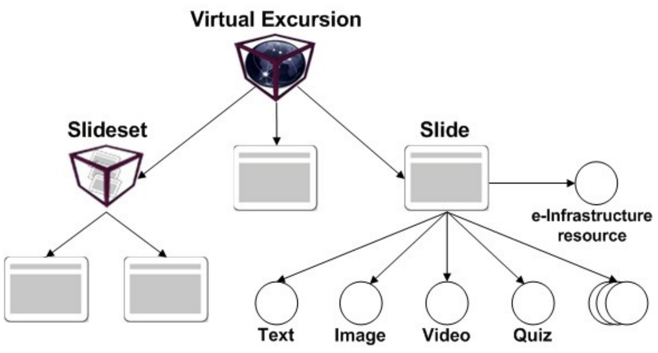

Fig. 2. Virtual Excursion aggregation levels

elements such as quizzes or e-Infrastructure resources belong to the first level too.

- The second level covers only one LO called "slide" that consists of a collection of level 1 LOs.
- The third level includes any LO that is built as a composition of level 2 LOs (i.e. "slides"). These LOs are identified under the name of "slidesets".
- Finally, the fourth level corresponds to the Virtual Excursion LO. A Virtual Excursion can contain level 3 LOs or directly a slide without using a slideset as a wrapper. Nevertheless, it cannot contain other Virtual Excursions. These are the main differences with respect to the LOM specification.

So, according to this structure, e-Infrastructure resources are fine-grained LOs. This means that they can be reused in multiple Virtual Excursions or slidesets through the slides. On the other hand, slides LOs can be used as components or building blocks of more complex LOs such as virtual experiments [29] or educational games [30].

Lastly, considering that LO metadata describes relevant characteristics of the LO to which it applies and can be used to facilitate its searching, retrieval and evaluation, Virtual Excursions are tagged with metadata based on LOM standard.

VI. ViSH Editor

ViSH Editor is a web-based e-Learning authoring tool that aims to create and edit Virtual Excursions. It is open source and the code is available at http://github.com/ging/vish_editor. Today, it is available to end users through the ViSH platform.

A. *Interface and basic features*

ViSH Editor is based on the WYSIWYG (What You See Is What You Get) paradigm. It provides a usable and user friendly web interface designed with low-tech teaching contexts (where teachers are not computer specialists and also may have poor IT support) in mind. The user interface (UI) is mainly based on graphics but also have few textual elements (Fig. 3). ViSH Editor presents the Virtual Excursion as a slideshow, on which users can add new slides and move or remove the existing ones. Each slide is created from a template selected by the user. Inside a slide users can insert different resources and/or generate their own content. All of the inserted

Fig. 3. User Interface of ViSH Editor

resources can be moved using the drag and drop technique. Furthermore, other actions can be performed over the distinct resources such as resize, zoom or hyperlink aggregation. Despite usability and user experience studies point out that ViSH Editor interface is very intuitive, a walkthrough is available for novice users to get started with the tool and learn new features. In addition, context-sensitive help is always available, providing help for the specific situation of the user. Users can preview the Virtual Excursion while they are creating it at any time. Also they can save the excursion as a draft to continue completing it later. In summary ViSH Editor assists teachers (or any other user) in the process of creating and publishing a Virtual Excursion.

B. *Resources and own content*

ViSH Editor allows users to insert many types of resources: images, videos, websites, PDF files, flash objects, etc. Any resource can be inserted via its URL. Also, ViSH Editor provides interfaces to search resources in the ViSH LOR as well as in external services like Flickr, YouTube or Vimeo.

Fig. 4 illustrates a search in the ViSH LOR. A catalogue of e-Infrastructures obtained from the ViSH LOR is also available. ViSH Editor facilitates the access and integration of these e-Infrastructures by managing the connections with live streamings and interacting with the web services and the particular interfaces of the e-Infrastructure resources. Moreover, users can upload their own resources to the ViSH. The slidesets and slides LOs of other Virtual Excursions can be also inserted. More types of resources are expected to be available to be integrated. For instance, the next coming version will have the functionality of insert and convert PowerPoint or PDF presentations in Virtual Excursions.

Besides adding resources, teachers can generate their own contents. They can insert paragraphs of text using a WYSIWYG rich text editor. Also, they can create their own quizzes to evaluate the acquired knowledge of the students. These quizzes can be inserted inside a slide as any other

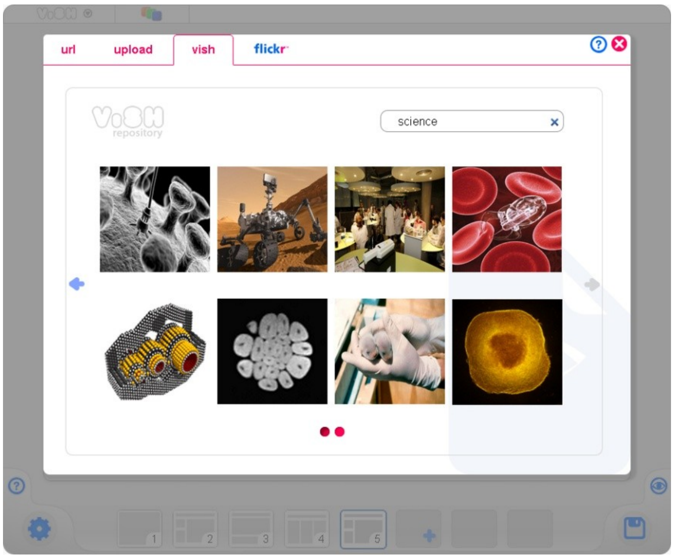

Fig. 4. Searching resources in ViSH Editor

content and hence they can be combined with any other resource. The questions can be true-false, multiple choice or open ended. Self-assessment is also possible. The results are stored and they can be accessed both in real time to be discussed in class or later to be analyzed in detail. The teacher can represent the data in many ways such as a bar graph or a pie chart.

C. *Metadata*

ViSH Editor also facilitates authors to fill the metadata of the Virtual Excursion LOs. They can indicate several metadata elements: Title, Description, Author, Language, Avatar (an image to identify the excursion visually), Tags (that act as keywords for the ViSH search engine) and others related to pedagogical qualities: Subject, Age Range, Educational Objectives and Acquired Competencies. There are other metadata elements that are inferred rather than specified by the author. For instance: metadata elements related to the structure or technical requirements, version, contributors, etc.

D. *Creating slidesets*

Besides creating Virtual Excursions, ViSH Editor can be used to generate other LOs called slidesets. These LOs are built using the slides LO as components and at the same time, they can be used to be part of an excursion as a conventional slide. Three slidesets can be created in the current version: flashcards [29], virtual tours and educational games [30].

To create a flashcard users select an image background (from ViSH LOR or Flickr, via URL or uploading it) and above it hot zones representing by arrows to link the slides. This way the slides will not have to be consumed in order but they will appear when touching or clicking on a hot zone.

Virtual tours are quite similar but instead of a static image background users can use an interactive map. They can search for any address and add locations representing by pins to which the slides will be linked.

Finally the same way the slides can be linked to hot zones in images or maps, they can be linked to actions or events in a game. A role-playing web game was developed where the teacher can link the slides to specific actions in the game, like “touch a blackboard” or “talk to some character”. When the player performs any of these actions the slides appear. This way the game is customizable with the content from the slides.

E. *Interoperability*

The Virtual Excursions and their metadata are saved in the ViSH LOR in JSON format. However, in order to increase their interoperability, they can be downloaded as SCORM. So, they can be integrated in any Learning Management System (LMS) that supports this standard (e.g. Moodle or Blackboard). This way the students will have the excursions integrated with the rest of the resources that they use for their daily learning.

Moreover, all of the LOs generated by ViSH Editor provide an API (Application Programming Interface) which allows third party web applications to communicate with them and to use advanced functionalities (e.g. event notifications, advance slides, etc). Thereby they can be integrated in any website or web application. In the ViSH scenario this API has been used to integrate the Virtual Excursions with a videoconference tool called MashMe (http://mashme.tv). This integration allows teachers to share Virtual Excursions synchronously in real time with any other users.

F. *Technology and implementation*

ViSH Editor is a web application based on HTML5 [31], the new standard for the web. For this reason, any HTML5 compliant web browser can run the web tool and hence create Virtual Excursions. ViSH Editor has been developed as a JavaScript library and a set of HTML pages and CSS (Cascading Style Sheets) files. Despite it is a client-side application, some tasks (e.g. upload files) need a server backend. However, ViSH Editor is not tied to any specific backend technology, in fact we have developed two different implementations using Ruby on Rails and Node.js.

G. *Virtual Excursion examples*

Finally, to have a better understanding of how ViSH Editor can help teachers to create enhanced LOs through the use of e-Infrastructures resources, we present in this section some examples of Virtual Excursions.

The first example (illustrated in Fig. 5) is a Virtual Excursion to learn about physics in which students have the chance of accessing and controlling remotely three different instruments of a real physics laboratory: a pendulum, a pulley and a spring. First off to create this excursion, the teacher has written some physics exercises which are formulated at the beginning. Then, he/she has searched and included the e-Infrastructure resources, which were previously uploaded to ViSH by BIFI. Lastly, the teacher has created some quizzes to collect their students’ answers. This way the students can compare their theoretical calculations with the measurements of the real systems before they answer the quizzes.

Many other Virtual Excursions have been created in the ViSH platform by teachers and scientific organizations.

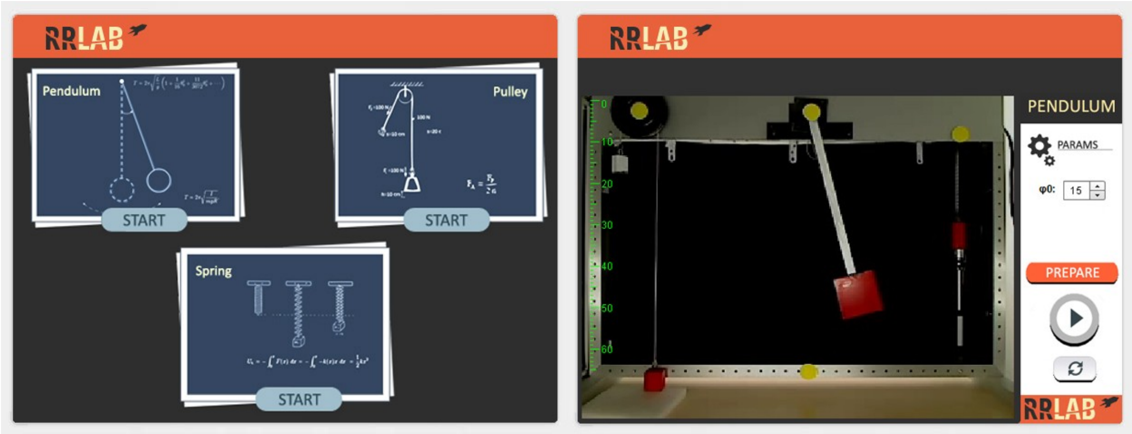

Fig. 5. Virtual Excursion of a Remote Physics Laboratory

For instance, a virtual visit to the Doñana Biological Reserve where students can observe a huge variety of animal species through live webcams.

Another interesting example is one where students can observe in real time the video output of different microscopes provided by the Nanoscience Centre of UCAM as well as receive explanations of the researcher who will be operating the microscope.

VII. Conclusions and Future Work

In this paper we have presented ViSH Editor, an innovative web-based e-Learning authoring tool to create enhanced LOs called Virtual Excursions using e-Infrastructure resources. ViSH Editor creates Virtual Excursions as reusable and granular LOs. It also provides several mechanisms to integrate them into websites, third party services and LMSs. Lastly, we have exposed some examples of how to enrich learning using Virtual Excursions.

From our experience with ViSH Editor, where we had to develop several tailored solutions to facilitate access to selected e-Infrastructures, we believe that providing a standardized way to access e-Infrastructures resources is one of the main challenges to promote the use of e-Infrastructures in education.

On the other hand, an authoring tool should be adapted to the needs of their end users to be successful. So, if the end user is a teacher, who does not have to be a computer specialist, the authoring tool must provide a simple, intuitive and user friendly interface including context-sensitive help and optional walkthroughs.

Authoring tools can play an important role in modern e-Learning platforms creating and maintaining didactic contents. In collaborative environments, the reusability of these contents is the cornerstone. Thereby these contents should be created following a learning object model that defines appropriately the granularity levels, the structure and the metadata. Moreover, several efforts should be undertaken to achieve interoperability, especially with LMSs by using e-Learning standards.

The Virtual Excursions created via ViSH Editor are a great example of how technology can enhance learning, but there are some future works that can be performed to bring new contributions in order to keep improving.

First off, based on our experiences, we plan to define a standard for e-Infrastructure access and develop and test it in real cases. Also, we want to define a model to integrate the existing learning objects into games, building a bridge between game developers and teachers. Finally we will carry out an evaluation of the use of the Virtual Excursions in the classroom to measure their educational impact.

Acknowledgment

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Scaffolding online laboratory experiences as inclusive and motivational tools for students and teachers

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Abstract— **The ability for accessing learning tools at any time and from anywhere is highly increasing. Technologies such as Internet and mobile devices provide universal integration of teaching and learning. For scientific or engineering subjects, the use of real resources through on line laboratories is another step towards bringing the students to the practical laboratory sessions. These platforms show how teacher and student share a common work space in which they work together to solve problems. UNED (Spanish University for Distance Education) is working on the development of techniques that facilitate the building of remote laboratories and their access, both for students and for teachers. Current experience shows that the interaction of the students with these tools makes them more receptive to learning, regardless of their age. It also helps them to understand more easily abstract concepts in engineering and science subjects, associating these abstract concepts with daily life. It is also relevant that students can commit mistakes without any real risk. Moreover as the system will facilitate the building of customized reusable laboratory practices for teachers, these will be motivated to use them in their classrooms whenever possible. Both effects reinforce learning and reaffirm the position of teacher-student couple.**

Keywords—eLearning; remote laboratories; modular tool; practice; distributed learning; reusability; distance education

I. INTRODUCTION

The ability for accessing learning tools at any time and from anywhere is highly increasing. Technologies such as Internet and mobile devices provide universal integration of teaching and learning. For scientific or engineering subjects, the use of real resources through online laboratories is another step towards bringing the students to the practical laboratory sessions, [1]. These platforms show how teacher and student share a common work space in which they work together to solve problems. UNED (Spanish University for Distance Education) is working on the development of techniques that facilitate the building of remote laboratories and their access, both for students and for teacher.

The development requires establishing a learning environment based on modular scaffolding tools. The objective is grouping those elements needed to build the experiments and the laboratory activities, by using modular tools, making easy their use in a simple and intuitive way. Experience from existing projects on other fields has been used and has been merged with collaborative and tracking features, [2]. These features, offered by social networks and learning analytics on learning environments, together with the development of an API, have led to the definition of a new concept of work space and on-line distributed experiences.

This work space is oriented to learning and it covers the whole experiences of teaching-learning in real laboratories. By using it, the teacher can design and implement a great variety of experiments using the provided devices. The system allows the use of specially designed widgets (basic blocks) and technical documentation that exists, into a multidisciplinary network of laboratories. The student accesses the system from a fixed or mobile terminal; using a standard mobile Internet browser; safely and at any time, from anywhere, with any others resources, because tools needed are on server side.

This modular development allows the teacher to include new blocks in the system. These new blocks can be reused by other teachers for other activities, optimizing and increasing the original utility (open life cycle) into the system. The system uses the philosophy of reusable learning objects but taking it to the field of development of remote laboratories packaging [3].

The system has a laboratory structure based on the students' age; each teacher can select the optimal laboratory configuration that best suits his/her needs at any time. Free software tools have been used when possible through the entire project.

The opinions of learning professionals and students have been taken into account for designing user interfaces and developing API utilities and the packaging system of laboratories. Current experience shows that the interaction of the students with these tools make them more receptive to learning, regardless of their age. It also helps them to understand more easily abstract concepts in engineering and science subjects, associating these abstract concepts with daily life.

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It is also relevant that students can commit mistakes without any real risk. Moreover as the system will facilitate the building of customized reusable laboratory practices for teachers, these will be motivated to use them in their classrooms whenever possible. Both effects reinforce learning and reaffirm the position of teacher-student couple.

The rest of the paper is organized as follows: section II shows the previous experience on UNED working on distance learning, section III shows how this experience put the basis to design tools to improve distance learning, section IV describes the use of a couple of examples and the importance of both sides, teachers and students, section V show the importance of the feedback cycle among modularity, reuse and generalization of this tool. And finally section VI explains the importance of this path to improve the existed tools and to motivate to teacher and student along the educational and training process.

II. Previous Experience as a Basis

During the last 40 years the UNED (Spanish University for Distance Education) has shown that distance learning is possible and greatly enriches traditional teaching. UNED has been using the typical traditional classroom learning tools and combined with other specific tools for distance learning. The objective has always been to bring closer theory to practice for students, [4].

At the same time, and given the importance of university education as social engine for business, economic and as point of integration, UNED has always tried to bring students to the appropriate level for their access to the labour market as fast and skilled as possible, [5], especially in certain areas such as engineering, [6].

Such experiences have focused not only in university, but have gone further, engaging in activities to promote, into pre-university environments, the interest about engineering among students and teachers in primary and secondary schools, [7], making spreading a fundamental tool in the education system.

During that time UNED has accumulated experiences, both on the student and the teacher side, to improve these tools. Today, after several decades of online technologies, the accumulated knowledge is being integrated into a system to standardize all the knowledge and make the most for education, both on the side of the teacher and the student's side. Several stages, analysed below, have been followed to reach this point.

A. Detection of needs of students and teachers

Firstly, the teachers need a working environment that allows continuous tracking of the progress of their students. This involves establishing a user management system to identify each of the students uniquely and let store all their information while they use the available educational tools. Learning analytics is key at this stage, [8].

In addition there should be a similar tool that allows monitor progress of teachers. For this, a similar system to that of the students must allow to know, in each case, which student group is assigned to a specific teacher and what is the teacher's progress in class, face to face and/or virtual classes.

Finally an adequate space where students and teachers could plan their sessions must be implemented. In this space the teacher can establish the proper scheduling of practice, theory and tutoring hours. In the case of students, to keep track of the lessons to study, practices to comply or exams to be performed. If this space is structured taking into account the needs of students and relying on their ability to engage in the process, [9], their motivation to study will increase and they will become an essential gear of the system, even in pre-university ages, in support of their teachers.

It is also important to take into account the management and evaluation of the rating of students and teachers, which will allow detecting system failure to proceed to correct them.

B. Review of current systems based on the needs

Once the needs are established it is necessary to review the current system. In the case of UNED, the current system meets most of the requirements mentioned in the previous section, except that in some cases the different systems that manage those needs are spread across the network and information technology that is currently used.

Nowadays, the possibility of using wireless systems for connecting laboratories and the practice experiments, [10], or the existence of mobile devices with the widespread use of the Internet, [11], has allowed that engineering in particular, and by extension other disciplines, use all the resources at their disposal to improve their formation paths, [12].

That situation obliges teachers and students to access different parts of the system to test different things. In some cases that is not a problem, but in all cases obliged to take the time that otherwise could be used in other activities: improvement of material, more attention to the tutorials or just to organize the university classes daily.

C. Finding a unified solution

It is at that point where it feels the need of finding and implementing a unified solution. A solution that will be useful for both the teacher and the student and, at the same time, will be sufficiently widespread to be used in the largest number of subjects and courses, and specific enough to be useful. UNED and specifically DIEEC (Department of Industrial Electrical Electronics and Control Engineering) is working currently in this kind of solution.

III. Setting the Right Environment

Since the value of the system aims to promote distance education as an integration tool, Internet is a key tool. For this DIEEC into UNED has developed a portal which encompasses several of the tools to be used, by students and teachers in the day-to-day teaching of engineering disciplines, because only through practice, [13], you can get to know in depth the importance of this discipline in the real world.

Figure 1 shows the gateway quoted. It has a self-explanatory structure and lists the various sections in function of the characteristics of each of them: Virtual and Remote Laboratories, Learning Management Systems, Mobile

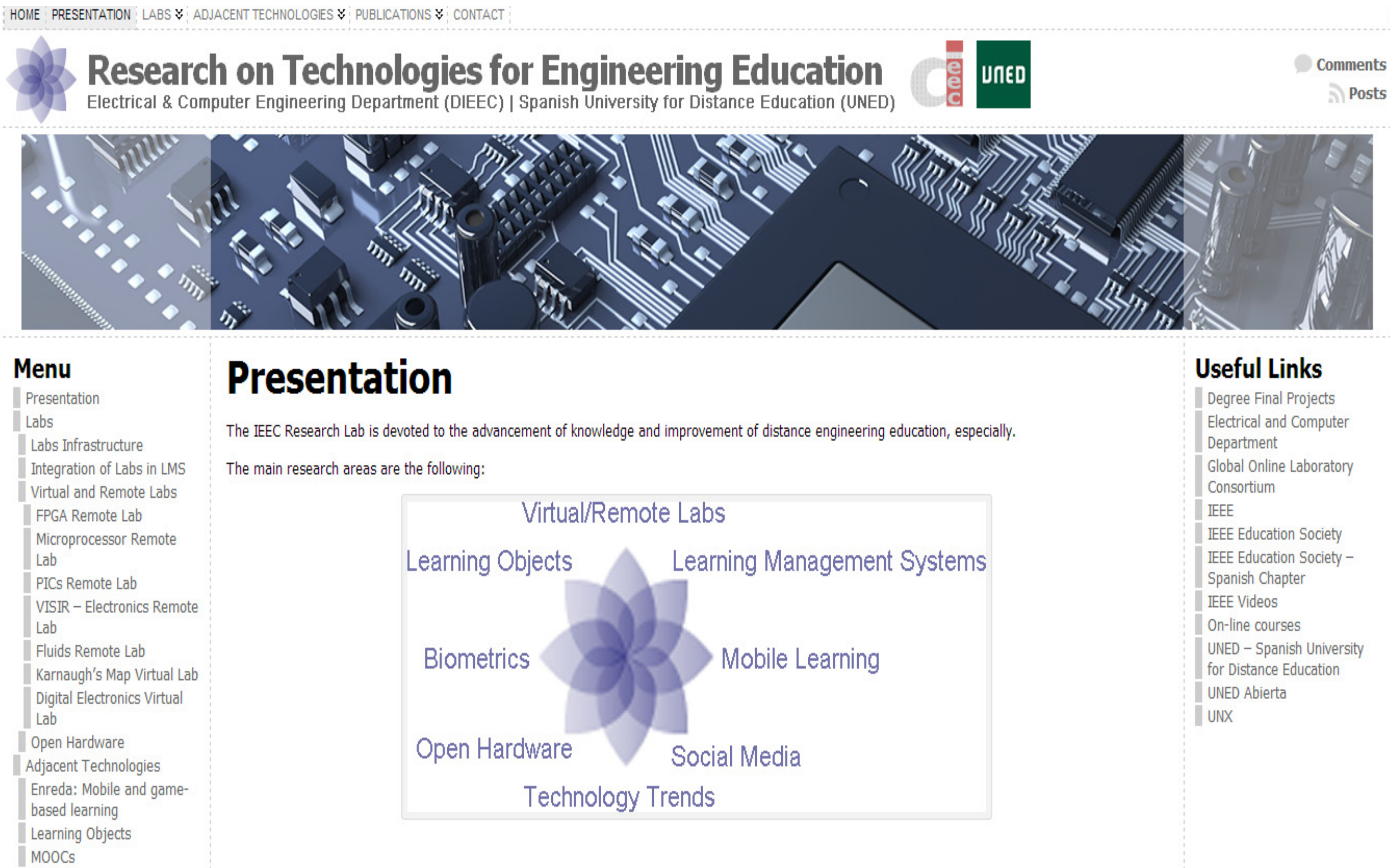

Fig. 1 Main page of the portal (source: http://ohm.ieec.uned.es/portal/)

Learning, Learning Objects, etc. Each of these sections has its own web tour.

This paper focus a little more on the section of remote and virtual laboratories, to show the performance of the system and practical applications for the learning and teaching processes.

The above environment should be useful for both teachers and learners. The different approaches must be properly integrated to get things working properly and maximize its use. In that sense must at least meet the following requirements:

1) For teachers

It is needed that this environment complements the classes, strengthen the theory and serve to demonstrate real-time performance of the technology used. Following these point, the system must be:

a) Ease of Use: For its use does not cause loss of time in class and the teacher does not need to spend too much time learning how to use it.

b) Interactive: To fulfil the characteristics solving exercises in real time. Also the system must be able to demonstrate that different changes in the data or initial hypotheses cause different output behaviour in the system.

c) Visually attractive: With a friendly interface for faster data input or load.

d) Reliable: Reducing the number of malfunctions to avoid wasting time during class.

e) Decisive: Given a load or input, the system should always have an immediate exit, and if loops appear it should indicate it to not get hung up indefinitely. There is nothing more annoying than waiting for a result that never comes out.

2) For students

It is necessary for the students to access the system to check by themselves how it works. Therefore, the system must be:

a) Consistent with what is taught in class: Since the system is understood as a practical continuation of the class.

b) Available 24 hours 7 days a week: Given the profile of the students of UNED, the possibility of practices at any time of day and any day of the week is essential and is the basic nature of distance learning.

c) Intuitive and easy to use: As in the case of a teacher, the students want to test what they have learned, and do not want to spend hours learning to use a system with a complex interface. The system should be a tool, not the long process of acquisition of a skill. For this purpouse every laboratory has a video, linked into the website refered on Figure 1, showing how must be used.

d) Clear error handling: For the use of the system may be the student has not got a teacher available all time, for that reason, the system itself must have a clear and defined error handling. Error messages can not be ambiguous, they must be concrete: "You must load the file", "Connection to the system has lost", "You are in wait queue", etc. Wide enough explanatory messages will avoid the stress caused to the student and it will allowd to use their time more productively.

With the above requirements as basic, the system can get going with some assurance and relief that it will be useful for both the student and the teacher.

Following the exposed above, the scaffolding is sustained by:

a) theory on class, presentation of the laboratory's website,

Covering these objectives the laboratories would be ready to use and to offer to the students and teachers for their training.

IV. From Theory to Practice

While there is still much work ahead, several tools developed using the philosophy described above can currently be used. Figure 2 shows the main screen of a virtual laboratory.

1) Case I: Digital Electronics Virtual Lab

The role of the laboratory is to demonstrate the operation of a virtual digital electronics system.

The lab shows the symbolic structure of its different logic gates with its various NAND, XOR, etc., and under quoted structure shows also its virtual operation use modifying the inputs and showing the relevant outputs based on the progress of a virtual clock that runs it.

The clock pulses are marking the advance of output graphics. Finally, the outline of a state automaton ends by

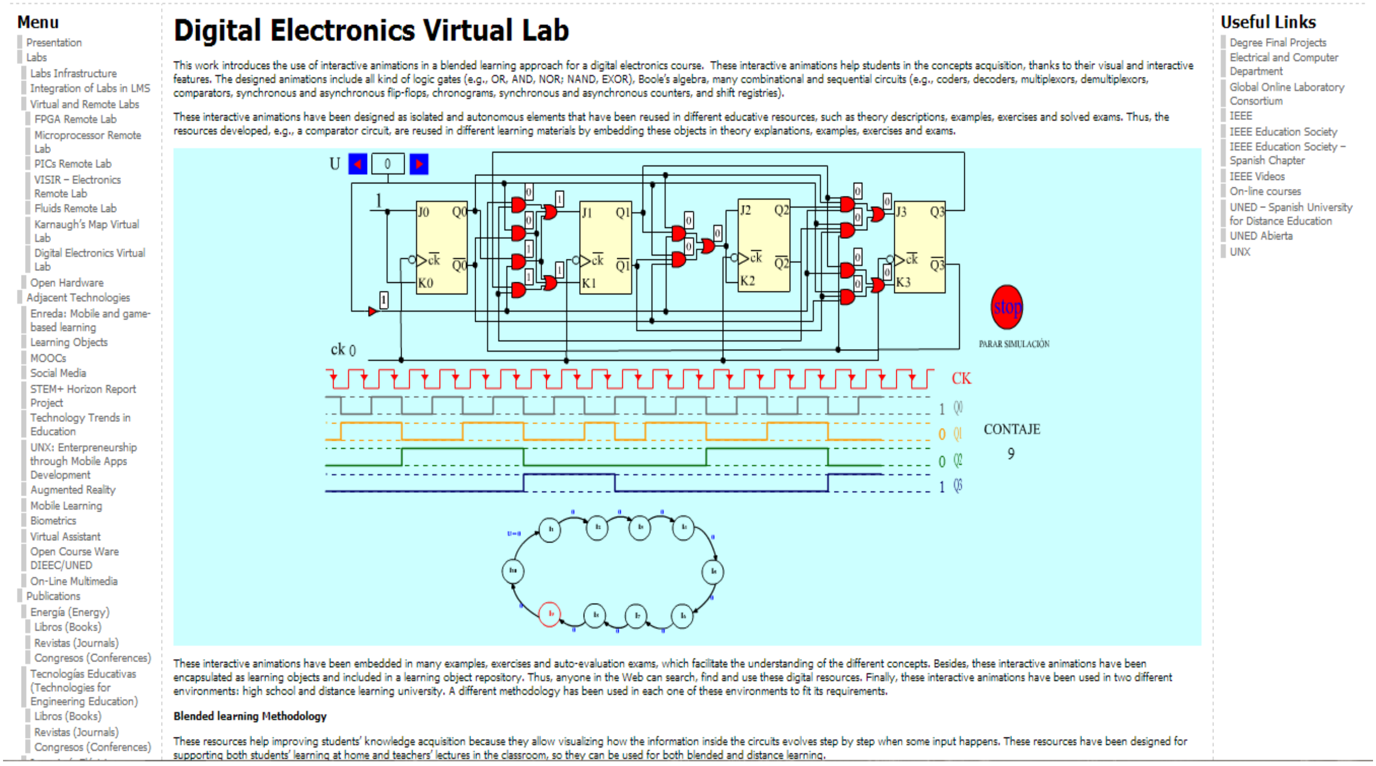

Fig. 2 Virtual remote lab example (source: http://ohm.ieec.uned.es/portal/)

b) students learn to use use of the different laboratories following the instructions into the website,

c) students give a feedback of the use of the laboratories preparing an academic work using it,

d) teacher and students discuss about the experience and the works prepared.

complete explanation of the system.

The usefulness of the system is clear. After a theoretical lesson about different types of logic gates, microprocessors, etc., some notes on state automata, and the importance of clock cycles, access to this virtual laboratory completes the class.

2) Case II: PICs Remote Lab

The second scenario is a real and not virtual laboratory. In this case, as shown in Figure 3, there is a physical place that is a board with PICs that is always available to students and the teacher. Access to it is managed through queues, and access to the board itself is performed through a simple user interface that allows students to upload the source code to be loaded into the test board.

The process is managed through advance reservation by the student that has entitled to use it for slots of about 45 minutes. As the availability is 7 days a week and 24 hours a day, the students can easily plan their study schedule.

Moreover, the teacher can use the same tool to teach a virtual class using a live practice without having to be physically in the laboratory.

The possibility of unlimited access during and outside of the regular academic hours, the intuitive use, the access from mobile devices and the availability of test exercises from the first moment, provokes that the students feel motivated to use the tool and get used to see it as an ideal complement to the study sessions of theory.

The students that have used the laboratories since the open of the project on 2012, are studying, every year, Industrial Engineering at UNED. The laboratories are being used on three subjects: *Microprocessors & Microcontrollers, Advanced Digitals Systems & Microprocessors*, and *Advanced Electronics Systems*. Using the feedback, about 80% of them think that laboratories were useful to understand the theory learned, and 60% showed interest; after use the laboratories; on depth into the subject; more than academic needs required to pass the subject.

Fig. 3 Real remote lab example (source: http://ohm.ieec.uned.es/portal/?page_id=100)

The advantage of the system in both cases is that both, theory and practice, are accessible from the same web portal. By accessing each laboratory, the student can see an explaining video showing how to use the available tools and doing a journey through the repository of available tools for the student. One of these tools is the access to the theory and several solved exercises and ready to use.

This facilitates the teacher the organization and delivery of its class, and the student the theory, query and planning the study hours.

The ease of use, the possibility of planning, the option to have a class always available on line, makes the teacher feels motivated to use this new educational tool and find widespread use in all disciplines who teaches and where possible fit it.

V. Modularity, Generalization and Reuse

The tools described previously are tools that UNED is currently using in their daily classes. The next goal is to turn this system into something more powerful, capable of spreading to other disciplines and not just engineering and more widespread among teachers. Figure 4 provides cycle relationship between these three factors. It is so interesting to analyse the possibilities of this system.

A. Modularity

Nowadays, and respecting the previous design, the system allows creating new spaces within the main portal site to gradually increase the number of existing laboratories. While this gives certain modularity, the system must be clearly improved and efforts are conducting in that line.

The most relevant aspect will be to design laboratories according to the age of students whom it may concern, their previous training and future training needs. However once a laboratory is created, it is always easier to adapt it to playing with different educational levels and simplifying content if necessary.

That's one of the keys to the modularity and scalability of a system, [14], and it allows its use becomes widespread as quickly as possible.

The design of predefined templates to help teachers with the creation of new spaces into web portal or the integration of new laboratories are priorities reflected in investment in research that the UNED has been done in this direction through national and international projects.

B. *Generalization*

At this point the key is to facilitate the use of the system for first time by the teachers. Once they see its usefulness, it is clear that the generalization step will be much easier and faster. While there may be some initial reluctance, especially by those teachers who may have less contact with IT, these will be outweighed by the benefits that eventually brings the system for lesson planning in general and particular practices.

C. *Reuse*

Actually this is the easy part if you get the other two. The more teachers to use the system, more modules will be prepared and will be generalized use.

This will facilitate the reuse of existing modules and in turn attract new teachers who want to use the system in their classes. Only when they start to reuse the education modules and start sharing tools, [15], it will can speak of a true generalization of the system.

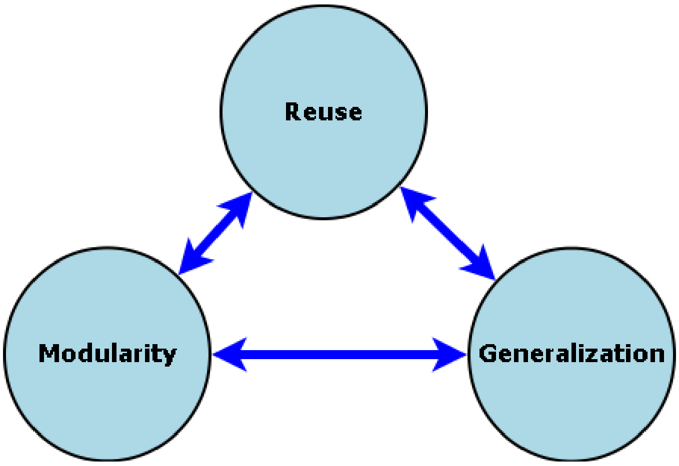

Fig. 4 Feedback cycle

As Figure 4 shows, the system is fed by the feedback provided for use by teachers.

On the other hand the use by students also increase more demand of this system on teachers improves its quality, [16]. Once again this shows the important relationship between students and teachers in sharing learning tools.

It is important to emphasise that the two points of view are necessary to improve the system. On one hand the growing experience of the teaching staff in using the IT as educational tools allows to correct errors (many of them based on an overly technical system) by detecting errors in use every day, or incorporation of new tools with suggestions from teachers.

From the point of view of the student, Learning Analytics technologies allow the system to discern which tools are used, and which are more problematic for students. At the same way just as the existence of a feedback with the student and suggestions provided by them will further enhance the knowledge of the actual use of the system. With that information is much easier to improve the system to continue to promote its use among the educational community.

VI. Conclusions

The extensive training experience in distance education techniques treasured by the UNED has been designed the development of new technologies that facilitate the learning process both for teachers and for students.

UNED has developed systems in recent years following these ideas, to ensure modularity for future generalization. Several of these efforts have been made in engineering courses and specifically on remote electronics laboratories. This work has shown several of them, the feedback from students about its use, and their importance for both students and teachers.

With experience in the use of these tools has been concluded that the time, independence, improved planning, universal access through mobile and fixed devices, and its use as a supplement to the class received theory, promotes integration of the educational path.

At the same time, our experience has led to increase the motivation on the teachers, who have seen facilitated their teaching and have been able to practice classes without physical access to a laboratory. Also for students, who have been able to use laboratory tools from their own homes without incurring on material costs, or displacement, or potential risks of electrical installation, and increasing their motivational feelings about the subject to learn.

While there is still much work to do, at the moment and given the success of the system, it is already working on the generalization, not only among engineering courses, but also among many other disciplines.

At the same time it is looking for the possibility of increasing the existing laboratory modules. UNED is expecting that students, who have already used the existing ones, contribute with their suggestions or even create new modules and designs through their final year projects.

Finally, it exists also a spread collaboration with other institutions nationally and internationally to reuse existing laboratories.

All these actions encourage UNED to continue working on improving these systems and continue to demonstrate that teaching is a two-path-address: teachers and students, and only by the integration of their needs, a successful learning path can be achieved.

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Online Engineering Course Design, Part I:

Toward Asynchronous, Web-based Delivery of a First Course in Thermodynamics

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***Abstract*— As part one in a series of two, this paper describes the development of a web-based [1] first course in thermodynamics. The course is conceptualized, designed and course materials are introduced to engineering students by a team of practitioner – researchers. The course builds from previous work concerning the development of web-based thermodynamic cycle teaching modules for undergraduate mechanical engineering students [2] and relevant educational literature. The design goals for the online course are that it a) be delivered primarily through asynchronous means and b) fulfill requirements of ABET accredited degree programs in civil, electrical and mechanical engineering as is accomplished by the current face-to-face course.**

The course design team, consisting of engineering faculty, administrators, and instructional design professionals, used a collaborative approach to move the online course through concept, development to initial introduction. As constructed, example segments ("exemplar modules") were introduced within the current face-to face Thermodynamics I course to witness student reactions and solicit feedback. Once this feedback is filtered back and addressed in the design, the course will be implemented and evaluated in whole within the civil, electrical and mechanical undergraduate engineering programs. The full implementation, evaluation and results will be the focus of a part two paper.

Keywords—online engineering education, asynchronous delivery, constructivism

I. Introduction

As Porter [3] suggests, the idea of *tradition* within mainstream education - as in the "traditional" way of learning or the "traditional classroom"- is changing rapidly. The practice of an established time and location where learning occurs continues to be challenged. The requirement for an immovable, physical classroom is steadily giving way to an acceptance of virtual meeting spaces where learners engage with course materials and each other through electronic communication and Internet-based technology. With this evolution, online learning is forming a basis of its own educational paradigm.

Despite an acknowledged need to produce more engineering professionals in this country, engineering education in the United States has been slow to embrace online learning. As noted in [4], most of the available online engineering degree programs exist only at the master's and certificate levels. Significantly more limited online options are available at the pre-engineering (associate degree) and bachelor's degree levels. Increased fiscal pressure on our nation's colleges and universities, combined with never before seen challenges of educating the "net generation" [5], underscores the imperative for engineering educators and administrators to jointly agree that the online waters are fine and it is time to venture in.

Yet, teaching with technology is hazardous duty [5]. To be successful, online educators must approach curricular design with equal parts caution and insight. Insight does not come for free; rather it comes at the expense of experience. Thus, to make web-based engineering education a viable reality, we believe that there is a strong need for more examples of its implementation, including both the successes and failures, to be published within the literature [5]. This effort, in turn, will require more support, training and resources for these faculty who often have to "…relearn how to teach in a new [online] environment…" as they redesign their courses into something akin to a "computer product" [6].

In undertaking this two part paper series, our goal is to describe and document one attempt at developing, implementing (part I) and evaluating (part II) a fully asynchronous and online introductory course in thermodynamics. In this manner, we hope to help build a knowledge base in this area within the engineering educational literature. At our institution, Thermodynamics I is a required, sophomore level course for undergraduate students pursuing bachelor's degrees in mechanical engineering and an elective for students in civil and electrical engineering. The course has a single co-requisite of enrollment in the multivariable calculus course. As one of the first courses in our undergraduate engineering curriculum to undergo this sort of extensive redesign, we reflect on our process and outcomes with the hope developing useful insight for others involved in similar ventures.

II. Building on Prior Work

Previous work [2] describes the development and pilot testing of a one credit hour multimedia course covering the final third of a traditional introductory thermodynamics course. The complete multimedia course included eight modules, each consisting of approximately thirty pages, covering a variety of thermodynamic cycles. Audio, text, graphics and animations were used to create the modules, which were delivered in CD-ROM format or over the Internet.

Seventy-one students participated in an independent learning exercise by learning the Rankine Cycle using one of the modules delivered over the Internet. Results showed that these students performed as well on a single final examination question as students in a previous semester who were exposed to the material delivered in a traditional lecture format. The authors [2] further described that three students, who had successfully completed the entire one credit hour course, performed well on the same final examination given to students in the traditional lecture-based class. A survey of all students showed that they preferred the traditional lecture format. Students felt that attending lectures forced them to learn the material at a reasonable pace. They were fearful they would procrastinate if required to learn the material on their own over the Internet.

Prior work [2] influenced the current work in a few important ways. First, the results provided us indication that, while students may prefer traditional learning environments, they can effectively learn thermodynamics concepts and problem solving skills via online course materials. Second, student preference for traditional learning environments prompted us to consider student affective outcomes, in addition to performance outcomes, during the design and assessment of the online course. Finally, the cycle animations and online content constructed under the previous work were revised and implemented within the current work.

III. Online Course Development as Group Process

Teaching is a complex, time consuming and risky endeavor. Instructors in higher education may take years, or even careers, to develop their subject matter expertise and refine their courses [6]. Engineering instructors assigned to the development of a required course, such as Thermodynamics I, often work in conjunction with a program's ABET committee to insure the content aligns with appropriate Student Outcomes criteria [7]. (Formerly called the Accreditation Board for Engineering and Technology, ABET changed its name in 2005 [8].) Anecdotally speaking, however, engineering instructors typically enjoy full freedom, and bear full responsibility, for defining *how* teaching will occur with little oversight from administration. In this way, the ideal of curriculum as "group process" [9] is infrequently realized throughout the entirety of engineering curriculum design.

The prospect of redesigning a proven, traditionally taught course into a web-based version of itself can be a great source of anxiety for post-secondary instructors. Current expectations of online course design has eclipsed those of the days when simply porting course materials to website was adequate. Online instruction today involves teaching the "what" of traditional courses in a whole new way to a different generation of student. Meeting these new expectations requires not only subject matter expertise, but also knowledge of pedagogy, learning theory and technology implementation. As discussed in [6, 10], teachers tend to teach in the ways they were taught. Since most post-secondary teachers employed today have never experienced online instruction, they are faced with designing a complex, interactive "computer product" with which they have no relevant experience.

In light of these concerns, we chose to adopt a collaborative team approach, taking care to include principle stakeholders of the curriculum design outcome. Teaming enabled collaboration between key instructional, technology and administrative stakeholders of the course: engineering faculty experienced in teaching undergraduate thermodynamics, instructional design and technology professionals responsible for online course delivery within the distance education branch of the university, and administrators responsible for the delivery of the pre-professional undergraduate engineering curriculum. Student stakeholders were also given voice in the process: Students enrolled in the current Thermodynamics I course worked with exemplar modules and provided feedback that was subsequently woven back into the online course design. In this manner, the online course was built from the inside out, insuring that learner, instructor, administration, and technology infrastructure requirements were jointly and continuously addressed by the course design.

A. *Engineering Faculty Collaboration*

Two faculty members in the College of Engineering, one an instructor in the distance delivered pre-professional engineering program and one a full professor and Senior Associate Dean within the engineering college, took responsibility for selecting and sequencing course content, developing learning activities and assessments, and developing the website for the course. Each had several years of experience teaching Thermodynamics I within the college; both were teaching Thermodynamics I during the 2012-2013 academic year. One brought recent experience teaching with technology as distance education faculty. The second brought subject matter expertise, having taught Thermodynamics I over many years at multiple institutions and worked professionally in areas directly related to thermodynamics. Her experiences developing web-based modules for teaching thermodynamic cycles to undergraduates [2] proved beneficial and insightful.

B. Instructional Designer Collaboration and Support

As an integral member of the design team, a senior instructional designer from our institution's Center for Innovative Design and Instruction (CIDI) provided ongoing support of the course design and implementation. Support involved direct assistance with the technical implementation of the course, including integration of external tools, creation and refinement of simulation content, and help with user-interface design. Working daily with the design, development, and maintenance of online courses, he was able to provide guidance on best practices in online teaching, the feasibility of development timelines, and possible solutions to challenges.

C. Administrative Support

Administrative participation must expand from traditional support roles in order to accommodate a successful online teaching and learning environment [11]. Administration must exhibit strong commitment to web-based curriculum by providing adequate infrastructure, planning, resources, time and training to promote faculty to not only to participate in online course design but also to embrace an online pedagogy.

As part of our collaborative development approach, the Associate Dean for Undergraduate Affairs within the College of Engineering also played an important role in the development of the online thermodynamics course. Having primary responsibility for the operation of the pre-professional engineering program, he brought to the team not only knowledge of curricular requirements, but also insight, based on data driven assessment of the current engineering curriculum, into the areas wherein the course could be improved so as to better meet the needs of the students. His presence and active participation on the development team helped to highlight a serious commitment within the college of engineering to developing and deploying innovative and effective online instruction.

D. Student Feedback

During the primary development phase, two online "exemplar" modules and updated cycle animations from prior work [2] were introduced to engineering students enrolled in the Spring 2013 face-to-face Thermodynamics I course as additional (non required) learning material. This preliminary data, gathered from the learning management system (LMS) as students worked with the online modules, suggested that students were actively accessing the online material primarily at critical junctions in the course. There was moderate activity during regular intervals until a homework assignment is due, at which time participation increases. The activity is substantially increased prior to a major exam.

While this usage pattern is considered, at least in part, a result of piecemeal introduction of the online modules to students enrolled in a traditionally taught course (the students have not enrolled in an online class), the preliminary data leads us to ask and consider additional questions concerning the student experience within the online material: How do the students use the information? How much time is spent on each activity? Why do some students access the information often and others do not? Currently, we are working with CIDI professionals to develop methods to access LMS data to answer these questions. Preliminary data also suggest that online course performance should not be evaluated solely on student academic achievement while in the course, but rather online student assessment should account for their preparedness for participating in online course (i.e. student readiness for learning in an asynchronous, web-based environment). The latter approach may provide a more meaningful assessment of the online materials.

In order to get more direct feedback on student opinion of these online materials introduced during the semester, an end of course survey was assigned to the Spring 2013 Thermodynamics I students by the instructor. The survey consisted of both Likert scale and open-ended questions and was conducted within the course LMS. Survey questions queried student impressions of the learning effectiveness and ease of use of the online material. The overall survey response rate was 74% (113/152) as reported by the LMS. Students completing the survey received full credit for the assignment.

What we saw in the student responses was significant by-in, not only to the approach we took to designing our online web-site, learning environment and materials, but also to the very notion of learning thermodynamic in a web-based environment. Almost half (48%) of the respondents reported that they used the supplemental (i.e. not required) online materials about or more than half of the time. Significant groups of students responded that the Piazza online learning forum (37%) and the cycle simulations (52%) were beneficial to them as learning tools. A large number of students (77%) either agreed or strongly agreed that they were able to understand and follow the online materials. Moreover, 72% either agreed or strongly agreed that the advantages of the online components outweighed the disadvantages.

IV. THE INFLUENCE OF CONSTRUCTIVISM

Online course design is neither necessarily behaviorist nor constructivist. The choice of pedagogical approach is entirely in the hands of the curriculum developers. Porter [3] notes that a blending or balance of behaviorist and constructivist approaches is most often seen in online courses. Based on personal philosophies about learning and previous experience in web-enhanced classrooms, the design of this course was heavily influenced by constructivist learning theory and Chickering and Gamson's "Seven Principles" for teaching in undergraduate education [12, 13].

A. Constructivism: A Learning Theory

Constructivism is a theory of learning and not an approach to teaching or instructional practice [14]. While this idea is often heard, it is an important one to reiterate because it helps to focus attention on how people learn instead of on how people teach. Recognizing this distinction is critically important when designing an online course, since the role of the educator changes drastically in online instruction away from the traditional instructor archetype. Instead of teaching in an online course, instructors become coaches, mentors and facilitators of the curriculum [15]. As a learning theory, constructivism can influence the design of student activities, experiences and assessments and thus can inform a learner-centered approach to teaching [3].

Constructivism stands distinct from the more traditional learning theories of behaviorism and maturationism [16]. Instead of behaviors or skills, concept development and deep understanding are the primary objectives; stages are viewed not as developmental but rather as a result of active reorganization of knowledge on the part of the learner [16]. The constructivist paradigm is fundamentally non-positivist and requires that we relinquish the idea that the world exists in a singular, "immutable" or unchanging fashion. While there is no "…pat set of instructional techniques that can be abstracted from the theory and proposed as a constructivist approach to teaching" [16], Fosnot describes some general constructivist principles that informed our educational strategies:

- Learning is development, not the result of development
- "Disequilibrium" facilitates learning
- Challenging investigations in realistic settings should be offered to allow the learner to explore and generate possibilities
- Reflective abstraction is the driving force of learning
- Dialogue within a community engenders further thinking
- Learning proceeds to the development of cognitive structures

In carefully studying these principles, one can easily discern some common themes. First, learning is a time dependent process requiring adequate practice. Learning activities should present significant learning challenges, yet allow enough time so that each learner can go through a process of mistake-making and "disequilibrium" until knowledge restructuring, or the adaptation of current knowledge to new knowledge, occurs.

Second, learning is an active process requiring not only sufficient time, but also sufficient time on task. Learners must actively explore content and create their own knowledge connections in order to achieve deep understanding. Learning activities are most beneficial when they are authentic and realistic.

Third, learner reflection is key to understanding. Learners should be encouraged to think about their thinking and build their metacognitive skills. In addition, learners should reflect on what they have learned in relation to what they currently know in order to make connections and resolve cognitive disequilibrium.

Finally, learning is a social endeavor. Interaction within a community of learners generates new knowledge and deepens understanding. Interaction includes feedback from the instructor as well as discussion and group problem solving with peers. Engagement within a learning community feeds learner extrinsic motivation and supports diverse ways of learning.

It is informative to recognize the congruencies between these general constructivist principles and the "seven principles for good practice in undergraduate education" proposed by Chickering and Gamson [12]. According to these widely accepted principles, good practice:

1. Encourages contact between students and faculty
2. Develops reciprocity and cooperation among students
3. Encourages active learning
4. Gives prompt feedback
5. Emphasizes time on task
6. Communicates high expectations
7. Respects diverse talents and ways of learning

Thus, the constructivist principles for learning can be seen as underpinning these widely accepted principles for good teaching practice. Additionally, as is found in [13], use of Internet technologies and electronic communication tools readily help to promote these good teaching practices defined by Chickering and Gamson [12].

B. *Benefit of Constructivism to Online Course Design*

Perhaps one of the most important benefits of adopting a constructivist framework in online course design is that it helps focus attention on an issue labeled as one of the most critical to the success of online course instruction [4, 6, 17]: the establishment of a learning community in an environment where instructors and students will, most likely, never meet in person. As Garrison and Cleveland-Innes [18] discuss, student interaction is commonly accepted to be a critical component within any learning process and, thus, has been an important topic for early research within online education. The promise of always newer, faster, easier communication technologies resulted in an early focus on the connection and participation of learners, or social presence, within virtual learning environments.

Recent research [18-20] suggests that social interaction, by itself, is not enough to promote deep and meaningful learning. New studies discuss that one of the critical requirements for building strong virtual learning communities, in addition to social presence, is *teaching presence*. Teaching presence [18] includes actions taken by the instructor to a) design and organize the course in order to set clear expectations, appropriate learning activities and congruent assessment, b) facilitate student-centered discussion that is guided yet not dominated by the instructor, and c) provide direction instruction only at the appropriate moments. Thus, we see the application of a constructivist framework as a means to facilitate the development of a strong sense of teaching presence within our online course.

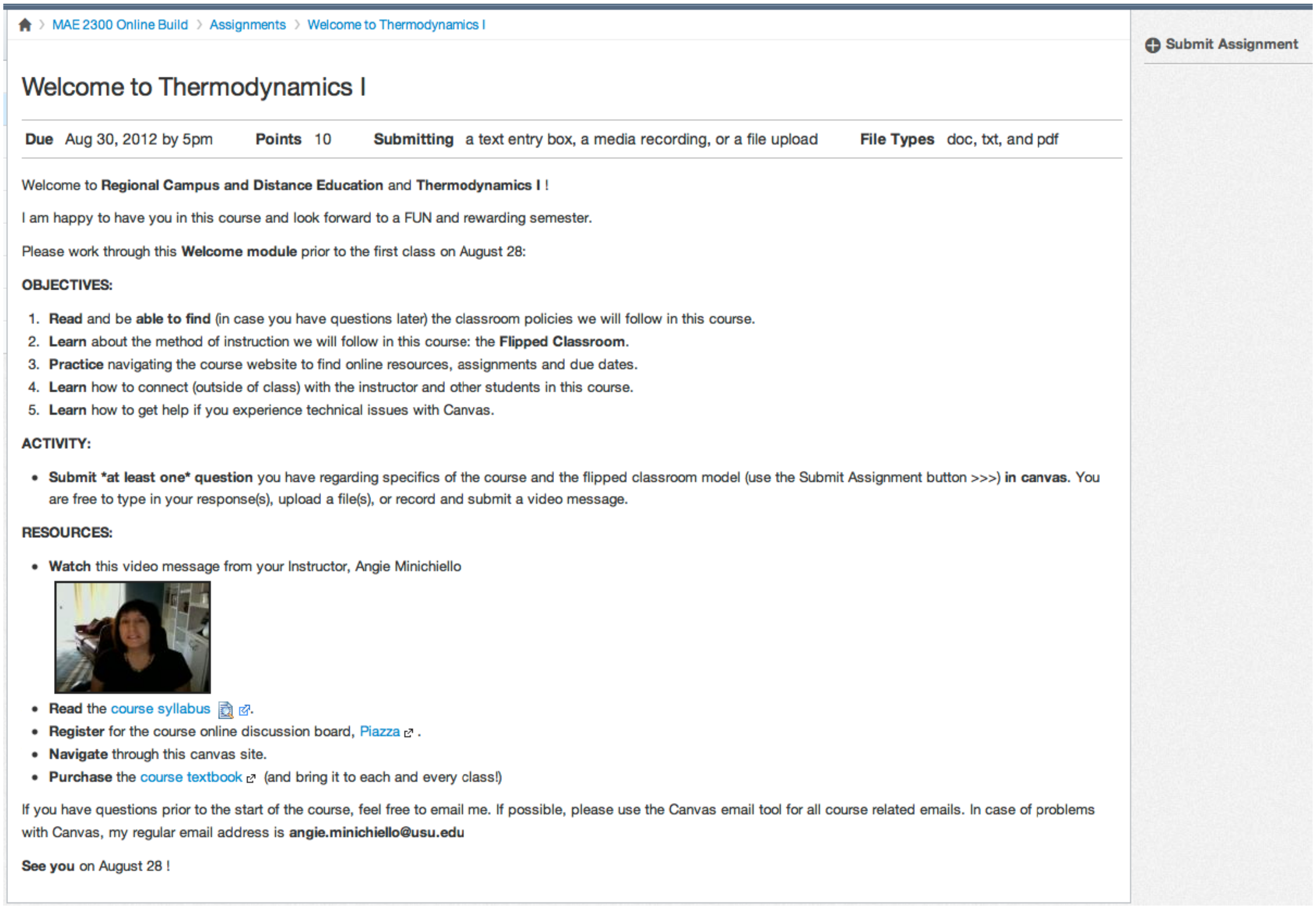

Fig. 1. Assignment –Centered Online Welcome Module.

C. Examples of Constructivism in Course Design

The application of a constructivist framework in our online course design may be best shown through examples.

1) Assignment–Centered Modular Design: The underlying structure of the online course is a set of ten weekly online learning modules accessed through a course homepage. Each learning module is built around a weekly assignment that is electronically submitted by students to the instructor. The framework for each module is the same and follows the OAR Model of Instructional Design [21], specifically developed for delivery of online courses in higher education using learning management systems (LMS). The acronym "OAR" respresents objectives, activities and resources.

In our course, modules are constructed within the "Assignments" tool in Instructure Canvas instead of the more traditional design choice of the "Learning Modules" tool. The Assignments tool was selected in order to place the contents of an entire learning module, including objectives, activities, multiple resources and the assignment submission link, all on one online page. In doing so, we attempt to leverage the capabilities of the LMS to streamline navigation and organize course content for the learner.

Use of the OAR model and Assignments tool facilitates a constructivist-style learning environment. Content is organized and accessible so as to facilitate time on task and the creation of knowledge structures. Multiple resources in varied formats (text, audio, video, virtual manipulative) are consistently provided to allow students to construct their knowledge and complete assigned activities in a manner that best suits their personal learning style. A screen shot display of the course online Welcome Module is provided in Figure 1.

2) Beautiful Homework Presentations: A variation of the "Beautiful Homework" assignments presented by Eschenbach [22] is used to provide students the opportunity to reflect upon and readdress conceptual understandings of key problems. At least once during the course, students present, in a online synchronous session, the conceptual framework and solution procedure for an assigned problem.

Beautiful Homework problems are assigned out of a larger weekly homework assignment that has been graded by the instructor and returned to students with feedback. Oral and visual presentation to a group of peers compels student presenters to revisit and deeply understand the concepts and nuances of the assigned problem. In this way, student presenters become the class experts on their assigned problems. Students are encouraged to be creative and present their solutions in unique and meaningful ways. In many cases, students voluntarily present multiple solution techniques, thereby creating new knowledge structures and linking them with existing or prior knowledge. Content from student presentations is posted to the course website and is frequently referred to during exam reviews.

3) Student Centered Discussion Forum: To foster dialogue among students in the course at any time of the day (or night), our online course implements a freely available online question and answer forum, Piazza [23]. As a wiki-based online tool, Piazza has capability not only for students to co-construct solutions, but also for instructors to facilitate virtual classroom interactions by a) endorsing student questions and responses, b) redirecting or correcting student responses, or c) simply answering student questions directly. In this manner, the instructor can easily promote an open discourse among students in a course, interjecting with direct instruction only when required to insure understanding. Posting to Piazza is a required part of weekly assignments until such time that the learning community discourse becomes self sustaining. At that time, participation in Piazza becomes voluntary.

V. TEACHING WITH TECHNOLOGY

Teaching with technology plays a significant role in online learning [4]. Online instructors need access to sufficient technology support and expertise in order to be successful in their attempts to design and implement online courses [6]. Additionally, as discussed in [24, 25], institutional adoption of newer web-based LMS significantly benefits online instructors by providing easy means of automating many administrative aspects of online course delivery as well as allowing for easier communication and feedback. Use of such automated features reduces technology barriers for online instructors and helps to facilitate the online curriculum for learners.

Our institution has invested in a strong infrastructure of technology and support for delivering and maintaining fully asynchronous, online courses. Our LMS, Instructure Canvas, is student-centric in its design, providing students with collaborative resources, the ability to receive instant notifications, options for evaluating how performance will affect their final grades, and ready access to materials and interactions via mobile devices. The same affordances are given to teachers, along with tools that speed the grading and assignment markup process. Canvas benefits from integrated multimedia tools that enable audio and video instruction and interaction at all levels of the system for both teachers and students. It also integrates with numerous existing external tools, such as the Piazza discussion board [23]—a resource used extensively and to great effect in our online class.

Additional tools are licensed at the institutional and state levels to provide further options for instructors to expand the capability of their courses. These include multimedia repositories, enterprise lecture capture solutions, quiz editing resources, options for videoconferencing, and more. For online students, the institution provides extensive support services, including access to e-tutoring, library services, proctoring services, advising, and more. For online teachers, the university has purchased access to 24/7 tier 1 technical support from Instructure. This enables teachers to respond to technological challenges in their courses whenever they arise.

VI. ONLINE COURSE FORMAL EVALUATION

Evaluation of an online curriculum is a critical component of its implementation as it facilitates a successful learning experience for online students as well as helps the larger teaching and learning community assess what quality online course delivery looks like. We cannot assume that quality online instruction mirrors the traditional notions of quality teaching. As Peercy and Cramer [5] discuss:

> *There is a persistent perception that the highest quality instruction is delivered the old fashioned way with a wise and experienced faculty member engaging face-to-face with the inquiring mind of an eager, well-prepared student. It is a nice image and sometimes it is true, but more often it is not (p.627).*

A. Institutional Infrastructure for Course Evaluation

In Fall 2011, our institution adopted The IDEA Center Student Ratings of Instruction system to assess course effectiveness with a focus on learning and curricular objectives [26]. The IDEA system requests students to provide feedback on their progress in achieving specific learning objectives in each course in which they are enrolled. This feedback is statistically analyzed by the IDEA Center and results are given back to the faculty and administration responsible for delivery of the course. The IDEA system has a "… documented history of reliability and validity… [that] provides specific feedback on teaching methods and practice" [26]. This formal student end of course evaluation is one method we will use to evaluate our online course during its pilot in the Fall 2013/Spring 2014.

B. Online Course Targeted Surveys and Focus Groups

Additionally, we will develop and deploy a student survey framed by the eleven online course evaluation categories proposed by the IDEA Center [27]:

- Course design/course materials
- Online activities
- Interactions with the instructor
- Student interactions

- Student characteristics
- Instructor use of technology
- Technology and learning
- Technology support
- Learning Outcomes
- Open-ended/ free response

These categories will form the basis for mid and end-of-term survey questions to be given to students enrolled in the Fall 2013 and Spring 2014 semester pilots of the online course. Together with surveys, focus groups of students in the pilot courses will be formed and interviewed to deeply explore students' satisfaction and affective outcomes with the online course. In this way, both quantitative and qualitative data will be gathered to guide future online course development and improvement efforts.

Finally, our formal course evaluation plan includes gathering student performance data directly from the LMS using built-in analytics tools as well as APIs for extracting additional performance data and reports. Some of the data we are targeting includes students' last login, their use of specific course items, their adherence to course deadlines, their interactions with the instructor, their performance on specific assessment items and linked outcomes, and their final grades in prerequisite classes.

In combining data from all of these sources (IDEA course evaluations, targeted student surveys and focus groups, LMS performance data) we will construct a strong, balanced picture of the strengths and weaknesses of our course. We will use this data in an iterative process of evaluating, improving, and re-evaluating to maintain an online learning environment that responds appropriately to our students' needs.

VII. SUMMARY

In this part I paper, we describe efforts to redesign a traditionally taught, introductory thermodynamics course into a fully asynchronous, online version. Reflection on our efforts has helped to highlight four important considerations for online course development: a collaborative development effort, adoption of an instructional framework supportive to online learning, infrastructure that supports teaching with technology, and implementation of effective course evaluation at multiple points throughout the development process. Part II of this paper will provide analysis of course evaluation data in order to provide recommendations for future engineering online course development.

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An Autonomous Articulating Desktop Robot for Proctoring Remote Online Examinations

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Abstract—**In this paper we describe a new low-cost, autonomous desktop robot for proctoring examinations in online/distance learning courses. The robot is attached to the student's computer via a USB port and monitors the examination environment using a webcam that articulates in both altitude and azimuth together with an array of acoustic sensors that provides audio directionality. The examination may be monitored in real time by a live proctor via the Internet or the data may be recorded for future review. Authentication of the identity of the test taker is accomplished using the webcam and simple, reliable ear recognition techniques. This eliminates the need for expensive digital fingerprint hardware.**

Keywords—online education; distance learning; academic integrity; cheating; remote proctoring

I. Introduction

Online education is now an integral part of the higher education landscape. In fact, the growth rate for online student enrollments now far exceeds the growth rate of the overall higher education student population. This growth is not projected to slow down, particularly with the advent of Massive Open Online Courses (MOOCs). As of 2012, 32% of all students have taken at least some or all of their classes online [1], and online education is now a multi-billion dollar market.

Academic integrity is an important consideration in online/distance learning courses due to the inherent opportunities for cheating. This problem is of particular concern in science and engineering courses, first because the students in these courses have the technical skills to cheat in ever more creative ways, and, second, because engineering students apparently cheat in greater numbers than those in many other curricula. As many as 81% of engineering students report having engaged in "serious" cheating [2], and this number is likely to increase with the increasing availability of online courses.

In this paper we review the available data on the incidence of cheating as well as the advantages and limitations of currently available technologies for reducing its prevalence. We then describe a new low-cost, autonomous desktop robot for proctoring examinations in online/distance learning courses. The robot is attached to the student's computer via a USB port and monitors the examination environment using a webcam that articulates in both altitude and azimuth together with an array of acoustic sensors that provides audio directionality. The examination may be monitored in real time by a live proctor via the Internet or the data may be recorded for future review. The acoustic sensors are used to identify and direct the camera toward interesting acoustic events and to flag these events in the video record for subsequent review. The robot's webcam could also be used to scan and transmit student solutions involving diagrams or detailed equations. These could later be compared to a mailed-in version if desired. Authentication of the identity of the test taker is an important and potentially expensive issue in online testing. In our system authentication is accomplished using the webcam and simple, reliable ear recognition techniques. This eliminates the need for expensive digital fingerprint hardware.

II. Prevalence of Cheating

Research into the rate of student cheating, both in in-class and online courses, has produced a wide range of results, all of them disheartening. Davis and Ludvigson reviewed three studies and found that the number of students who report having cheated on at least one exam is between 40 and 60% [3], Stearns evaluated five studies of cheating by college students and found that between 65 and 100% report having cheated at least once [4], and Whitley evaluated 107 studies and found an average of 70% [5]. Two studies found that over 80% of college students reported having engaged in "Serious Cheating" [2, 6]. There are a number of reasons that can account for the wide variation in results. These include the types of questions asked, personal beliefs of the students, their perceptions of the incidence of cheating, students' understanding of what constitutes cheating, the emphasis placed on academic integrity by the faculty and institution, and how the students regard the fairness of the exam, course load, or instructor. Students also tend to believe that limiting cheating is the responsibility of the instructor or institution rather than the students themselves [7].

The data for engineering and science students are particularly discouraging. McCabe surveyed over 4,000 students at 31 campuses and found that 81% of engineering students admitted to serious cheating and 51% reported serious cheating on an exam. For science majors the numbers were 73 and 45%, respectively. The engineers were surpassed only by business majors (88 and 64%, respectively) [2].

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There is comparatively little data on cheating in online courses. One might think that cheating in online courses would be worse than in in-class courses due to the relative ease of cheating but the available data give mixed results, probably for the same reasons responsible for the variation in surveys of cheating in face-to-face classes, but also because some students may feel freer to deny cheating in an online environment. Stuber-McEwen, Wiseley, and Hoggatt surveyed 225 students at a single mid-sized university and found that online cheating was actually reported less than in face-to-face courses [8]. Watson and Sottile surveyed 635 graduate and undergraduate students at a single university and found no significant difference between reported rates of cheating in online and in-class courses [9]. However, they did find the reported incidence of students receiving answers from another person during a test or quiz was significantly higher for online classes.

Harmon, Lambrinos, and Buffolino looked at six studies evaluating students' perceptions about the incidence of cheating [10]. Students' perceptions are important because they may be more likely to cheat when they believe cheating is prevalent. In three studies of students' about the incidence of cheating one found that students perceived less cheating in online classes, one found that students perceived more cheating, and one found that students perceived about the same level of cheating. Interestingly, the remaining three studies looked at students' perceptions of cheating in unproctored vs. proctored exams in both online and in-class exams. They concluded that

> "On balance, the results of these three studies imply that cheating risk is greater in unproctored than proctored assessments. The six studies, considered as a group, imply cheating risk is less correlated with instructional format (online v f2f), and more correlated with unproctored online assessments."
>
> This level of cheating has two important consequences. First, it impacts the student's long-term view of professional and ethical behavior. Second, many instructors, particularly in STEM subjects, are reluctant to teach online courses due to the poor reliability of online test scores and their inability to give detailed test questions.

III. Currently Available Technologies

Techniques aimed at suppressing cheating in online classes break down into four categories. These categories include techniques that authenticate the identity of the test taker, make it difficult to cheat, detect cheating when it occurs, or a combination of these. Given the technical abilities of many students, and engineering and science students in particular, it's unlikely that any system for preventing cheating will be completely foolproof. The goal is to increase the uncertainty of detection to an unacceptable level for the potential cheater.

As a result of the passage of the 2008 Higher Education Act, U.S. accreditors are now required to ensure that institutions with distance education programs have policies to verify the identity of distance learning students [11]. As a result, many data security corporations are developing innovative authentication techniques as a path to penetrate the growing online market. Some examples include

> Acxiom Information Security Services—multiple-choice security questions/quizzes for students; questions are based largely on a student's prior address history (now teamed with Learning House to provide audio and visual proctoring) [12];
>
> Digital-Persona—digital fingerprint scanner and software; students can log in to campus networks, access university-based websites, access Blackboard [13];
>
> Fujitsu PalmSecure—vein recognition, which identifies individuals from the veins in the palms of their hands [14].

Authentication, while important, does not preclude other methods of cheating such as sharing of information or using unauthorized sources (books, webpages, etc.). Efforts to address this problem include requiring the students to travel to specific exam sites or recruiting remote proctors, modifying the exam conditions in some way (e.g., instituting time limits or locking down the computer with respect to communications or web access, giving different exam questions to different students, etc.), or monitoring the exam environment (for example, using audio monitors and/or fixed cameras, as in several of the techniques described above).

The first method defeats the purpose of distance learning and may not be feasible for very remote students, and hiring remote proctors can be expensive and subject to abuse. The second can be time consuming (although some textbook publishers are beginning to offer banks of questions that can be mixed to provide differentiated tests) and distorts the testing procedure by limiting the kinds and format of test questions that can be asked, and locking down the computer does not preclude using a second computer or a second person at the test site.

Several companies are now offering sophisticated technologies for identifying the test taker and monitoring their behavior during the exam. Kryterion Inc. offers Webassessor, which monitors test taking. In addition to audio and video monitoring, the program uses a complex algorithm that analyzes and flags aberrant behavior, keystroke activity and response time [15].

Coursera, a company that offers MOOCs available from 62 universities, provides a keystroke system to recognize individual students' typing patterns using error patterns, typing speed, and how long specific keys are held down [16]. Coursera has teamed with Proctor U, an online test-taking company that pays proctors to monitor the student with a webcam trained on the student's face in real time [17]. At the beginning of each test the proctor asks the test taker to scan the room with the web camera to detect unauthorized materials such as books or other people in the room.

The systems described above do not provide continuous monitoring of the test environment. To address this issue, Software Secure Inc. developed the Securexam Remote Proctor. This device uses a conic mirror to project a 360° image of the room downward to a webcam connected to the test taker's computer via a USB port. It also has fingerprint scanner and audio monitoring. The system's software records a continuous image and can restrict the computer's functionality during a test to, e.g., limit access to selected websites [18]. The image is, however highly distorted and does not cover the ceiling of the test room.

All of the systems described above may be susceptible to a sophisticated attack strategy, for example, by installing the software on a virtual machine located inside the student's computer.

IV. The Exam Proctor Robot

To address some of the problems identified in the last section we have developed an autonomous articulating desktop robot for proctoring exams in online/distance learning courses. A prototype of the robot is shown in Fig. 1. The robot is about 5 inches in diameter and 7 inches high. In the figure, a clear dome is used for testing; a half-silvered dome would be used during a test to obscure the student's view of the camera. The robot is attached to and powered by the student's computer via a USB port and monitors the examination environment using a webcam that articulates in both altitude and azimuth for full 360-degree coverage. The robot also uses an array of acoustic sensors to provide 3-dimensional audio directionality to detect and record acoustic events.

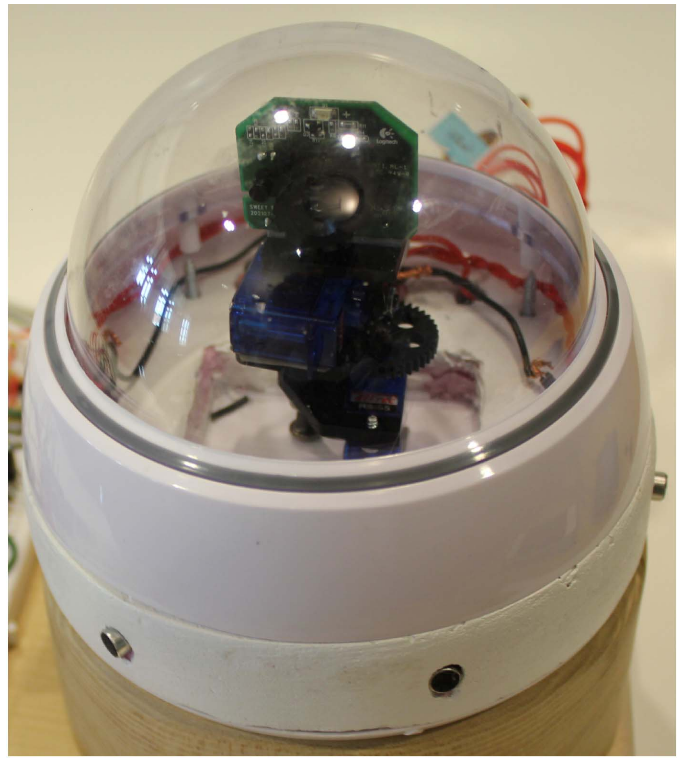

Fig. 1. Prototype of the exam proctor robot. The robot measures 5 inches in diameter by 7 inches high.

The examination may be monitored in two modes, real time and autonomous. In real time a proctor may monitor the exam and communicate with the student via the Internet. In autonomous mode the webcam continuously sweeps the test environment in a random pattern but will momentarily scan the area surrounding any anomalous acoustic events that are detected. Audio and video data are recorded and transmitted to the proctor after completion of the exam for future review. The locations of interesting acoustic events are flagged in the video signal. Also, the webcam is periodically aimed at the computer screen to verify that, for example, the software is not running in a virtual machine.

The prototype system uses an Arduino microcontroller board that can function as a limited HTTP client or server. As a client, it has the ability to pull an IP address via DHCP, download a page from a predetermined URL, and parse that page for relevant data. Once the data has been retrieved, it can then be used for any given purpose locally. In this case, we are using the data to control the position of altitude and azimuth servomotors that aim the webcam.

Ethernet, TCP/IP, and HTTP client libraries allow downloading of a simple text file from an arbitrary Web server. This text file is formatted as follows:

```
!X#####~~
!Y#####~~
```

where ## represents an unsigned 16-bit integer in decimal format. (Leading zeros are not needed; the number itself can be from one to five bytes in length.) Once the two numbers are retrieved and parsed, they are scaled as needed and then used as the input to the Servo libraries (also built in to the Arduino IDE). These configure the appropriate pins as digital outputs and set up the PWM units to send the correct width pulses to the servos, moving them to the requested position.

By continually polling the Web server once every few seconds, the Arduino can update the servo positions – and therefore the camera's target – according to the remote proctor's directions.

To authenticate the identity of the test taker, simple ear recognition software is used. At the beginning of the exam webcam is aimed at the test taker, who is instructed to turn to present a profile and brush away any hair that is covering the ear. This provides accurate authentication at no additional hardware cost. Ear recognition techniques have been found to be more that 95% accurate [19]. In our tests with live volunteers, the system correctly identified four out of four test subjects.

The robot provides a flexible and powerful test administration system. It will support a variety of test formats ranging from open or limited Internet to closed book/closed notes. It could also support written exams with solutions in the form of complex diagrams or equations. For such exams the robot could scan the completed exam and then instruct the student to place the hardcopy inside a pre-supplied addressed envelope that is sealed and signed while being recorded. It would also simplify the administration of frequent short quizzes that would be less prone to cheating than conventional homework assignments. The approach has the added advantage that it produces an archival record of the test in case questions of academic integrity arise at a later time. We estimate that in quantity the robot would cost about $35 to produce, and could be sold for about the cost of a textbook.

A two-component software suite to accompany the robot is currently being developed. The first component is a heavily-customized distribution of Ubuntu Linux (or a similar, free/open-source distribution of Linux) running from a bootable DVD-ROM on the student's PC or Intel-based Macintosh computer or a computer at a designated test site. The customized, kiosk-like operating system mutually authenticates with the robot unit and allows the creation of a secure, verifiable remote-site testing environment for high-stakes certification exams. Students will be able to plug the robot into their computer, boot to the included test DVD-ROM, and the test environment software will automatically start. The software and robot will use public-key authentication techniques to mutually authenticate each other (to combat spoofing and/or reverse engineering of the protocols etc); the test software will provide its full functionality with a robot connected via USB to the PC; and the robot will only complete the authentication sequence when in communication with a genuine copy of the proctor software. In addition, the software will contact the instructor's server for an authentication key to verify that the distribution disk has not been tampered with.

The second component is a Graphical User Interface (GUI). The GUI is a key component in this development. An important requirement for the GUI is to provide a clear and comprehensive view of the workflow involved in developing the test, quiz, or assignment. The GUI will provide a visual representation of the workflow allowing the instructor to interactively choose to start at the beginning or to start on subtasks. The GUI will allow the user to define his or her own workflow and to use it interactively. The ability to define workflows allows the user to transfer expertise to the tool that can then be reused repeatedly. The GUI should support the invocation of external applications and the marshalling of data to them as well as the unmarshalling of data from the external applications. Some of the external tools the GUI should support include such standard applications as Bb Visa, Blackboard (and Blackboard NG), and Moodle. When completed the GUI will seamlessly support the performance of all needed tasks ranging from test or assignment development and definition of test conditions such as allowable Internet access (accessible URLs. etc.) or use of texts or course notes, email access, etc.

At the beginning of the course the software will scan the student's computer to determine the availability of needed resources, such as memory and power available from the USB port. The computer will also scan the computer for any needed drivers not found on the boot disk. This information will be reported back to the course instructor for appropriate action. For example, for students with older PCs only USB 1.0 might be available, which might be insufficient to power the robot. These students could then be provided a double USB cable or a wall-powered USB 2.0 hub. Similarly, if disk space is an issue the student could be provided an external USB memory stick controlled by the test application.

V. CONCLUSIONS

Cheating in online classes is a major problem, particularly with respect to cheating on examinations. In this paper we have reviewed the available data on the prevalence of cheating in both online and face-to-face classes. We have also reviewed some of the available technology used to suppress cheating in online classes. Finally, we have described a new low-cost autonomous desktop robot that can be used to monitor exams in these courses.

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Changing Perceptions: Do Engineering Activities Make a Difference in K-12 Environments?

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Abstract— **K-12 educators often incorporate projects into the science curriculum. Students conduct the activity, fill out answers on a corresponding lab sheet, strive toward results, and then move on to a new topic. With such an abrupt change in pace and lack of assessment, a question emerges: do these activities have a lasting impact on student learning or are these labs extraneous additions to the general curriculum?**

In an effort to integrate engineering concepts into a middle school environment, sixth graders were tasked with a design lab popularly known as "the marshmallow challenge," which requires student teams to construct a tower from uncooked spaghetti, tape, and a single marshmallow.

Approximately two months after the activity, the students who participated were asked to take a survey with four components: identification, opinion, objective, and open ended. The fifteen question survey was designed to determine if students enjoyed the activity and if students retained information from the short lecture before the activity.

The results for the objective portion were averaged between classes and compared; this paper presents an analysis of those scores. Also, commonalities between written student responses are examined and discussed.

These results are applicable to schools wishing to evaluate the effectiveness of brief activities similar to "the marshmallow challenge."

Keywords— **K-12 Engineering, activities, design lab, STEM, science standards**

I. Introduction

In the K-12 environment, students are typically tasked to conduct labs for a science class, turn it a worksheet, and then stampede into the next lesson after they complete the activity. Since this transition is so quick, it's possible that all meaning of the activity is lost due to the vague relevance to the rest of the curriculum. To investigate, students were instructed to conduct an engineering activity and take a short test concerning details of the lab about two months after the activity. The questions on this test were meant to assess vocabulary introduced to the class on the day of the activity. Another section of the test was devoted to collect feedback from the "engineering day" to improve the presentation for future labs.

II. Theoretical Framework

Recently, efforts have been made to slip engineering into the K-12 environment through the back door. With upcoming revisions to science standards, these efforts will become more and more prevalent. In fact, notable curricula like "Engineering is Elementary" and "Project Lead the Way" have made impacts across numerous states by increasing student interest in engineering both in and out of school [1, 2]. Another subtle way of introducing important concepts into the K-12 setting is through hands-on, engineering-like activities such as Model-Eliciting Activities (MEAs). These activities are math problems that are applicable to real world scenarios and involve students collaborating to create an appropriate model that describes a certain situation [3]. Since engineers use modeling constantly during the design process, the use of MEAs to educate students in the field would be a fairly easy addition. Each of these methods involves some degree of "hands on" learning.

Naturally, a support system for "hands on" learning already exists and is implemented in most science classes to some degree. Le Buffe praises this method, claiming that it "makes science vivid, meaningful and fun for most students" [4]. In fact, Wasserstein found that 27% of middle school students rated "hands on" science activities as their most memorable work [5]. High school science classes should not be left out though, considering the infrequency of "hands on" opportunities in this grade band. With this said, Piburn and Baker warn teachers to avoid the abstraction of content in science, especially in the higher grades. Students need context for the material—something physical—not just preaching theory [6].

On a more special occasion, students may be treated to visits by professionals or undergraduate/graduate students running programs like STEM academies through a university engineering outreach program [7]. STEM academies can range in levels of complexity and span of time spent at the school. For example, a project such as "Engineering Adventures" could include multiple modules covering a wide array of topics ranging from product design to controlling invasive species [2]. It has been demonstrated through quantitative studies that these modules do indeed provide a positive impact on student learning and motivation to study engineering [8]. However, these programs are long term and often require large amounts of time dedicated to running the modules with students. Determining the impact of a single session on student perceptions of engineering would allow curricula designers to make informed decisions on the value of short term STEM academies and adjust accordingly.

III. Engineering Activity: the marshmallow Challenge

The 6th graders were tasked to do a lab known as "the marshmallow challenge" that was originally a design challenge introduced by Peter Skillman and popularized by Tom Wujec at a TED conference in 2010 [9]. Today, it is commonly used as a team building exercise in businesses and universities. Both the engineering applications and team dynamic components were examined for this lab activity.

The goal of "the marshmallow challenge" is to build the tallest free standing structure using the following items in a premade kit in under 18 minutes:

- 20 sticks of spaghetti
- 1 yard of tape
- 1 foot of string (modified from 1 yard in Wujec's original instructions)
- 1 marshmallow

However, there is a clever twist that elevates this challenge to a different level. For the structure to qualify, *the marshmallow must be at the highest point.* Also, the following rules apply: students can use as much or as little of the kit as they wish and items in the kit can be manipulated in any way (i.e. breaking spaghetti sticks in half), except the marshmallow must remain whole.

A. Observations

The final designs across the three sections began to exhibit some similarities. As expected, the last class did the best at demonstrating the value of self-reinforcing geometric shapes like triangles. However, earlier classes seemed to understand this concept to a point, but fell short in delivery. The students were not taught this explicitly during the opening lesson, but were most likely clued in through the latent curriculum that an iterative design project creates.

By sharing experiences with the later sections, a sort of "communal design" project was created—where the group of students working separately eventually converged to one design pattern as time went by and information was passed from class to class. When comparing the average height of the "communal design" structures to the average height of those that do not follow the pattern, the average for "communal" structures is 18.65 inches while the "non-communal" average is 13.83 inches—a spread of almost 5 inches. One group's design was disqualified for being a supported structure, but was averaged into the "non-communal" values since it was standing and measured anyway—unlike three other disqualified structures. Perhaps the structures would have grown in height and become more similar if more classes were involved [10]

IV. Methods

In the study two months after the activity, a total of 42 students across three classes of sixth graders were given a test online totaling 8 questions covering concepts learned during "the marshmallow challenge" activity. Additionally, students were asked to report their opinions through 4 open ended questions and respond to 4 statements on a five point Likert scale. The test was developed by the investigators to correspond with material covered during the 40 minute session. Both the activity and test were conducted during a normal school day under normal school conditions. Students were given a brief review session the day before the test, but no questions were disclosed.

V. Engineers Build Things, Work in the Sun, Mix Chemicals…

What does an engineer do? This question can be polarizing for a variety of reasons, and in the open response question, the common misconceptions didn't seem to appear as frequently. Generally, twenty one answers contained the following concept at some point: "*engineer builds, fixes, or designs things.*" Four students were a bit more specific: "*engineers apply math and scientific principles to solve problems.*" In five answers, the students distinguished between the different engineering disciplines. Also, whenever a pronoun was used in place of "an engineer," it was always "he," while two students referred to the possibility of a female engineer.

In addition, five students mentioned engineers "improve society's quality of life." While these students did not go into detail, one could infer that they are referring to the grand challenges [11], which were mentioned in the lecture introducing the marshmallow challenge. Through this lens, engineers are seen as the social handymen of this modern day society.

In fact, the students touched on each major dimension of engineering discussed in a paper by Figueiredo. These four dimensions describe an engineer as a *scientist, sociologist, designer, and maker or "doer"* [12]. As stated indirectly by the middle school students, these four dimensions paint the complete picture of the engineer rather than in disparate parts as usual.

The next question was, "*How would you describe engineering to a friend?*" Results for this question were fairly similar, with a notable example. One sixth grader explained that "an engineer is a kind of mechanical doctor or scientist[;] they can fix machines and invent them." Since this question was fairly similar in nature to the last, the rest of the answers were essentially recycled responses. It was not until the students answered the final open response question that the misconceptions started to surface.

VI. What do you want to be when you grow up? An Engineer?

The final question in the open ended section asked the student the following question: "*Do you think you want to be an engineer when you grow up? Why or why not?*" While it is a harmless question to ask, the responses occasionally tend to hold a great deal of passion by revolving around an idealized profession or personal goal. Further, there is a distinct possibility of response bias, where students would tend to give the answer they perceive the researcher desires. To minimize this, the instrument was administered by the classroom teacher rather than the researcher. Among the responses, the students shared their aspirations of becoming doctors, veterinarians, teachers, professional athletes, animators, and authors—as expected.

This question also revealed student misconceptions about engineering. One student had this to say, "I'm not that much of a building guy, and I don't like to work in the sun all day long." While this was not the only instance of the profession being misrepresented, phrases and words such as "fixing machines," "building," and, "architecture" appeared frequently. A paper examining students' perceptions of engineers through a "draw an engineer" study reveals a similar trend; similar verbs like "build" and "fix" were used by students frequently in one-on-one interviews [13].

Numerous students also dismissed engineering as a profession based on their disdain for the math involved. Twelve responses expressed incapability in one or many skill sets such as math and designing. Additionally, four students thought that engineering seemed to be a boring profession, devoid of any excitement. Quite a few students weeded themselves out of becoming an engineer based on arguments from a list of nonexistent prerequisites. Students believe that being an engineer requires superior sketching abilities and that their minds need to be bursting at the seams with creativity.

On the other hand, some of the responses painted the profession in a more positive light. Two students added that one of their family members was an engineer—both gave the most detailed answers as to why they would choose engineering as a career. Ten students claimed to some extent that they would be interested in being an engineer when they grow up. More hands-on activities could shift the number of students either way—especially when the math involved is exposed in context.

VII. Administering an Objective Test

In addition to the survey, an eight question objective portion including questions on content from the "engineering day" lecture before the activity. Since the test was administered in different sessions, it is possible that the lapse in time is significant. For this reason, it is difficult to find a meaningful comparison between the sections. Yet, the results can still be commented on.

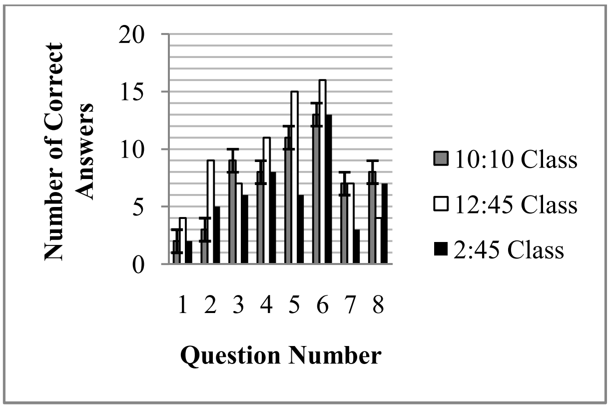

Fig. 1. Number of correct answers given by students in each section.

The following eight questions were given to each sixth grade class.

1) *Good criteria should be ________*
   - *quantifiable*
   - *related to design*
   - *opposite to constraints*
   - *descriptions*
2) *We want to design a roller coaster, which of the following would be good criteria in a list to work from?*
   - *Fun, cheap to build, and tall*
   - *Should be taller than the other coasters, attract a lot of customers.*
   - *Have the tallest height be 200 feet, be able to seat 20 people per train.*
   - *Get good reputation in the park, not too intimidating for small children.*
3) *If a luxury car is only offered in pink, this would be an example of a poor _______.*
   - *criterion*
   - *design quality*
   - *constraint*
   - *idea*
4) *Requiring the marshmallow to be at the highest point in your design is included in the _______. (Note: It was not a limitation, it was a requirement).*
   - *constraints*
   - *criteria*
5) *Would the limited materials be a constraint or part of the criteria?*
   - *constraint*
   - *criteria*

6) *Every design we have today has experienced some degree of failure.*
   - *True*
   - *False*
7) *The marshmallow was a metaphor for something in the context of the lab. What does it represent?*
   - *important issues*
   - *facts*
   - *criteria and constraints*
   - *hidden assumptions*
8) *"The Marshmallow Challenge" emphasizes the value of _______.*
   - *design and prototyping*
   - *structures*
   - *criteria and constraints*
   - *drawing*

For the 10:10 Class, there was a double submission; to compensate, error bars denoting a variance of ±1 overlays each representation of their number of correct answers. The 12:45 and 2:45 sections did not have any problems with the survey.

Of all the questions, number one, "*Good criteria should be…*" was intended to be a fairly straightforward "fill in the blank." During the introduction, emphasis was made that good criteria should be able to have a number assigned to it—in other words, quantifiable. Surprisingly, less than a fifth of the participants answered correctly. However, one option, "related to design," is applicable enough that it may also be a valid answer. While "quantifiable" is qualified by "*good* criteria," "related to design" is qualified by "*criteria*" alone. Therefore, both answers are technically right—raising the percentage correct to about 84%.

While the second question, "*We want to build a roller coaster, which of the following would be good criteria in a list to work from?"* was an application of the first, the percentage correct was 37%, compared to the previous 19%. An incorrect option D, "*get good reputation in the park, not too intimidating for small children*," was unusually popular—more responses than option A and B combined. The object of this question was to determine whether or not students could identify good criteria, but they were unable to distinguish between criteria that are quantifiable and criteria that are already quantified.

The following questions, all concerned engineering design as well, specifically criteria and constraints. In fact, these two concepts were topics from the introduction the class was given prior to the activity. For example, question five asked the following: "*Would the limited materials be a constraint or part of the criteria?"* Since students learned the definition of constraint to be a limitation on design, that should be the correct answer. In the results, nearly all of the students in the first and second class responded with constraint; yet, slightly under half of the third class had the right answer.

However, "the marshmallow challenge" is not designed to illustrate these concepts; instead, its purpose was to help the participants become aware of the hidden assumptions in a project. This fact was explained after the activity had ended, but did the students make that connection or refer to the introduction for the activity's purpose?

Student responses to "*The marshmallow was a metaphor for something in the context of the lab. What does it represent?*" provide some insight as to which part of the lesson had the most impact. Option D, hidden assumptions, is the correct answer; however, with "criteria and constraints" placed in option C, the intention is that students will be torn between the two choices and pick the most applicable to their recollection of the activity. Scores for question seven proved that this intentional trick did create cognitive dissonance with the students; both option C and D had 17 responses (7 for A and 2 for B).

The last question, "*The Marshmallow Challenge emphasizes the value of…"* functions in the same manner—with "criteria and constraints" as option C as well. For the responses to the last question, the results were as follows: 35% of students associated the activity with the brief lesson before, 44% of students picked the *correct* answer, "designing and prototyping" while the remaining 21% picked option B, "structures." Therefore, 79% of the students recognized the significance of the lesson—a promising number despite two months had passed since the activity.

VIII. What did the Students Think?

In the opinion section of the survey, four questions were set up using the 5 level Likert scale—strongly agree to strongly disagree. In conjunction with the open ended responses, the results from this section of the survey can be analyzed for certain characteristics or attitudes found in the student's writing. For this set of questions, the following statements were posed:

- I enjoyed "the marshmallow challenge" activity
- The information was presented clearly and in a way I could understand
- I'm interested in learning more about engineering
- I'm interested in doing more engineering related labs and activities

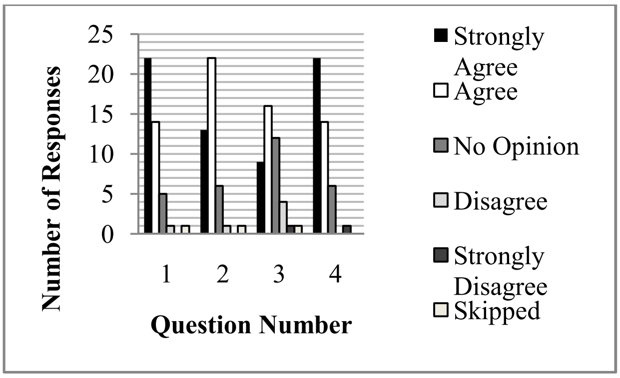

Fig. 2. Responses to opinion questions based on the Likert Scale (1-5). Results are taken in aggregate.

A. I Enjoyed "The Marshmallow Challenge" Activity

With the law of averages, it's expected that not everyone will enjoy a certain activity—this is no exception. For this lab, 86% of the students praised the activity and reported with a positive response, either agree or strongly agree. 12% of participants had no opinion either way while only one student was unsatisfied. With 98% of students receptive to the activity, learning outcomes seem more likely to be successful.

B. The Information Was Presented Clearly and in a Way I Could Understand

When giving a short introduction to engineering and then conducting a lab at such a fast pace, one would expect some students to tune out the information. Thankfully, students seemed to grasp the concepts and responded positively on the survey—83% answered with agree or strongly agree. Again, only one student couldn't follow while 14% had a neutral stance.

C. I'm Interested in Learning More About Engineering

For this statement, the results were a bit mixed. 60% of the class expressed interest in learning more about engineering while 29% answered with indifference and 12% responded negatively. The source of the disinterest can be somewhat ambiguous; yet, the open-ended responses provide some perspective. As stated earlier, some students have a "dream job" already in mind. In that sense, other career pitches end up fading into white noise. If the same question was posed to high school or college students with more uncertain career goals, maybe their interest in learning about a different field would be significantly higher.

D. I'm Interested in Doing More Engineering Related Labs and Activities

Since conducting an engineering lab is a conduit for learning about engineering, one would expect the responses to be the same as the answers from the previous question. Yet, 89% of the students reported that they would be interested in doing more activities in the future, 14% were indifferent, and one student was completely uninterested. Regardless, as long as students are excited about doing an activity intended to instruct, positive learning outcomes are likely to be fulfilled.

IX. CONCLUSION

While the sample size is relatively small, the application to K-12 is immense with the onset of new science standards. It is advantageous for science and math teachers to gain a fundamental understanding of engineering concepts and become comfortable with the subject matter. Through outreaches similar to this, a body of research can be formed to determine which activities and models work best in the K-12 classroom environment.

After verifying student perceptions with the survey, it can be inferred that a hands on activity such as the "the marshmallow challenge" activity with a short grounding lecture for perspective does have a positive effect by giving students a better understanding of the engineering profession—more so than one would expect. K-12 instructors should continue this method of enrichment to determine which activities are more apt to benefit experimental learning and advance STEM education.

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Middle School Students' Conceptions of Engineering

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***Abstract*— This study investigated middle school students' conceptions of engineering. Participants were sixth through eighth grade members of afterschool engineering clubs. Thus, the study contributes to understanding middle school students' knowledge of engineering, and also to how afterschool activities shape students' conceptions of engineering. Researchers have increasingly attended to students' perceptions of themselves as engineers, and their attitudes towards engineering majors and careers. However, little research has investigated middle school students' conceptions of engineering– what engineering is and what engineers do. The purpose of this study was to understand how middle school students who join afterschool engineering clubs conceptualize engineering and how engineering afterschool club experiences influence students' conceptions of engineering. The results of our study indicate that many participants had limited conceptions of engineering and suggest a need to connect design activities with knowledge of engineering.**

Keywords—Middle school, middle grades, conceptions of engineering, K-12 engineering education

I. INTRODUCTION

Recent interest in K-12 engineering education has prompted development of outreach programs designed to increase pre-college students' awareness and understanding of engineering. Afterschool programs may be instrumental in increasing students majoring in STEM fields [1, 2], perhaps because college students' choice to major in STEM fields is related to a growing interest in mathematics and science rather than enrollment or achievement [3]. However, inaccurate conception of what engineering entails may lead to dropping out of engineering degree programs and pursuing engineering careers. It is therefore important to understand students' early conceptions of engineering and how educational experiences influence those conceptions. The purpose of this study was to understand how middle school students who join afterschool engineering clubs conceptualize engineering and how club experiences influence students' conceptions of engineering. Two questions guided the research:

1) What conceptions of engineering do middle school students' involved in engineering afterschool clubs hold?

2) What influences these students' conceptions of engineering?

II. BACKGROUND

K-12 engineering education has made great strides in the past decade, making its way into the public eye and into K-12 local, state, and national curriculum standards, principles, and frameworks [e.g., 4, 5]. However, knowledge and practices of engineering continue to have low visibility in schools, and few people conceive of engineering as a K-12 subject. A national survey found that introductory engineering courses are still rare in American high schools and there is little reason to think that that is any less true in elementary and middle schools. Currently, engineering education at the K-12 level is largely delivered through outreach programs. The National Research Council [5] reported that what students experience in engineering instruction "does not always align with generally accepted ideas about the discipline and practice of engineering" (p. 4).

Rising attention to K-12 engineering education has prompted interest among educators and researchers in assessing students' conceptions of engineering. K-12 students' conceptions of what engineers do, have primarily been investigated in elementary contexts, often with participants who have not been exposed to engineering education interventions. Cunningham, Lachapelle, and Lindgren-Streicher [6] explored the conceptions of engineering of more than 500 first through fifth grade students (60% of who qualified for free-or-reduced lunch) in a district that had not made any efforts to teach engineering concepts. Based on students' conceptions and misconceptions about the work that engineers do, these researchers created a table with 16 images and descriptions of people at work and asked students to circle the kinds of work that engineers do. They also asked students to complete the sentence, "An engineer is a person who…" Participants tended to conceive of engineers as auto mechanics and construction workers. The authors suggested that a tendency to associate repair of automobile engines with engineers was likely influenced by the phonetic association of the two words. Capobianco, Diefes-Dux, Mena, and Weller [7] reported similar trends. In their study of approximately 400 first through fifth graders, they found that engineers were primarily associated with laborers, mechanics and technicians—those who fixed things. These results were obtained through administration of the Draw an Engineer Test prior to an engineering education intervention in one inter-city and one suburban school setting in the northeast US. In a rare pre-post study, Carr and Diefes-Dux [8] administered the

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Draw-an-Engineer Test to second, third, and fourth graders. These authors found a common conceptual thread centered around manual labor (building) and those who fix things, as well as drivers. In a post-test following an engineering curriculum intervention, about half the participants had moved away from a manual labor conception to a design conception of engineering.

Fewer researchers have investigated middle school students' conceptions of engineering. In one exception, Fralick, Kearn, Thompson and Lyons [9] obtained results similar to Carr and Diefex-Dux when they administered the draw and engineer test to middle school students. In another noteworthy exception, Welty and Stricker [10] asked seventh and eighth graders "What does the word engineering mean to you?" Responses revealed that the number of number of references to designing, creating and inventing increased from pre to post-engineering intervention, indicating that design activities associated with the intervention may have helped dispel students' previous misconceptions.

English, Dawes, Hudson, and Byers [11] posed the question, "How can the nature of engineering and engineering practice be made visible to young learners?" We hoped to shed light on this issue through our investigation of engineering conceptions held by middle school students engaged in an engineering afterschool program.

III. METHOD

A. Participants and Context

Study participants were middle school students participating in engineering clubs in eight Southwestern U.S. schools in one urban district. The clubs were open to all middle school students. Of the 108 club members who participated in the study, 68 were eighth-graders, 25 were seventh-graders, and 15 were sixth-graders; 48% were female; 64% were Hispanic, 13% White, 7% African American, 7% Asian, and 2% Native American. Of these students, 73% were eligible for free or reduced lunch.

Participants were part of a university-based engineering outreach program. The program involves a club-like afterschool model primarily focused on schools with a high percentage of low-income students. Its objective is to provide an opportunity for low-income, first generation and historically under-represented minority students to explore STEM college majors and career interests with a group of peers interested in attending college. Two large state universities were involved in administration of the program. Near the beginning of the school year, teachers attended a workshop where they learn about each challenge along with ideas on how to promote and implement them amongst their club members. Students chose one of nine team-based design challenges and competed in state-wide completions. The engineering afterschool clubs typically meet once a week for one to two hours, working in teams of two to four students to develop their ideas and devices. During the first couple of months of the spring semester, state regional competitions are held so that teams from different schools can compete against one another and prepared for the state final competition in April. Local volunteer engineers act as judges during the regional and state competitions. The clubs were part of a national organization. Thus, in many ways, this club context is similar to others operating across the country and to those described in past research.

B. Data Collection

The afterschool clubs had been operating for at least six weeks before data collection began. All participants completed a survey composed of Likert items (5-point scale) and open-ended questions related to students' demographics, knowledge, practices, and perceptions of engineering and to students' experiences related to club activities. Forty-eight students were randomly recruited to participate in one-on-one interviews. Only open-ended survey items and interview questions pertaining to students conceptions of engineering were analyzed for the purposes of the present study.

C. Data Analysis

After all interviews were transcribed, a coding scheme to address the research questions related to students' conceptions of engineers was created. We took a Structure-Behavior-Function approach [12, 13] to coding students' conceptions of engineering by trying to account for students' understanding not only of what products engineers are associated with, but also what they do (the processes/behaviors in which they engage), and why they do it (the purpose/functions associated with engineering). Analysis began with the two authors meeting to read through the transcripts, comparing within and across student responses to two interview questions (What do you know about engineering and what engineers do? What kinds of engineering activities do you do outside of the club? (at home? at school?). Reading through interview transcripts, we negotiated our understanding of students' descriptions of structures, processes, and functions associated with engineering. After coming to consensus about how to define and operationalize these constructs, the first author then coded all the interviews and recorded frequencies of codes, using NVIVO 9 to organize the data. Re-reading the interview transcripts, we looked for evidence related to our second research question, "What influences students conceptions of engineering," identifying all sources of influence. Finally, the first author examined the open-ended survey questions and identified themes before comparing survey responses with interview data.

IV. RESULTS

Qualitative analysis of open-ended survey questions and interview responses revealed four themes.

First, students spontaneously described structures, processes, and functions associated with engineering (see Table 1). The top five structures to which students referred in their interviews were cars (coded 20 times), buildings (coded 18 times), bridges (coded 7 times), computers (coded 5 times), suggesting that students' conceptions of engineering are highly influenced by mechanical, civil and electronic engineering fields. Most students also spontaneously mentioned processes associated with engineering. These included overarching processes (fixing things [that break], building, creating, maintaining) as well as sub-processes. Fewer students referred to functions of engineering: to improve on things to make them easier, better, safer, faster, or more efficient); to help people, to make life easier, to make the world better. The function of engineering to solve problems was explicitly mentioned by only four students.

Second, students' conceptions of engineering can be clustered under four prototypes, engineer as (a) repair person who fixes and maintains things, (b) scientist who studies things, (c) builder who makes things, and (d) designer who invents or improves things (see Table 2 for examples). These categories were first identified based on coding of the interview transcripts. However, an open-ended question on the survey asked students their definition of an engineer. This question reinforced the prevalence of these categories. Of the 108 students who completed the survey, only one made no response to this question; ten other responses could not be categorized. Of the other 97 students, 6 gave responses that clearly showed a conception of engineer as scientist; 12 described engineers as people who fix things; 42 responses displayed students' conceptions of engineers as people who build or make things; and 46 conceptualized engineers as designers (note, some responses fell into two categories).

Third, despite the fact that students were all engaged in engineering club activities, their conceptions varied substantially in sophistication. Some students did not recognize the term engineering despite their club participation. Some of the least developed conceptions of engineering came from sixth grade students whose answer to the interview question, "What do you know about engineering and what engineers do?" seemed to reveal that they were unfamiliar with the term "engineering" even though they were in an engineering club. For example, one student responded with the following:

Student: *They help people.*

Interviewer: *How do they help people?*

Student: *When they're hurt… And when you take them to the hospital.*

Or, as another student responded,

I could take a guess. I think it's about science and math and I think that's the only thing I know that it means something about math and science. You make stuff, build stuff.

This lack of conceptual development can be contrasted with one of the most sophisticated conceptions in an interview:

From what I know in my nine years of schooling, basically, engineering, for me, is just making things, making plans, creating things to make life and tasks more easier and efficient… Like a civil engineer, they work to make for an example, parking lots. They work to make parking lots more efficient so that there's less space wasted and more people can get around easier. Or, another engineer, an electrical engineer works to see if they can have more electricity flowing through a certain place and also have the least amount of safety – I mean the most amount of safety possible.

Thus, students varied significantly in the sophistication of their explicit conceptions of engineering, despite the commonality of their experience in an engineering afterschool club.

The fourth theme relates to our second research question of what influences students' conceptions of engineering. Students differed in whether their conceptions of engineering were influenced primarily by home experiences or by school experiences. An open-ended survey question asked students whether they did any engineering activities outside of their afterschool club. Of the 107 students who responded to this question, 64 indicated that they did not do any engineering activities outside of their afterschool club; 43 indicated that they did participate in engineering activities beyond the club. Although most students did not elaborate, 14 described activities they did at home. Most home connections were based on helping family members build or repair things (e.g., fixing cars, home repair, landscaping) or creating fun projects with family members (e.g., building rockets). They also reported working on engineering projects alone (e.g., "I break objects to see the mechanics," build or fix toys, program computers).

TABLE 1 STUDENT-IDENTIFIED STRUCTURES, PROCESSES, AND FUNCTIONS

Engineered Structures		*Processes*		*Functions*	
Type	*#**	*Types*	*#*	*Types*	*#*
Civil (buildings, water transportation, roads, dams, parking lots, bridges)	37	Build stuff Create, invent, design Fix, maintain	25 21 10	Improve on previous products	10
Mechanical (cars, trains, engines, turbines)	35	Study things	5		
Electrical (cell phones, I-iPod, computers)	17	*subprocesses* Use science	 9	Help people	6
Aerospace(airplanes, NASA satellites, Mars Rover, rockets**)	7	and/or math Make blueprints Make models or	 2	Make life easier	6
Biomedical (prosthetics**, medicines)	7	prototypes Do experiments Test/plan	2 3 3	Make the world better	3
Environmental (rainwater harvesting**)	1	Use tools Work as a team	2 2	Solve problems	4

*number of instances

TABLE 2. PROTOTYPICAL CONCEPTIONS OF ENGINEERS

Repair Person	*Scientist*	*Builder*	*Designer*
Fixes and maintains stuff	Studies stuff	Makes stuff	Invents and improves stuff
"With cars, some of them fix the engines or see what's wrong with it."	"They make new objects to study different topics, like if they're trying to study something, to get more evidence from a science experiment"	"They're scientists who build stuff, and who do experiments and help other people."	"Like a television. They've made it new over the years. First there was black and gray, and then they made it into color, and then into 3D. And like cells phones…"

Interview transcripts also revealed home influence, whether that influence resulted in a conception of engineer as designer, as in the following interview;

> *Well, I have a basic idea about what engineers do like there's different types of engineers. When I grow up I want to be, I'm planning on being an engineer, an aeronautical engineer. I guess there's like civic, civil, civil or civic engineers, that do road construction or bridges and I have a pretty general idea about what they do. I know engineers, they're basic engineers, their goal is to help solve problems in modern day, just fix things that should be fixed or improve upon things that we already have. Stuff like that. [My dad] used to be an engineer. He used to be an aircraft engineer.*

or resulted in a conception of engineering as mechanic, as revealed in this response to the question "What engineering activities do you do outside of the club?"

> *Fixing my bike; finding tools and fixing it…I change the tire like every month…And I help my dad do the cars; I give him the tools.*

School experiences of engineering were overwhelmingly club-related. In the open-ended survey question, only seven students reported doing any engineering activities in their other classes or in other outreach programs. The influence of engineering club activities was not explicit in most descriptions of engineering in student interviews. Most students' descriptions of engineering did not explicitly reference the collaborative engineering challenge activities with which they were engaged. Structures associated with club engineering challenges (windmills/turbines-3, rockets-3, prosthetic arms-2, water transportation-2, rainwater harvesting-1; Bridges-7) were included in only 10 interviewees' description of engineering (an equal number of interviewees explicitly referenced home influences in their description of engineering; there was no overlap among students who referenced home influences and those who mentioned structures associated with club design challenges). The majority of students did not include any club challenges in their descriptions of engineering. Much like the students' conceptions shaped by home experiences, students' conceptions shaped by club experiences varied in sophistication. The following is one of the most sophisticated conceptions of engineering that was explicitly shaped by club experiences of designing a windmill and a prosthetic arm.

> *Engineering has to do with science and physics and it's a lot of work and a lot of aerodynamics they have to go through for it. And you have to learn about gravity also because the project that we're doing when you learn about how gravity will work with – like with force pushing towards it (the windmill). And engineers figure out new ways how to make things work better for people in different ways, I guess. Like one of the projects that you can do in [our club] is a prosthetic arm. And they have already made prosthetic arms. And I think that's really cool because prosthetic arms have helped a lot of people, people who have been in war and their arms blew off or their legs. And other people who have just been born like that.*

Students varied in the extent to which they explicitly recognized the collaborative design challenges associated with the engineering club as engineering.

V. DISCUSSION

The results of this study indicate that many of the afterschool engineering club participants held misconceptions and limited conceptions of engineering and engineers. Despite their participation in engineering after school clubs that had been meeting at least once a week for at least six weeks, many students conceived of engineers as builders, repairpersons, or scientists. Few students identified more than two or three examples of things that engineers design, and many failed to include mention of any club challenges in their description of engineering.

That making and building and fixing were prevalent in students' conceptions of engineering may be an artifact of their general experience with the engineered world. When individuals pass by a construction zone, they are not likely to see actions associated with building than actions associated with designing. In the case of the participants in this study, these tendencies may be especially strong because few of their parents were engineers, but many of their parents were construction workers or mechanics. Thus, these conceptions of engineering were doubly reinforced by their experiences of the world. Previous research indicates that about a quarter of Americans conceptualize engineers as builders [14]; children's conceptions may map on to their parents' conceptions. Students' conceptions of engineering may also be related to their developmental trajectories. Building is a concrete activity that young students can easily picture in their head, whereas the act of designing is more abstract. Some middle school students may be yet be facile with abstract thinking. Finally, students' conceptions of engineering as building may be an artifact of their club participation. Students' misconceptions may be reinforced by prolonged attention to production processes if they are not preceded and followed by sustained attention to problem definition and idea generation processes.

Results of previous analysis indicated that these students were highly interested in engineering. They had joined the club out of interest and they reported enjoying the club activities [15]. We see these as positive signs, given the importance of growing interest in students' matriculating into STEM college majors. It appears that club participation was meeting at least one important goal or engineering education that makes a positive difference in sustaining long-term engagement in pursuing engineering careers. But sustaining effort towards engineering degree majors also requires knowledge and accurate conceptions of what engineering entails and there may be more work for engineering initiatives in this area.

It seemed to us that students' explicit conceptions of engineering were not as informed as they might be by their engineering club experiences. Informal observations of club meetings, as well as our previous experience working with and observing in these and similar settings, we tentatively suggest that the nature of students' club experiences were based largely around the building and testing aspects of the engineering process. Young students frequently try the first thing that comes to mind when asked to design and create a product. They spend little time with problem definition or idea generation, quickly moving into production. These students were involved in engineering in a concrete way. However, particularly for students who have limited or no contact with professional engineers, and for students whose exposure to engineering concepts and practices is largely limited to club experiences, these activities may not transfer easily to generalized conceptions of engineering and may not be reaching the student in terms of stimulating their association between the challenges and engineering as it is practiced in the larger world.

We also see positive value in some of students' non-standard views of engineering, particularly when those views were influenced by home and community experiences. For one, previous analysis indicated that students highly value opportunities to build things that the afterschool engineering club setting afforded. Thus, their conceptions of engineers as builders and makers may have supported their decision to join an engineering club. Additionally, when students come to engineering clubs with home experiences they identify as engineering-related, their identity as engineering club members and potential future engineers may be strengthened; particularly when the activities and practices they experience in the clubs match the conceptions they bring. Also, many students bring funds of knowledge [16] that apply directly to the skills and practices they will use in engineering club activities.

A. Limitations and Future Research

Doubtless, some of these results are an artifact of the research methods. Pre-post measures were not collected, so we cannot tell how much students' conceptions of engineering changed due to their participation in the after school engineering clubs, nor did we compare the responses of club members with non-club members. Future research should address these issues. Further analysis should also attempt to take into account individual differences such as which of the nine clubs an individual attended as well as other demographic variation.

Based in part on the findings reported here, we suggest that more scholarly attention needs to be paid to students' funds of knowledge [16] as they pertain to conceptions of engineering, particularly to funds of knowledge that are embedded in students' experiences and practices in their home communities. Understanding what students bring with them to engineering education settings might inform the design of engineering interventions, particularly of collaborative engineering design challenges.

We are curious as to the correlation between student's engagement in engineering practices and the formal cognitive conceptualization of engineering that students are able to articulate. Because we used open-ended survey and interview questions, there were few cognitive cues for students in the study materials as to what the researchers may have wanted in the way of a "correct" response. This was purposeful, as we did not want to lead students to our definition of engineering, for instance, by using research protocols that involve more recognition or pre-determined categorization strategies. Rather, we were interested in students' conceptions of engineering as it was potentially being shaped by their participation in engineering afterschool club experiences. It is likely that if pressed further, students would have revealed more conceptions of engineering that more closely resemble standard concepts and practices. Based in part on the findings reported here as well as on K-12 engineering frameworks [4,5], we are in the process of developing a scaled measure to assess students' conceptual knowledge related to engineering practices, including structures, behaviors (processes), and functions (purposes). An observational study comparing students' explicit conceptions of engineering and their actual engineering practices as enacted in club activities would also be a useful next step.

It is worth noting that in our data, references to persons for whom engineered products are designed (i.e., the voice of the customer) were rare, as were descriptions of engineering "habits of mind" such as systems thinking, creativity, and collaboration [5]. While these may have been internalized and assumed by students, or otherwise not uncovered through our research methods, it is also possible that the interdisciplinary nature of engineering, particularly its social aspects, may be getting lost in standards that emphasize the correlations between engineering and science practices. These are important issues for future research, given recent attention to engineering habits of mind.

B. Implications for Practice

Based on the findings of our study, we suggest that educators, researchers, and other K-12 engineering education stakeholders consider the following questions:

One, how can educators capitalize on the funds of knowledge related to engineering that students bring from their home communities? How can they use our understanding of these funds of knowledge to inform educational practice? One thing that might help is simply becoming more aware of what experiences are influencing students' conceptions of engineering and finding ways to capitalize on those experiences. Another idea is to expose students to community-based engineering projects, for instance, through books such as, William Kamkwamba's "*The Boy Who Harvested the Wind*," or through newspaper articles or other media sources. Such practices might help students broaden and deepen their conceptions of engineering and connect them to their own community practices.

Two, how can we help students construct more standard conceptions that match current K-12 standards and the real-life work of engineers? How can we do so without disrupting the autonomy and hands-on experiences that may be critically important for attracting students to engineering afterschool clubs [13]? Interjecting more cycles of doing and reflecting might facilitate this goal. Educators might, for example, consider reflection activities that can support transfer of students' hands-on building experiences. Public design critiques in which students present, defend, and elicit suggestions from peers about their works in progress might support such reflection.

Three, how can we help students transfer engineering design practices to conceptions of engineering to support their trajectories toward continued engineering studies, STEM majors, and STEM careers? Integrating brief descriptions of relevant information pertaining to engineering fields into the specification sheets for specific design challenges might help students make more explicit connections between their design challenges and the work of professional engineers. Design challenges need to convey the notion of what engineers do, how they do it, and why they do it (structures-behaviors-and functions). We have noticed that here are few resources accessible to young students that show clearly how engineers fit into the creation of the designed world and that facilitate appreciation for planning and design processes. K-12 engineering education stakeholders can make important inroads in the creation of such resources.

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Learning to Manage Uncertainty in Collaborative Engineering Design Projects:

Lessons from a fifth grade class

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***Abstract*—Collaborative engineering design projects are fraught with subjective uncertainty associated with task issues ranging from understanding math and science concepts, to manipulating technological and digital tools and evaluating design ideas. Also, engineering design projects are contexts in which uncertainty is likely to stem from social issues as students encounter unfamiliar sociocultural practices and as individuals with diverse histories, beliefs, motivations, expectations, and values attempt to share the small space of a classroom. This qualitative discourse analytic study relies on observations and interviews to examine how social and task uncertainty management varied across three groups of students engaged in a collaborative design project. Specifically we asked, (1) how do groups vary in their management of uncertainty during engineering design projects; and (2) how does variation in uncertainty management influence groups' design practices and products? Data were drawn from a larger project that took place over one-school year in an ethnically and academically diverse public fifth grade class in the U.S.**

Keywords—elementary school, engineering, design projects, uncertainty, uncertainty management, peer interaction

I. INTRODUCTION

Guided by communication and sociocultural theories, this qualitative discourse analytic study relied on observations and interviews to examine how students in one fifth grade class managed uncertainty experienced during collaborative engineering design projects. Taking the collaborative group as our unit of analysis, we focused on three four-member teams. Research questions guiding this exploratory analysis included: (1) How do groups vary in their management of uncertainty during engineering design projects?; and (2) How does variation in uncertainty management influence groups' design practices and design products?

II. BACKGROUND

Collaborative engineering design projects are fraught with subjective uncertainty associated with task issues ranging from understanding math and science concepts, to manipulating technological and digital tools and evaluating design ideas. Also, engineering design projects are contexts in which uncertainty is likely to stem from social issues as students encounter unfamiliar sociocultural practices and as individuals with diverse histories, beliefs, motivations, expectations, and values attempt to share the small space of a classroom. Thus, learning to participate in engineering design practices may require students to learn to manage feelings of uncertainty associated with engineering practices.

Subjective uncertainty is a state of mind, sometimes revealed in one's words or actions and sometimes not, associated with a judgment that one is confused about or unsure of something, either because one does not know or understand something that could be known, or because the "something" is inherently probabilistic, ambiguous, or unknowable. Uncertainty can also pertain to one's sense of not being sure of one's value judgment or preference. Feelings of uncertainty can induce a wide range of cognitive, affective, and behavioral responses. Cognitively, "[un]certainty can both empower and incapacitate" [1]. Uncertainty often prompts negative affective responses but can also induce positive emotions. Uncertainty can facilitate action, but it can also prohibit action [2].

Uncertainty has been recognized as an experience permeating design endeavors because of the inherent complexity and ambiguity of design processes [3-5]. Previous studies have identifies ways expert designers manage uncertainty [6-10] and the difficulties that college-level engineering students have managing uncertainty associated with task issues [11-13]. Little research exists on how expert designers or adult students manage social uncertainty in collaborative design contexts.

Previous analyses have indicated that fifth grade students experience much uncertainty as they participate in collaborative engineering projects and that this uncertainty creates communication challenges related to task, relational, and identity issues [14]. Students manage uncertainty through tactics for reducing, ignoring, maintaining, or purposefully increasing it [15]. Individuals vary in their propensities for managing uncertainty primarily in terms of their willingness and ability to acknowledge uncertainty and their range of strategies for managing uncertainty [16]. At the same time, social interaction can be a source and resource for coping with perceived probabilistic and evaluative uncertainty [17]. Thus, peer support is crucial for helping students enact management strategies in collaborative learning projects [18].

Fig. 1. Identify applicable sponsor/s here. If no sponsors, delete this text box (*sponsors*).

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In the current study, we are interested not only in how individuals manage uncertainty, but also in how groups manage uncertainty during the collaborative engineering design process. Previous researchers have argued that different sociocultural groups develop norms for how members are allowed to manage uncertainty, and what actions are expected and appropriate [19, 20]. Thus, this study is grounded in socially oriented theories of learning that focus on interactional patterns in collaborative learning groups [e.g., 21-23]. We conceptualize small groups of students collaborating on engineering projects as complex systems embedded in larger classroom systems and group members as interdependent self-regulating agents [e.g., 24-28]. Complexity theories emphasize the critical role of interactions in how systems unfold, causing us to consider the reciprocal interdependences of individual and social processes in shaping human activity [29].

III. Method

Data were drawn from a year-long research project in an ethnically and academically diverse fifth grade class in a suburban neighborhood in a public U.S. school. Students engaged in three collaborative robotic engineering projects across the year, switching group membership for each project. Only Project 3, the focal project for this study, can be classified as a design task. Groups were tasked to design, build, and program a robot to address an environmental problem. Three focal groups, each comprised of four members, were selected for close observation by the first author. Each group was diverse in gender, ethnicity, and academic achievement. Field notes and video recordings of each group were conducted across the 14 days of the design project. Multiple semi-structured interviews were conducted with the 12 focal students, and artifacts associate with the project were collected.

Our methods of analysis can best be described as involving an interpretivist qualitative approach [30, 31] with a focus on naturally-occurring discourse to characterize and compare patterns of uncertainty management in the three focal groups. Analysis was ongoing throughout data collection; field notes were expanded, usually within 24 hours after an observation, rough transcriptions were made, and memos created. We draw from interactional sociolinguistics because of its focus on how people construct the social significance of events they jointly create through their interaction, how individuals act and build on each other's actions, communicate their intentions and convey their interpretations of others' intentions in contextualized settings [32-35]. We also draw from communication theory to characterize interactions related to social and task uncertainty [3, 14]. Taking a page from Van Boxtel [36], we are analyzing each group's processes for managing social and task uncertainty as they (a) talk about concepts related to their engineering design project, (b) make elaborative contributions, (c) attempt to achieve shared understanding, and (d) make use of available tools.

Finally, we use cross-case analysis [37] to compare patterns of uncertainty management, individual learning (based on a coding scheme developed through consultation with content experts), and robotic products (based on evaluation by two expert reviewers) within and across groups.

IV. Preliminary Results and Next Steps

Although analysis is ongoing, we tentatively suggest that, over time, groups developed unique patterns of managing uncertainty. Learning in each group was situated in the specific context of that group [38] and was oriented around the goal of building robots successfully. Although the initial physical surroundings were much the same for every group, the social relations were unique to each group. As students participated in and contributed to communal activity, the members of a group co-constructed knowledge of what it means to do robotics and of how to do robotics. Through joint interaction, members also co-constructed practices for managing uncertainty.

Initial analysis suggests that the three focal groups can be characterized as having their own unique patterns for managing uncertainty, patterns that were shaped by both the propensities of the individual members and by the social interactions among them. Briefly, a pervasive pattern that emerged in the Water Washer Group was to disparage uncertainty and side with the most powerful group member. As a group, members exhibited a strong need for immediate consensus; the need to revolve social uncertainty seemed a strong motivator for action. Uncertainty management in the Recycling Rover group took the form of introducing and questioning new design ideas, acknowledging uncertainty by expressing doubt and checking understanding of group member's ideas. In the Trash Claw group a strong desire to learn exhibited by three out of four members was held in tension by a dynamic of vying for social and intellectual power by the two female group members. A need to resolve social uncertainty by one group member reinforced by another member's reluctance to acknowledge uncertainty inhibited the introduction and uptake of uncertainty and new design ideas.

Contrasting group patterns of uncertainty management revealed that the engineering design teams not only made use of different strategies to manage uncertainty, but they also managed uncertainty about different things. Members of the Water Washer group seemed to focus on gaining consensus about shared decisions about actions to be taken (i.e., What are you doing?), while the Recycling Rover group seemed more concerned about developing a shared understanding of their joint ideas (i.e., What are you thinking?) and the Claw Grabber group concentrated on reducing uncertainty related immediately presenting problems. Initial analysis suggests that groups differed also in the extent to which and the ways in which they used sketching to manage uncertainty. Further analysis will continue to explore this issue.

V. Discussion

Analysis is ongoing. Discourse analysis of the first two design sessions is complete, final group products have been evaluated by two expert reviewers, and initial themes have been identified. We are in the process of coding additional transcripts of group sessions and coding interviews for evidence of individual learning. We are continually comparing within and across groups.

Students' capacities to perform in small-group systems is not simply a matter of individual strengths or the quality of the sets of strategies individuals who comprise a group have developed, but also of the interaction among group members and between individuals and the academic task. Uncertainty management is dialogical, relational, and reciprocally influencing. As members of a collaborative engineering design group interacted, they provided feedback to one another, feedback from which individual agents learned, adjusting their behaviors on an ongoing basis.

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Pedagogical Application of RFID Technology for Hard of Hearing Children during Mathematics and Science Learning Activities

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***Abstract*—The purposes of this work-in-progress paper are to explore the effect of using RFID technology to assist hard of hearing children learning mathematics and science and the pedagogical implications of using RFID technology to maximize conceptual understanding of mathematics and science for hard of hearing children. Taking into consideration the children's visual learning characteristics, we present a system that uses RFID-tagged lab objects to help young hard of hearing children do operation task during exploration. The preliminary experimental results and the questionnaire results to evaluate the effectiveness of using this system are discussed. Perceived benefits to hard of hearing children up to ten years of age are presented. The use of RFID technology can enhance instructional opportunities for educators in teaching primary STEM and extend learning opportunities for deaf and hard of hearing students.**

Keywords—children; hard of hearing; RFID

I. INTRODUCTION

Hard of hearing children experience various difficulties in conventional mathematics and science instruction. Mathematics and science lessons involve technical terms and demonstrations to illustrate the concept being taught. The technical words may have no concrete referent. Hard of hearing children have less exposure to acquire the words from incidental learning. If hard of hearing children are unfamiliar with the meanings of some words, even non-technical terms, some comprehension will be lost. In particular, hard of hearing children with poor lexicon and limited knowledge are vulnerable to difficulties with acquisition of mathematics and science.

For hard of hearing children, amplification may or may not help sufficiently. Hard of hearing children may miss some words of a sentence or pieces of information of hands-on activities. When the children still try to understand previous concept, the instructor may move to the next concept. If the experience is repeated with missing auditory information, then comprehension will be seriously impaired. Although hard of hearing children can absorb some class lecture material to the extent they can by instructors' slides on presentations and writing on blackboard, the children have a fragmented view of what information that need to convey to all children. Hard of hearing children desperately need what has been said in class is repeated.

Several suggestions have been made in the literature on how to accommodate the difficulties experienced by deaf and hard of hearing students in inquiry-based science activities [10]. Physical manipulation of objects, combination of simplified text and explanations with pictorial or animated content, and additional practice on vocabulary and content graphic organizers are effective means to accommodate [1, 4]. Easterbrooks and Stephenson [2] suggested adding visual prompts, graphic organizers, and lower-level reading materials in the use of scaffolding.

The use of radio frequency identification (RFID) technology for creation of various educational interactive applications is possible [3, 11]. Augmenting the RFID tags with additional sensors could respond intelligently to people's needs [9, 8, 7]. Alex Pentland at MIT Media Lab had pioneered work in Smart Rooms that help users navigate cyberspace [8]. In recent years, the MIT Media Lab has started using RFID technology to help guide and track visitors to different exhibits when they are in the building.

Educators and researchers have looked for creative ways to assist deaf and hard of hearing children, and have paid attention to emerging instructional technologies. There are little studies that appear in the literature on the use of RFID technology in the education of deaf and hard of hearing children. Hancock, Parton and their research team [5, 6] developed a physical world hyperlinking teaching system using RFID-tagged toys to teach American Sign Language to deaf preschoolers. An initial set of 500 real-world objects with RFID tags were constructed to initiate instructional contents, such as a video of an individual signing that object's word, as well as several pictures of the object. Deaf preschoolers could not only practice their words, but also encourage their hearing parents to learn to sign as well.

II. METHODS

Taking into consideration the hard of hearing children's visual learning characteristics, we are developing a teaching system with RFID-tagged lab objects to help the young children do operation task and explore concepts during hands-on experiments. Each object in lab activities is equipped with a unique RFID tag to help the children learn how to use the materials and equipment needed and procedures to follow in an experiment. Make sets of RFID-tagged cards for children and introduce the steps of an experimental procedure, give demonstration experiments. Add technical words, even non-technical words, to RFID tags to explain their meanings. A small RFID interrogator is connected to a laptop computer which provides visuals, such as science experiment videos, pictures, illustrations, the schematic representations of concepts and relationships, or other references. When any of the objects is scanned, the embedded RFID tag thus triggers the system to launch a matching digital content on a computer screen. It gives children a visual clue what to do. The system can record and measure the frequency of use of the different RFID tags among individuals during the exploration, and thus the instructor may gauge the level of individual child comprehension of mathematics and science concepts.

The observations are from the science camp held by Yuan T. Lee Foundation Science Education for All, Taiwan. The foundation has began its Science Camp for Hearing Impaired Children since 2012. The camp has depended on volunteers to run all the math and science activities. A total of 20 subjects attending the camp, 12 males, 8 females, age range 7-10 years (grades 1-3) were chosen to participate in this study. Seven of them are pediatric cochlear implant recipients. Questionnaires regarding to situational hearing handicap are conducted.

III. PRELIMINARY RESULT

The hard of hearing children demonstrate an increase in positive behaviors, and in the motivation to learn. The children participate actively to the math and science inquiry activities. By using laptop computer with RFID technology, the children could not only practice mathematics and science vocabulary words but also facilitate acquiring and understanding mathematics and science concepts.

IV. CONCLUSION

RFID technology improves the hard of hearing children's learning experience in activities. Although the proposed system is at beginning stage of the development and the number of the hard of hearing subjects is small, it would increase participation in the math and science activities and promote active learning for hard of hearing children. The use of RFID technology can enhance instructional opportunities for educators in teaching primary STEM and extend learning opportunities for deaf and hard of hearing students.

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General Engineering: An Innovative Program for the Region

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***Abstract*—This paper describes the efforts of designing an innovative interdisciplinary general engineering program which was recently introduced as part of the newly shaped engineering department at the American University of Iraq in Sulaimani (AUIS). Current progress includes building a state- of-the-art science building that will accommodate the physics and chemistry laboratory, completing the construction of the engineering basement that will accommodate state-of-the-art laboratories to complement engineering fundamentals and capstone courses, and meeting staffing needs. The objective of the program is to create an ABET-accredited program that is unique to the region and serves the development of the region's economy and people. The paper describes the details of the general engineering program, curriculum development, laboratory facilities, experiences, faculty and staff needs. It also touches upon the theme of global engineer. A concluding section is offered that presents the development and implementation of such a program in a rapidly developing post-conflict society in the Kurdistan region of Iraq.**

Keywords—Curriculum Development; Engineering Education; General Engineering; Innovative Program; Post Conflict.

I. Introduction

The General Engineering curriculum at the American University of Iraq in Sulaimani (AUIS) is a non-specialized innovative interdisciplinary program offering a BS degree with no designation. The program is established with a sound theoretical base complemented by practical laboratory work to strengthen professional practice. AUIS was established in 2007 and currently has enrollment exceeding 500 students drawn from all regions of the country with a projected steady growth in the coming years. AUIS is situated on more than 400 acres of land and is Iraq's only private, not-for-profit university based on the American model of higher education, with all courses taught in English. There are also ambitious plans to begin adding degree programs in civil, mechanical, and petroleum engineering. Engineering computing was offered Fall 2012 for the first time.

The design of the general engineering program incorporates fundamental preparation associated with the traditional engineering disciplines (civil, chemical, electrical, and mechanical), includes a practical component in laboratory experiences to go along with course fundamentals, and presents capstone basics in the areas of design, economic evaluation and industrial practice. The program is also designed to house additional concentrations leading to postgraduate certificates in areas of focus of interest in the region, such as petroleum exploration and production.
Recent developments include completion of a state-of-the-art science building that houses the physics and chemistry laboratory, finishing up the engineering basement to house state-of-the-art laboratories to accompany engineering fundamental and capstone courses, and meeting staffing needs. The educational objectives of the engineering degree program are: 1) providing students with a broad, sound fundamental education in engineering and the sciences, 2) blending practice and design with the fundamentals to equip graduates with the skills needed to function in professional engineering careers, and 3) inspiring students to continue their education through graduate study and lifelong learning.

II. General Engineering Curriculum Design

The General Engineering Program is based on a one-year liberal core education plus three years of courses in science, mathematics and engineering fundamentals. Table 1 describes the general engineering degree curriculum with a total of 131 credit hours to complete.

The freshman year focuses on the liberal arts core curriculum with pre-calculus in the second semester of the freshmen year. The engineering segment of the degree program encompasses the sophomore, junior and senior years, which include a year of science, a year of engineering fundamentals, and a year of engineering design.
The senior year is intended to include a capstone on the general engineering degree program which includes the following courses:

1. Transport Phenomena – includes heat transfer
2. Engineering Economics – covers economics and business methods for engineers
3. Technical Writing – a technical communications course
4. Design – a capstone course intended to include collaboration with industrial customers
5. Engineering Laboratory – a capstone course that includes a design and build project
6. Introduction to Petroleum Engineering – an introductory course to petroleum exploration
7. Material Science – includes a practical lab component

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The diverse educational and cultural backgrounds of AUIS students, with English being their second or third language, focus on industrial internships, and the nature of the design year ought to strengthen AUIS students develop much sought after skills of global competence. [1]

TABLE I. GENERAL ENGINEERING DEGREE CURRICULUM

Freshman Fall			Freshman Spring	
Life Science	3		Physical Science	3
English Composition and Public Speaking I	3		English Composition and Public Speaking II	3
College Algebra	3		Pre-Calculus	3
Computer Science and IT Applications	3		Core Option 1, Humanities	3
Civilization: Ancient	3		Civilization: Medieval	3
SEMESTER TOTAL	15		SEMESTER TOTAL	15
Sophomore Fall			Sophomore Spring	
Calculus I	4		Calculus II	4
Physics I	4		Physics II	4
Chemistry 1	4		Chemistry II	4
Engineering Computing	3		Engineering Geology	3
Civilization: Early Modern	3		Civilization: Modern	3
SEMESTER TOTAL	18		SEMESTER TOTAL	18
Junior Fall			Junior Spring	
Calculus III	4		Differential Equations	3
Mechanics I – Statics	3		Mechanics 2 – Dynamics	4
Thermodynamics	3		Fluids	4
Circuits	4		Electronics	3
Engineering Graphics	2		Mechanics of Materials	3
SEMESTER TOTAL	16		SEMESTER TOTAL	17
Senior Fall			Senior Spring	
Linear Algebra	3		Design	4
Engineering Statistics	3		Engineering Laboratory	4
Transport Phenomena	3		Introduction to Petroleum Engineering	3
Engineering Economics	3		H&SS Elective	3
Technical Writing	3		Material Science	3
SEMESTER TOTAL	15		SEMESTER TOTAL	17

III. CHARACTERISTICS OF A GLOBAL ENGINEER

Over the past several decades, the world has seen significant developments in and progress in technology, multinational corporations, free trade agreements, and newly developed regions that were previously off limits. These developments have increased global connectedness, making for an interdependent world and a globalization of the workforce. As an excellent example of globalization in engineering, the design of the Boeing 787 Dreamliner incorporates subcontracted assemblies from all over the world such as:

- wing, Mitsubishi (Japan)
- horizontal stabilizers, Alenia Aeronautica (Italy)
- wingtip, Korea Aerospace Industries (South Korea)
- Aft fuselage, Boeing (USA)
- passenger doors, Latécoère (France)
- cargo access and crew escape doors, Saab (Sweden)
- software development, HCL Enterprise (India)
- wiring, Labinal (France)
- tail fin, Boeing (USA)
- movable trailing edge, Boeing (Australia)
- landing gear doors, Boeing (Canada)
- main cabin lighting, Diehl Luftfahrt Elektronik (Germany)
- engines, Rolls-Royce (England)
- engines, GE (USA)

It is evident from the above list that the Boeing 787 Dreamliner is a globally developed and assembled product. The major subassemblies are from all over the world, and managing a project of this magnitude requires engineers with a broad set of competencies, capable of managing a global supply chain.

Parkinson [2] addressed what it means for engineering graduates to have global competence and identified 13 features as follows:

1. can appreciate other cultures
2. able to communicate across cultures
3. familiar with the history, government, and economic systems of several target countries
4. can speak a second language at a conversational level
5. can speak a second language at a technical level
6. proficient working in or directing a team with ethnic and cultural diversity
7. can effectively deal with ethical issues arising from cultural or national differences
8. understands cultural differences relating to product design, manufacture, and use
9. has an understanding of the connectedness of the world and the workings of the global economy
10. understands the implications of cultural differences on how engineering tasks might be approached
11. has some exposure to international aspects of topics such as supply chain management, intellectual property, liability and risk, and business practices
12. has had a chance to practice engineering in a global context, whether through an international internship, a

project, or some other form of experience
13. views one's self as a "citizens of the world," as well as of a particular country

Moreover, since it might not be possible to develop all of these features in an already crowded engineering curriculum, Parkinson[2] further surveyed university administrators and faculty and representatives from industry and governments, offered some preliminary results based on a sum of five rankings. The most significant features of global competence were:

1. can appreciate other cultures
2. proficient working in or directing a team with ethnic and cultural diversity
3. able to communicate across cultures
4. has had a chance to practice engineering in a global context
5. can effectively deal with ethical issues arising from cultural or national differences

The senior year of the general engineering curriculum is designed to incorporate a capstone experience calling for active engagement in practical learning of engineering work through direct collaboration with industrial customers on design problems. Some of the most significant features of global competence, such as proficiency working in or directing a team with ethnic and cultural diversity and the ability to communicate across cultures, fits well within the capstone context since most of AUIS student come from multicultural backgrounds. Also, many of the engineers working in companies in the region are foreign nationals, so student design teams collaborating with industrial customers might also learn to effectively deal with ethical issues arising from cultural or national differences while working on their capstone projects.

IV. Laboratory Facilities

Figure 1 below shows the actual layout of the engineering laboratory facilities currently being constructed in the basement of the Academic building. Descriptions of each of the rooms are also provided below the figure.

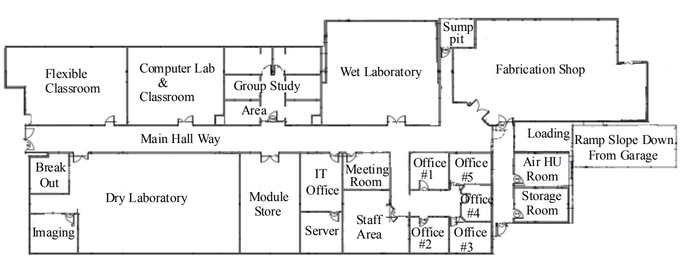

Fig. 1. Layout of Engineering Laboratory Facilities

Flexible Classroom used as a close, convenient classroom equipped for student demonstrations and presentations.

The Computer Lab & Classroom will be equipped with computers and software for computer-aided-design and data analysis

Dry Laboratory boasts generic labstations with test equipment, computers and data acquisition instruments to support courses with experiments such as circuits and electronics

Wet Laboratory includes fixed equipment for experiments in fluids, thermodynamics, and transport phenomena. It also includes a fume hood.

Group Study Area includes small conference rooms for four to six students with computers and whiteboards

Fabrication Shop has a separate student area, staff area, wood shop equipment, machine shop equipment, and prototyping equipment.

Module Store will be used for storing portable experimental modules on shelves that can be placed on carts and moved to the Dry Lab to customize labstations for specific uses.

Staff Area includes offices for administrative, IT, and other support staff.

V. Staffing Needs

Proper staffing has to be put in place in order to support and maintain all the course components of the general engineering degree curriculum. Once the program is fully deployed, the physics and chemistry sequences will require at least two teaching assignments per semester, along with several science laboratory support staff. The mathematics sequence will require at least three teaching assignments per semester.

The engineering sophomore year requires one teaching assignments in the fall and one teaching assignment in the spring. The junior year requires four teaching assignments in the fall and four teaching assignments in the spring. The senior year requires three teaching assignments in the fall and four teaching assignments in the spring. Furthermore, there is the need for two support staff for the engineering laboratory.

In the senior year, there are two further teaching assignments needed, one in the fall for technical writing and another in the spring for a humanities and social sciences technical elective course.

The total instructional load per semester for the engineering courses would be eight teaching assignments in the fall semester and nine in the spring semester for engineering faculty members.

The required teaching assignments for math, science, and engineering may double if classes are subdivided a result of increased enrollment in the general engineering program.

VI. Conclusion

This paper illustrated the efforts of implementing a general engineering curriculum at AUIS. There are numerous General Engineering programs in the United States and around the world that offer Bachelor of Science degrees without a specific designation that produce well sought-after engineering graduates. The multidisciplinary program at AUIS offers students design experience through professional practice, which should help them to attain some of the most significant features of global competence. The engineering program at AUIS includes a rigorous theoretical education in fundamental engineering science and mathematics, complemented with practical laboratory work, communication and teamwork skills to satisfy an industrial capstone project.

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Cell2ECG: A virtual laboratory to simulate cardiac electrograms

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Abstract—**Engineering approaches to indentify and reverse electrical instabilities of the injured heart have lead to innovative diagnostic and therapeutic solutions. Therefore, curricula of Biomedical Engineering (BME) courses include cardiac electrophysiology. This paper describes a virtual laboratory designed for the study of the generation of the electrocardiogram (ECG) based on cellular electrophysiology. In detail, the virtual lab includes (1) an equivalent source model for cardiac cells, (2) a formulation of the mathematical relationship between the transmembrane potential and the transmembrane current, (3) the determination of resulting extracellular potentials, and (4) the calculation of the ECG by a weighted summation of transmembrane currents. Since these tasks require specific presumption and knowledge concerning cardiac geometry, a geometrical model was constructed using anatomical stylized segments of the left ventricle. Propagation parameters control the activation sequence as well as velocity and direction for anisotropic conduction. In order to verify the developed models and algorithms simulation results were compared against experimentally obtained data under various physiological conditions. Although there is considerable scatter in the measurements, the comparison indicates that a definite relationship exists between measured and computed waveforms. Simulations interactively show physiological and pathophysiological changes in the ECGs for various user setting of the cell function. In conclusion, the interactive laboratory enables the user to study the relationship between the electric activity of cardiac cells and the resulting extracellular potentials including the ECGs on the body surface. Students increase their knowledge of cardiac electrophysiology, applied electrical circuit theory and the understanding of differential equations as well as numerical methods for solving them.**

Keywords—Biomedical Engineering, virtual laboratory, simulation, heart model, electrocardiogram

I. INTRODUCTION

Engineering approaches to indentify and reverse electrical instabilities of the injured heart have lead to innovative diagnostic and therapeutic solutions. Therefore, curricula of BME courses include cardiac electrophysiology to provide a framework for understanding the genesis of the electrical signals themselves. In contrast to other engineering disciplines, experimental approaches in BME require noninvasive and invasive procedures on living systems. Thus, computer modeling is an essential tool for describing and analyzing biological systems [1]. One of the major challenges to teaching cardiac electrophysiology is gaining an understanding of the link between the electrocardiogram (ECG) and cellular electrophysiology. This paper describes a virtual laboratory, called Cell2ECG, and related projects, designed to simulate the genesis of cardiac electrical potentials under various physiological and pathophysiological conditions. The interdisciplinary approach of Cell2ECG includes cardiac electrophysiology as well as electrical circuit theory, mathematics and software development.

II. CONCEPT

The prediction of the ECG on the body surface requires knowledge of (1) cellular basics of electrical activation in the heart; (2) the sequence of these activations; (3) geometry and conductivity of the heart; and (4) a biophysical model describing current flow in the heart and current flow from the heart, through the intervening tissues, to the body surface. Therefore, Cell2ECG specifically incorporates

- a geometrical model of the heart,
- a biophysical model of an equivalent source generator,
- a simulation tool for action potentials (APs), and
- a simulation tool for specifying the propagation of electrical excitation in the heart.

In addition, a database of experimental data [2] is included in order to validate the results of the simulation. Based on these modules, the students are required to complete three experimental projects to estimate (1) a transmembrane current, (2) an extracellular potential, and (3) an ECG.

In contrast to more sophisticated simulations [3-5], the simple mathematical theory of the model allows [6] the

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students to implement a numerical solution for these projects. The simulation tools are based on LabVIEW/Mathscript, since it provides access to powerful programming and visualization functions and the students have had previous experience in this environment. The modular structure of the tools allows it to be easily modified or extended to other projects that are related to cardiac electrophysiology. Therefore, Cell2ECG should encourage active learning, group discussion, and problem solving skills.

III. MODELLS AND SIMULATION TOOLS

A. *The Heart Model*

The model is focused on the left ventricle (LV) since the effects of the right ventricle are not essential for understanding the genesis of the ECG. According to a modification of the Solomon-Selvester model [7], the LV is divided into three levels (apical, middle and basal) and four sections (quadrants) resulting in 12 segments (Fig. 1). Each of these 12 segments consists of endocardial, mid-myocardial, and epicardial layers of identical cells.

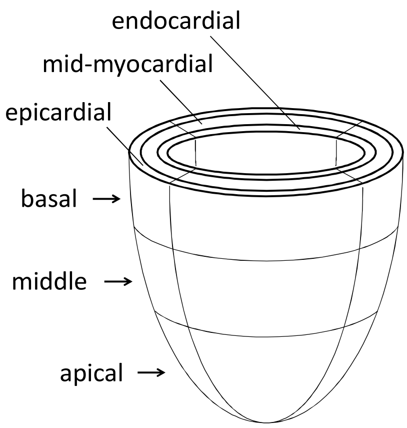

Fig. 1: Model of the left ventricle (LV). The LV is divided into quadrant-segments in the apical, middle, and basal level in accordance with the International Society of Computerized Electrocardiology (ISCE) nomenclature of myocardial wall segments [7]. All 12 segments are assemblies of endocardial, mid-myocardial, and epicardial layers.

B. *The Source Model*

For each segment of the heart model, an endocardial, mid-myocardial, and epicardial layer was approximated by a two-dimensional sheet of electrically coupled elements. Each element is modeled by a 2D-repetitive network of length Δx and Δy with the current source Im (transmembrane current) as described by the core-conductor approximation [8]. The network topology allows parameters governing propagation to be addressed easily and avoids computationally burdensome modeling. For the sake of mathematical simplicity and without losing the conceptual basis, Fig. 2 illustrates the one-dimensional case.

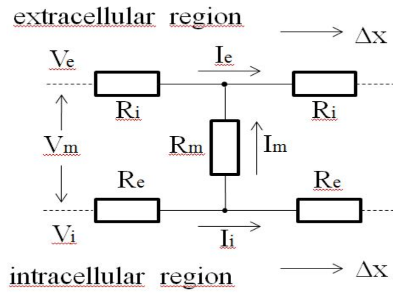

Fig. 2: Equivalent circuit of an element. Potential, resistance, and current are expressed per unit length Δx. Currents Ii and Ie are driven by the potential gradient Vm= Ve-Vi.
Vi, Ve: intracellular and extracellular potential, respectively
Ri, Re: the intracellular and extracellular potential, respectively.
Ii, Ie: intracellular and extracellular current, respectively
Vm: transmembrane potential
Im: transmembrane current

According to Fig. 2, the intracellular and extracellular current, Ii and Ie, respectively, are driven by potential gradients, so that,

$$Re \cdot Ie = \partial Ve/\partial x \quad (1)$$

$$Re \cdot Ii = \partial Vi/\partial x \quad (2)$$

where Ri and Re stand for the intracellular and extracellular resistance, respectively, and Vi and Ve for the intracellular and extracellular potential, respectively. By definition,

$$Vm = Ve - Vi \quad (3)$$

Taking the derivative on both sides of (1) and (2) produces,

$$Re \cdot Ie = \partial^2 Ve/\partial x^2 \quad (4)$$

$$Ri \cdot Ii = \partial^2 Vi/\partial x^2 \quad (5)$$

Since the total current must be preserved per unit length, the change in Ii and Ie must precisely equal the transmembrane current, Im (application of Kirchhoff's current law). In mathematical terms,

$$Im = \partial Ie/\partial x \quad (6)$$

$$Im = -\partial Ii/\partial x \quad (7)$$

Replacement of (6) and (7) in (4) and (5), respectively, yields,

$$Re \cdot Im = \partial^2 Ie/\partial x^2 \quad (8)$$

$$Ri \cdot Im = -\partial^2 Ii/\partial x^2 \quad (9)$$

Summation of (8) and (9) and recalling (3) leads to,

$$Im = 1/(Re+Ri) \cdot \partial^2 Vm/\partial x^2 \quad (10)$$

Including the extracellular current flow in the y direction, superposition of both results in,

$$Im = 1/(Re+Ri) \cdot [\partial^2 Vm/\partial x^2 + \partial^2 Vm/\partial y^2] \quad (11)$$

Thus, the transmembrane current density is directly proportional to the second spatial derivative of the transmembrane potential.

C. Simulation of APs

The transmembrane potential remains constant (resting membrane potential) without exterior influences. However, as the result of a local stimulus, an action potential (AP) is generated by the cell. In order to simulate the transmembrane current in the equivalent source model an estimation of the transmembrane potential, in particular for the AP, is required (11).

As proposed by [9] APs were composed using a parameterized AP profile where separate components control the initial upstroke (phase 0), the immediate fast repolarization and the AP plateau (phase 1 and 2, respectively) as well as the repolarization part (phase 3). In this way, APs were assigned individually to the cells of specific layers. The software enables the student to specify or modify the AP shape interactively, including the timing of depolarization and repolarization (Fig. 3).

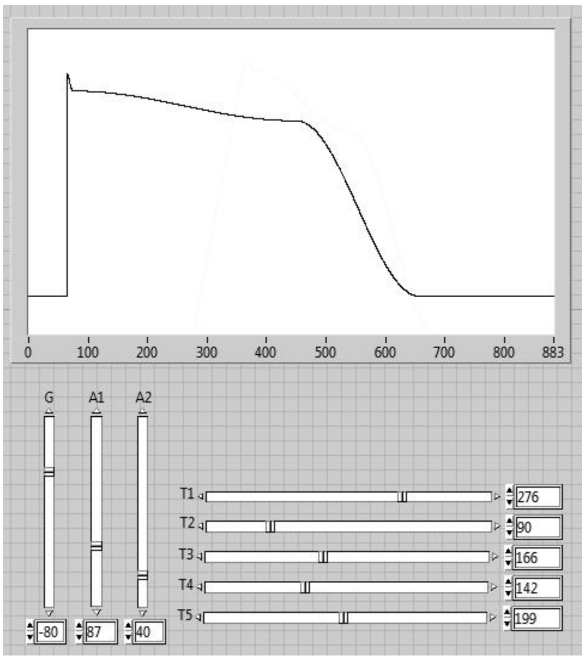

Fig. 3: Menu for interactive parametrization of APs. The scaling factors andtime constants relate to the different phases of the AP.

Differences between epicardial, mid-myocardial and endocardial cells are primary related to the AP duration as illustrated in Fig. 4.

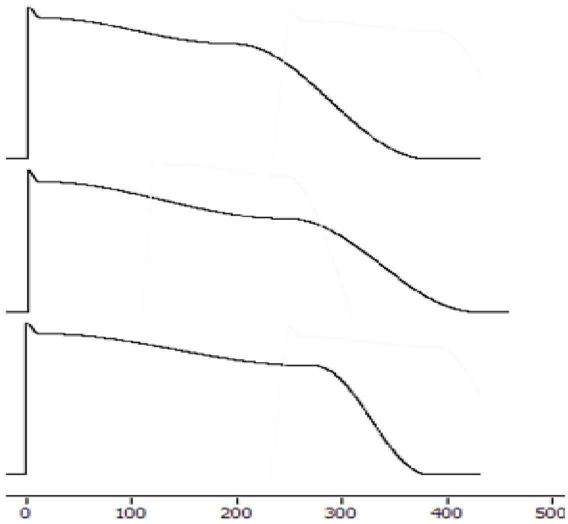

Fig. 4: Simulated APs assigned to epicardial (top) , mid-myocardial (middle) and endocardial (bottom) layers. The AP durations, given at 90 % repolarization (APD90) are 350 ms at the endocardium, 380 ms at the mid-myocardium, and 340 ms at the epicardium. The scale of amplitude for APs is arbitrary but normalized for all APs.

D. Simulation of Activation Sequence

The activation time (AT) represents delay between the start of myocardium excitation and activation of each individual element, and controls the activation sequence. The excitation starts at the endocardial layer and spreads through the mid-myocardium and the epicardium. Timing of activation may be changed interactively using a provided graphical user interface (GUI) as depited in Fig. 5.

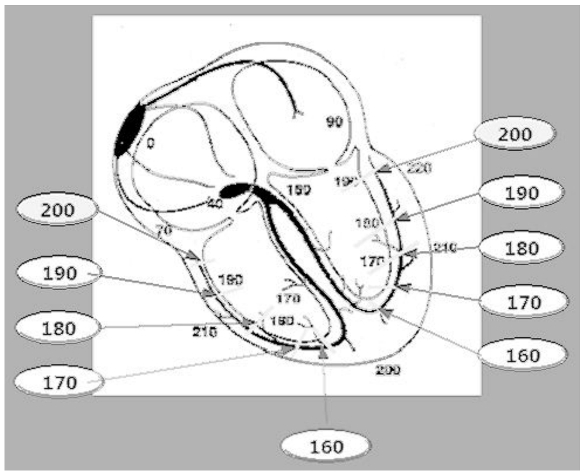

Fig. 5: GUI for interactive selection of activation times. The schematic drawing of a cross section of the heart represents the pathway of myocardial excitation starting at the endocardial layer and spreading through the mid-myocardium and the epicardium. Numbers indicate the activation time.

IV. PROJECT APPLICATIONS

A. Framwork

The subsequent projects are devoted to studying and understanding basic problems in cardiac electrophysiology related to (i) the estimation of transmembrane currents, (ii) the characterization of extracellular potentials, and (iii) the interpretation of the ECG on the body surface. The application of Cell2ECG requires knowledge of the physiology and anatomy of the heart, the understanding of cellular electrophysiology and a mathematical background for differential equations as well as numerical methods for solving them. After an introduction to the concept of Cell2ECG, students are required to reproduce the mathematical description of the equivalent source model as developed in (1)-(11). In contrast to other approaches [3-6], the numerical implementation of the source model is an essential step in the learning process. In order to verify the models, simulation results are compared against experimentally obtained data under various physiological conditions as provided by the database. For each project, a report is delivered consisting of derivations, physiological interpretation, figures, tables, programming code, results and discussion.

B. Estimation of the Transmembrane Current

Using (11), transmembrane current in an endocardial, mid-myocardial, and epicardial layer must to be determined. Specific aims include the investigation of the influence of the intracellular and extracellular resistance. A typical example of a simulated and an experimentally obtained transmembrane current is shown in Fig. 6.

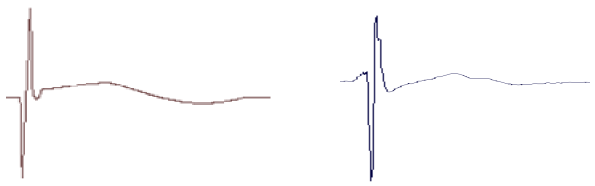

Fig. 6: A comparison of simulated (left) and experimentally obtained (right) transmembrane currents. Differences may be caused in part by the contributions of distant sources (far field effects). Scales arbitrary but normalized for both traces.

C. Estimation of Extracellular Potentials

The extracellular potential V(x,y) for a transmembrane current source, Im, is related to the distance r between the current source and the observation point [8]. In the two-dimensional case, the superposition principle for multiple linear current sources leads to

$$V(x,y) = \frac{Re}{\pi} \sum \frac{Im}{|r|} \quad (12)$$

where Re is the extracellular resistivity.

Besides assigning an AP, activation times need to be defined for each element. Specific aims include the investigation of the effect of the intracellular and extracellular resistance as well as the influence of the number of elements used for the simulation. Fig. 7 provides an example of a simulated and an experimentally obtained extracellular potential.

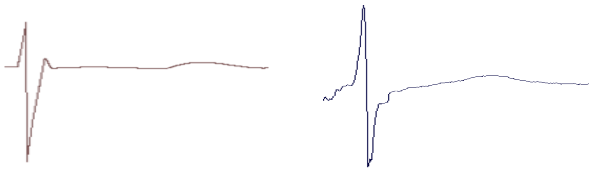

Fig. 7: A comparison of a simulated (left) and an experimentally obtained (right) extracellular potential. Significant differences may be due in part to the fact that the wavefront in the model is assumed to be planar and propagating with uniform conduction velocity. Scales arbitrary but normalized for both traces.

D. Simulation of the ECG

Extending the approach of Project 2, the simulation of extracellular potential will include current sources from all segments of the LV. For this purpose, APs and activation times are assigned and a representative current source is calculated for the center element of an endocardial, mid-myocardial,and epicardial layer in each segment. Assuming a homogeneous volume conductor, the ECG is obtained by the weighted sum of these representative current sources with reference to the distance between current source and observation point (12). Specific aims include the investigation of the relevance of the AP shape as well as the activation sequence. As Fig. 8 reveals, simulation leads to similar waveform morphologies observed in the experimentally obtained data.

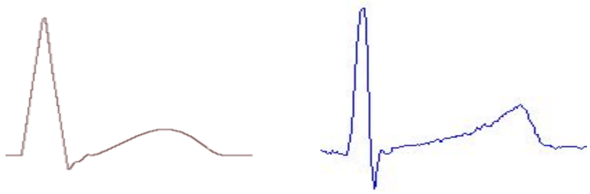

Fig. 8: A comparison of a simulated (left) and an experimentally obtained (right) ECG. The discrepancies were accounted for by variations in the AP shape and the activation sequence. Scales are arbitrary but normalized for both traces.

E. Effects of Cardiac Ischemia

In order to simulate the effects of epicardial ischemia on the ECG, the epicardial AP was modified as shown in the upper panel of Fig. 9. The severity of the ischemia can be modeled by an increase in the resting potential and a shortening of the duration of the AP plateau in the affected layer of a specific wall segment. The corresponding elevation of the middle part of the simulated ECG (lower panel) is related to the changes in the plateau of the epicardial AP. Similar effect can be demonstrated by modifying the endocardial AP.

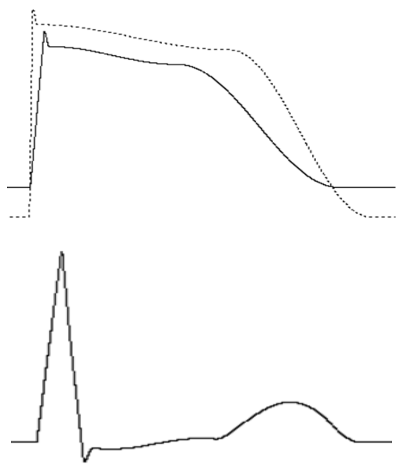

Fig. 9: Upper panel: Simulations of epicardial APs from normal (dotted line) and ischemic myocardium (solid line). Lower pabel: Simulated ECG corresponding to the ischemic epicardial AP. For reference see Fig. 8.

V. DISCUSSION

Cell2ECG provides a concept for an interactive simulation program that enables the user to study the relationship between the electric current sources of the heart and the resulting electrocardiographic signals on the body surface. A primary goal of the projects is for the student to gain proficiency in developing a mathematical description as well as a numerical implementation of the equivalent source model.

Comparison testing of Cell2ECG shows simulated and experimentally obtained data reveal quite similar waveforms. Furthermore, discrepancies were accounted for in the simple heart model due to the assumption of an infinite homogeneous volume conductor. A more accurate approach would have been to calculate the ECG from each point in the heart model. However, this would dramatically increase the complexity of the model and require a significant increase in the number of computations. This reduces the effectiveness of the simulation as a learning tool. At the designed level of complexity, it is hoped that the proposed projects will cultivate the student's interest in the analysis of physiological systems as well as in computational modeling, encouraging further study of more in-depth models.

In summary, Cell2ECG represents a simulation platform for electrical activities of cardiac cells, which provides a tool to examine the mechanisms underlying the genesis of the ECG under various physiological and pathophysiological conditions. It aims to serve as an educational tool and as a research tool as well, such as analysis of slow conduction in the infract border zone, simulating ECGs under ischemic circumstances, or during ectopic activation. The modular structure of Cell2ECG permits easy modification or expansion by adding more function to the defined menus, for example adding visualization of the activation sequence synchronously with the ECG waveform generation.

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Interactive Tools for Global Sustainability and Earth Systems: Sea Level Change and Temperature

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***Abstract*—Understanding global change is important for creating a sustainable environment, and is a key interest of the Earth systems science community. Here we present an educational tutorial that explores the relationship between sea level and global temperature using modern-day records and time-series analysis and the *Java-DSP Earth Systems Edition (J-DSP/ESE)* application. The objectives of the tutorial are to apply pre-processing steps based on signal type, perform spectral analysis and identify significant frequencies, perform coherency and cross-phase analysis between two records, and arrive at an informed understanding about the relationship between sea level and global temperature change. Preliminary student assessment indicates that students were comfortable using *J-DSP/ESE*, and quickly understood the signal processing concepts. The analysis reveals correlation between sea level variations and global temperature at inter-annual timescales related to the El Niño climatological phenomenon. In sum, the tutorial improved students' understanding of basic factors that influence global sustainability and habitability.**

Keywords—Earth signals, Java-DSP, multidisciplinary education, global sustainability, time series analysis.

I. Introduction

Global change science investigates the physical, chemical and biological processes that regulate the Earth's surface systems. A fundamental objective of the science is to understand the effects of anthropogenic activities on Earth systems. Primary among these are the consequences of elevated Earth surface temperatures on the global sea level. With rising Earth surface temperatures, the oceans are expected to experience thermal expansion and mass contributions from an ablating cryosphere. Quantifying the relationship between sea level and global warming is fundamental to forecasting future changes.

The Intergovernmental Panel on Climate Change (IPCC) [1] reported that over the latter half of the 20^{th} century ocean temperatures and sea level increased, both with significant interannual variability. Over the 20^{th} century there was an average sea level rise of 1.8 ± 0.5 mm/year, with evidence for acceleration to 3.1 ± 0.7 mm/year from 1993-2003 [2]. This rise is attributed to thermal expansion of the oceans and mass contributions from melting glaciers, the latter becoming the dominant source for sea level rise late in the century. Thus far, the polar ice sheets have not been considered by the IPCC to be major contributors to recent sea level rise.

Projecting forward with these estimates, sea levels will rise another 0.18 to 0.31 meters by the end of the 21^{st} century. However, the acceleration of global warming would mean that the rise could be greater, a 0.26 to 0.59 m rise by 2100 for "business as usual," and could even exceed 1 meter if polar ice sheets start to melt faster [3]. The new book, "Rising Sea Levels: Past, Present, Future" [4] explains the implications of sea level rise on modern society. The problem arises from the increased incidence of higher high tides and storm surges riding atop an elevated sea level. Thus, if sea level rises only 0.5 m, many of the world's largest cities, which are preferentially situated along coastlines, will be affected; a 5 m rise could affect ~670 million people, and a 10 m rise as many as 871 million. This is a significant change in society's habitable zone that needs to be anticipated by governments around the world, and ideally ameliorated through concerted reduction of anthropogenic activities and emissions contributing to global warming and climate change.

The tutorial presented here examines the global warming - sea level link through multivariate time series analysis of the global temperature and sea level records. While both global temperature and sea level have been increasing, it is not possible to ascribe causation based simply on linear trends. Numerical modeling is needed to demonstrate how added energy from global warming melts an ice sheet or thermally expands an ocean. Time-series analysis, such as that carried out in this tutorial, provides other, key empirical constraints. The global temperature and sea level records have strong inter-annual variations, which will allow the identification of lead and lags between the records, from which a determination of forcing and response time may be inferred.

II. CRITICAL SIGNALS OF GLOBAL CHANGE

2.1 The Global Temperature Record

The global temperature record consists of monthly-mean temperature data that are averaged over 5ºx5º (longitude, latitude) grids from more than 3000 stations. The data are preprocessed to remove the seasonal cycle and biases from stations at different elevations, and presented as a "temperature anomaly" record. Today there are now independent versions of the global temperature record; much of the contributing station data is the same, but the processing techniques and decisions are different [5,6]. The HadCrut3 temperature anomaly record [7] is used in this study (top curve in **Fig. 1**).

2.2 The Global Sea Level Record

Global sea level records are constructed from tidal gauge measurements and satellite altimetry [8,9]. Tidal gauges have been in operation since the early 1800's; sea level measurements from satellite altimetry have been available since 1992. The combined TOPEX-Jason 1 and 2 satellite altimeter record [9] with seasonal components removed is used in this study (middle curve in **Fig. 1**).

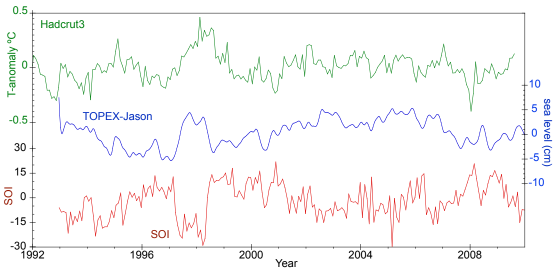

Fig. 1. Critical global change signals, 1993-2010. Top: the Hadcrut3 global temperature record, sampled at Δt=0.0833 years [7]. Center: the TOPEX-Jason satellite altimeter measurements of global sea level sampled at Δt=0.0272 years [9], low-pass Gauss-filtered over f=[0,4 cycles/year]. Bottom: the Southern Oscillation Index (SOI), sampled at Δt=0.0833 years [10].

2.3 The El Niño-Southern Oscillation

The El Niño/Southern Oscillation is a coupled ocean-atmosphere system in the tropical Pacific that generates interannual climate variability at the global scale, related to the Southern Oscillation and the atmospheric pressure difference between Tahiti and Darwin [10]. The variability carries over to both global temperature and sea level change [5,9] (compare the different curves in **Fig. 1**), but the phasing of the variations among the three processes is unknown, and is to be determined in this tutorial.

III. GLOBAL CHANGE ANALYSIS WITH J-DSP/ESE

3.1 The J-DSP/ESE standalone application

Java-Digital Signal Processing (J-DSP) is a web-based, platform-independent, visual programming environment that enables users to perform signal processing calculations and simulations. J-DSP was built from the ground up in Java to provide free and universal access to an array of signal processing functions that can be used for research and education. Signal manipulation functions appear in J-DSP as "blocks" that are brought into the simulation environment by a drag-n-drop process. Signal and data flow is established by linking the blocks. Original J-DSP functionality targeted engineering algorithms for signal processing, imaging, controls, time-frequency analysis and communications applications, and is currently used as an online Java-applet for undergraduate education [11].

A standalone version, *J-DSP/Earth Systems Edition (J-DSP/ESE)*, was developed with functions for input/output, interpolation, re-sampling, windowing, filter design, univariate and multivariate spectrum estimation, and time-frequency analysis, customized for the analysis of Earth signals. A full description of *J-DSP/ESE* appears in Ramamurthy et al. [12]; the application workspace is displayed in **Figure 2**. The application is free and available for download at (http://jdsp.engineering.asu.edu/jdsp_earth/index.html). Here *J-DSP/ESE* is used to perform univariate and multivariate time series analysis on the critical global change signals presented above.

3.2 Artificial test case

Figure 2 illustrates functions that are applied in this tutorial. Two test series of length 1000 with a uniform sample rate of Δt=1 are defined (t =nΔt, n=1,2,…,1000):

$$data1(t) = \sin(2\pi t/10)+n_1(t)$$
$$data2(t)= \cos(2\pi t/10)+n_2(t)$$

Simple periodograms (parameters set to single-frame, rectangular) of these time series are very similar, with a spectral peak at f = 0.1. Time-wise, data2 could be considered to lead data1 by a quarter-cycle, i.e., phased by 90º, consistent with the sine-cosine relationship. To examine this in the spectral domain single-frame coherency analysis is performed, with data1 input first ("top branch"), and indicates a peak at f = 0.1, where cross-phase registers -90º. Thus, in the J-DSP/ESE coherency function, negative cross-phase indicates that data2 leads data1.

Fig. 2. Workspace of J-DSP/ESE showing periodogram and coherency analysis of two test series data1 and data2.

3.3 Global change spectra

A first important step in comparing these critical global change signals is to characterize their spectra. This is accomplished with periodogram analysis. Here, the simple (single-frame) periodogram is used to calculate univariate spectra of the three records. All three records share a common trait, namely, large-magnitude inter-annual variations (i.e., cycles longer than 1 year); visual inspection of **Figure 1** suggests that many of the recorded variations are common among them. Thus, the frequency band f=[0,1 cycles/year] is expected to have most of the power in these records, and is the focus of this exercise.

The time interval 1992.96-2009.92 is examined, which is a common interval for all three records. The sample rates of the records are different (**Fig. 1**), and so are resampled to uniform Δt=0.02 years. Means and linear trends are subtracted. Each record is zero-padded to 8192 points prior to the periodogram estimation. Zero-padding is useful – even essential – when the record length is short (16.96 years here), and the frequencies of interest are low. The periodograms reveal multiple inter-annual frequencies in the three records (**Fig. 3**). Common among them are 1/(4 years); others may also reflect a common origin, e.g., 1/(3 years) and 1/(6 years) or 1/(7 years). The sea level spectrum has fewer higher frequency components, possibly indicating a filter response to forcing from temperature and/or the SOI. Multivariate methods must be applied to determine whether there are statistical relationships among the three records, as follows.

3.4 Coherency and cross phase spectra

To examine the correlation among the three records presented above, eight-frame, un-tapered coherency and cross-phase spectra are calculated (**Figs. 4-6**). For f=[0,1 cycles/year], coherency is elevated in all three analyses, indicating correlated inter-annual power.

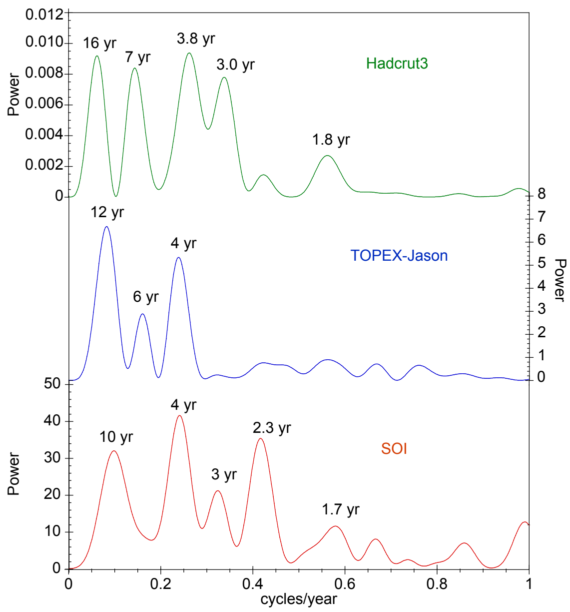

Fig. 3. Single-frame periodograms of the three records in **Figure 1**, for the time interval 1992.96-2009.92, and zero-padded to a 8192 point length (see text). Top: the Hadcrut3 global temperature record. Center: the TOPEX-Jason satellite altimeter measurements of global sea level. Bottom: the SOI index.

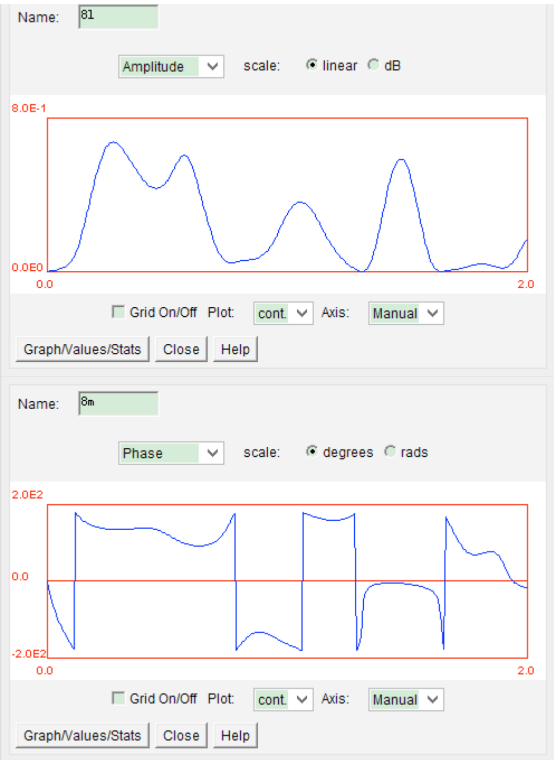

Fig. 4. Eight-frame coherency (top) and cross-phase (bottom) spectra for global temperature v. SOI for 1992.96-2009.92. The means and linear trends of the inputs have been estimated and removed. For f=[0,1/year] cross-phase decreases slightly from 180º, i.e., SOI leads global temperature.

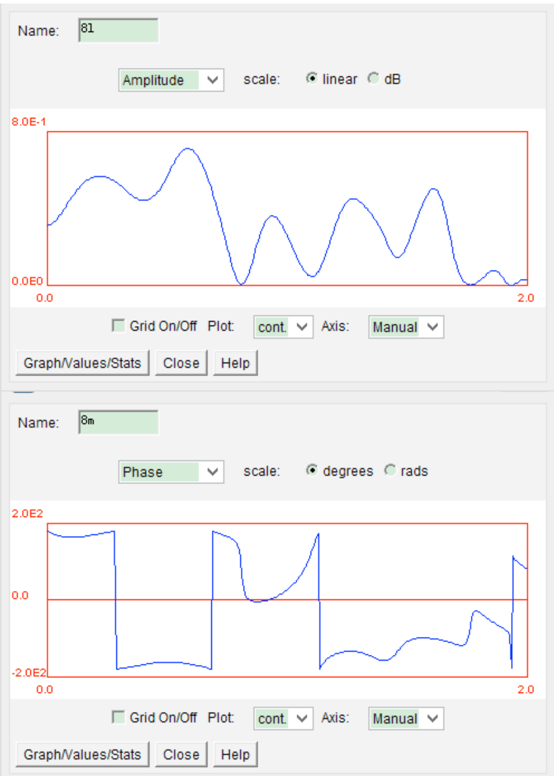

Fig. 5. Eight-frame coherency (top) and cross-phase (bottom) spectra for sea level v. SOI for 1992.96-2009.92. The means and linear trends of the inputs have been estimated and removed. For f=[0,1/year] cross-phase is 180º, i.e., SOI and sea level are out of phase.

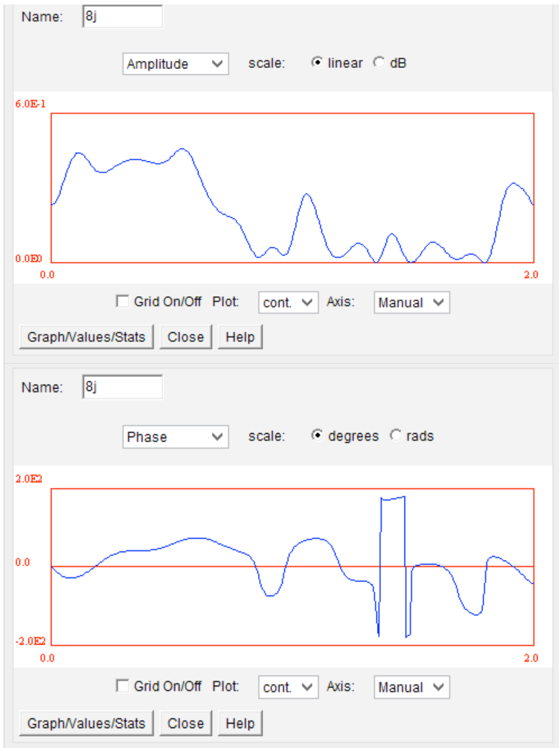

Fig. 6. Eight-frame coherency (top) and cross-phase (bottom) spectra for temperature v. sea level for 1992.96-2009.92. The means and linear trends of the inputs have been estimated and removed. For f=[0,1/year] cross-phase is positive, i.e., sea level leads global temperature.

The cross-phase spectra indicate that SOI and global temperature are out of phase, with the slightly decreasing phase indicating SOI leading temperature. SOI and global sea level are anti-phase-locked, and global sea level leads temperature. Additional measurements are required to determine the statistical significance of the coherency and cross phase. For example, is the measured global sea level lead over global temperature a significant result, or are the measurement uncertainties too large to rule out a zero-phase relationship? If it is determined that the lead is significant, then the more complicated question of why can be examined with confidence.

III. Tutorial Objectives and Assessment

The objectives of this tutorial are as follows:

1. Introduce concepts of time series, frequency, spectrum, and correlation.
2. Introduce common preprocessing steps and their benefits.
3. Perform periodogram analysis and identify significant frequencies.
4. Perform coherency and cross-phase analysis between two signals.
5. Analyze the relationship between El Niño, global temperature and sea level.

The overall objective is to increase student awareness of the response of the oceanic response to global warming, through hands-on manipulation of state-of-the-art global change data. The analyzed data reveal a dynamic and interactive Earth surface system that is rapidly evolving, and that poses profound

TABLE I. ASU WORKSHOP – CONCEPTUAL ASSESSMENT QUESTIONS WITH THE CORRECT ANSWERS

No.	Question	Type	Answer
1.	Consumption of energy by humans from a million years has increased:	Multiple-choice	100 fold
2.	The primary energy source in the USA is :	Multiple-choice	Fossil fuels
3.	The average human sitting burns:	Multiple-choice	100 watts
4.	Interannual variations of atmospheric carbon dioxide are characterized by:	Multiple-choice	Periodicities in the 3-5 year range
5.	Long term trend in the global temperature is:	Multiple-choice	Increasing but slowing in the past decade
6.	Global temperature variations have the following relationship with carbon dioxide variations	Multiple-choice	Carbon dioxide lags temperature
7.	Global sea level variations have the following relationship with global temperature variations	Multiple-choice	Sea level lags temperature
8.	At a frequency of 1 cycle/year, if the cross phase is 90 degrees, what is the lag between the two signals (Global temperature and carbon dioxide)?	Multiple-choice	3 months
9.	Over the past 30 years, what change has happened in the phase relationship between the global temperature and carbon dioxide variations?	Multiple-choice	The lag period has increased
10.	The phase relationship between the sea level and global temperature variations point to the possible following cause(s):	Multiple-choice	De-glaciation

TABLE II. ASU WORKSHOP – SUBJECTIVE ASSESSMENT QUESTIONS

No.	Question
1.	I understand the concept the use of coherency and cross-phase more clearly after performing the exercises.
2.	The user interface of J-DSP/ESE is intuitive and easy to use.
3.	I will be able to perform analysis of similar Earth systems datasets comfortably using the J-DSP/ESE version.
4.	How much time did you need to become comfortable in using the J-DSP/ESE version?

challenges to global sustainability and habitability.

We administered this tutorial at a workshop at Arizona State University in January 2012 to an audience of 14 electrical engineering graduate students with a background in signal processing, but not in Earth science. Prior to the tutorial, the students were introduced to key concepts behind 20^{th} century climate change. A pre-quiz conceptual assessment with seven questions was administered before the start of the workshop. At the end of the workshop, the participants answered a post-quiz conceptual questionnaire that consisted of the same seven pre-quiz questions plus three questions, and a subjective assessment questionnaire. The ten questions along with their correct answers are given in **Table I**. The questions in the subjective questionnaire are given in **Table II**. For each of the first three questions in the assessment questionnaire, the participants were asked to choose from the following responds: (a) Strongly agree, (b) Agree, (c) Neutral, (d) Disagree, and (e) Strongly disagree. For question 4, the possible four responds were (a) Less than 5 minutes, (b) Less than 10 minutes, (c) Less than 30 minutes and (d) More than 30 minutes.

The correction rates to the assessments and first three questions in the subjective questionnaire are summarized in **Figure 7**. The average performance in the assessments improved from 40% to 69%, as evaluated from the pre- and post-quiz results, which points to a successful use of the tutorials and J-DSP/ESE in interdisciplinary education. Furthermore, from the subjective assessment results, 85% of the participants agreed that *J-DSP/ESE* was easy to use and they were comfortable in understanding the concepts. Over 85% of the participants answered that they became comfortable using *J-DSP/ESE* in less than 10 minutes. From these assessment results, this tutorial along with the software, provided valuable information about global change to the non-specialist audience.

IV. CONCLUSIONS

This tutorial explores the relationship between critical global change signals related to global warming and sea level change. Students were asked to evaluate the frequency content of three records, global temperature, global sea level, and Southern Oscillation (SOI), and to assess correlations between the records. The strongest correlation was between global temperature and sea level change, that included frequencies associated with SOI variations. Sea level was shown to lead temperature variations. These results demonstrate couplings between major Earth surface processes that directly impact global sustainability and habitability of the Earth's coastal zones.

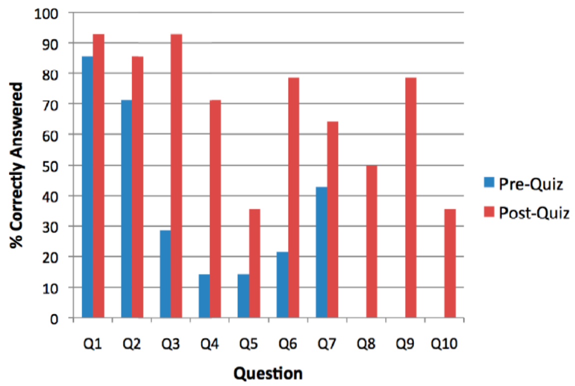

Fig. 7. Summary of the results in the technical assessment and first three questions of the subjective assessment.

This tutorial introduces students to basic concepts in global change and time series analysis. The new standalone application J-DSP/ESE was used to carry out sophisticated but simple exercises to elucidate the strong link between global temperature and sea level change. The plan is to build on this approach with alternative data, and to develop ways to statistically assess the measured dynamical interactions.

ACKNOWLEDGMENTS

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A Computer Science Course in Cyber Security and Forensics for a Multidisciplinary Audience

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Abstract— **The preparation of a graduate level cyber security and forensics course in a computer science department that addresses theory, policy, and application for a multidisciplinary student audience can be daunting when the majority of students in the class do not have a computer science background. The course takes a holistic approach to broaden knowledge and deepen understanding of the domain of cyber security using cross disciplinary teams to gain understanding and experience taking theory to practice and practice to theory. A framework of understanding is built through the examination of the body of scholarly conceptual and technical works and hands on experience with hardware and software platforms and networks. Computer Science provides the theoretical underpinnings and technical details, methods, and tools to examine security concepts; Forensic Science provides the approach to critical analysis of digital evidence; and Behavioral Analysis provided a way to synthesize knowledge and scientific method to gain some understanding of criminal behavior as well as the breadth and economic impact of cybercrime. This approach resulted in students who gained technical proficiency and perspective and experience working with people with divergent backgrounds, abilities and knowledge sets.**

Keywords—cyber security, forensics, multidisciplinary learning, security education, information security training

I. INTRODUCTION

In the era of information, security is a common topic of discussion in public and private, large and small organizations. While information security is not a new field, the increasing number of security breaches and threats to personal, organizational, and national safety have created a focus on cyber security. This has created an increased demand for qualified security professionals in both the private and the public sector. Emerging fields of study and practice in cyber security computer forensics, network security, software security, and critical infrastructure protection are increasingly important areas of interest [1].

The U.S. government has recognized that "securing cyberspace is an extraordinarily difficult challenge that requires a coordinated and focused effort from our entire society – the federal government, state and local governments, the private sector and the American people" [2]. In addition to the National Initiative for Cybersecurity (NICE) at NIST, the U.S. Intelligence Community established the Intelligence Community Center of Excellence in National Security Studies Program (IC CAE) in 2005 to strategically meet the nation's demand for a competitive, knowledgeable and ethnically diverse pipeline of professionals to meet the United States' National Security Imperatives in the 21st Century. In 2007, The University of Texas – Pan American, a Hispanic Serving Institution, established an Intelligence Community Center of Academic Excellence (IC CAE) with funding from the Office of the Director of National Intelligence (ODNI). The purpose of the Center is to prepare students for careers in intelligence and security through advanced interdisciplinary studies using an approach that assures that the next generation of Intelligence Community professionals is prepared with the appropriate skills and breadth of knowledge to be leaders in the national security challenges in the global economy of the 21st century.

Recognizing the breadth of knowledge required to lead security initiatives and recognizing that solutions to the current challenges in security demand the integration of human and technical resources, the UTPA IC CAE uses a multi-disciplinary approach to achieve substantial synergies in combining knowledge from different disciplines to IC challenges in information assurance and analysis, risk assessment, management, leadership, and technology. Housed in the College of Social and Behavioral Sciences, the IC CAE leads the discourse on national security across the campus and identifies specific needs associated with bridging seemingly disparate disciplines.

The UPTA IC CAE created and manages an interdisciplinary Global Securities Studies and Leadership Program (GSSL) that involves significant outreach activities to expand the potential workforce pipeline and educate the general community about national security. Like the other MSI based Centers of Excellence, the UTPA GSSL program includes significant outreach efforts to attract individuals to the pipeline for security professionals. However, unlike many of the centers, the GSSL program introduced new courses,

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new degree programs and a certificate program in Global Security Studies and Analysis to the UTPA curriculum. The GSSL programs also differ from programs offered by NSA Centers of Academic Excellence in Cyber Operations that tend to be deeply technical in a substantial number of topics. As of 2008, the GSSL program coordinates an undergraduate minor, a graduate certificate and a Master's degree in Interdisciplinary Studies (MAIS). With the exception of the new courses, the program design consists almost entirely of existing UTPA courses, taught by current faculty in established departments. Its near-universal reach across the university curriculum is ambitious because it articulates skill and knowledge sets that reside in many of UTPA's departments.

This paper discusses the challenges of delivering a Computer Science course in Cyber Security and Forensics as a part of the technical competency course sequence for the GSSL MAIS. The original course is designed as a masters level course in computer science that addresses theory, policy, and application. This course is modified to provide a computer science perspective on theory, policy and application to simultaneously meet the needs of a diverse multidisciplinary audience in three graduate programs: Computer Science, Information Technology, and Global Security Studies.

II. THE GLOBAL SECURITY STUDIES PROGRAM

A. Overview of Master's of Interdisciplinary Studies(MAIS)

The MAIS degree prepares students for careers in Intelligence and National Security through focus on advanced research, effective cross-discipline team communication, and critical analysis. Given that jobs in government or private industry often require multidisciplinary cooperation, the GSSL MAIS prepares students to work with people from different backgrounds, abilities, and knowledge bases. This approach assures that students have the opportunity to gain the perspective of and proficiency in multiple disciplines, preparing them for careers in national security.

The Intelligence Community has defined and organized 5 'Primary Critical Skill Sets/Competencies' based on categories of security employment that people will specialize in: 1) Information Technology Specialists, 2) Political/Economic Specialists, 3) Language Specialists, 4) Threat Specialists, and 5) Scientific/Technical Specialists [3]. The GSSL programs engage students and faculty in each of these five Primary Critical Skill Sets. In addition to the primary skill sets, a number of IC defined 'Specific General Competencies for Intelligence Professionals' areas are addressed in the program including analysis, analytical reasoning, critical thinking, communications (oral and written), research, developing rational conclusions and deriving alternative solutions from ambiguity and limited data sets[3].

B. MAIS Curriculum

The GSSL MAIS consists of 36 semester hours of study, including a 12 hour core sequence, a 15 hour concentration in interdisciplinary studies and a 9 hour technical competency sequence.

Through the core sequence the students learn how skill sets relate to the global context of intelligence and security work. The core courses address the competency skill areas including advanced research, problem solving, critical thinking, technical writing, and leadership. The core courses consist of Global Security, Open Source Research, Interdisciplinary Research and Analysis, and a practicum in Global Studies Security Studies. The interdisciplinary course sequence addresses critical competencies required to understand the globalization of communication, societies, cultures, governments, businesses, and technology. The required courses include Culture and Communication, International Management, Cross Cultural Psychology, Statistics and a graduate level elective.

The technology competency sequence provides students with the essentials of information technology and computer systems with a focus in information security. The course sequence consists of Information Security, Principles of Information Technology Systems, and Cyber Security and Forensics [3, 4]. The first course in the technology series is offered by the faculty in the Department of Computer Information Systems located in the College of Business. The second two courses are taught by faculty in the Department of Computer Science in the College of Engineering and Computer Science. All three of these courses existed in their respective departments with intended audiences other than the participants in the GSSL program prior to their identification as the technical competency sequence.

III. CYBER SECURITY AND FORENSICS COURSE

Using a variety of learning resources, the Cyber Security and Forensics course addresses a broad set of topics in cyber security and cyber forensics. The goal is to assure that students gain an understanding of the breadth and depth of what cyber security and cyber forensics mean in abstract terms and in the context of real systems. Through reading, lecture, discussion, and thought experiments [5] students learn about the underlying formalisms and technologies that address challenges and potential threats to confidentiality, integrity, and availability. Students learn aspects of cybercrime and ways in which to uncover, protect, exploit, and document digital evidence. Students are exposed to different types of tools, techniques, and procedures, as well as policy and legal issues.

The use of a hands-on-laboratory component reinforces formalisms and technologies introduced in lecture and discussion. Augmenting lecture and discussion based thought experiments, the labs support understanding through direct experience in applying knowledge in new situations [6,7,8]. Students develop skills in the reduction of theory to practice and abstraction of practice to theory.

A Blackboard instance of the course is used to manage learning resources, support communication, and the sharing of knowledge and perspectives on the discipline. Rather than assigning a textbook, the course uses a set of scholarly and technical works from academic, industrial, and government sources. Students have access to a variety of open source tools, commercial hardware and software products and a laboratory in which they are free to experiment.

A. Learning Objectives

Upon completion of the course, students are expected to (1) understand the basic theory and concepts of cyber security and privacy including policies, models, and mechanisms; (2) understand ethics, legal issues, and human factors associated with cyber security and forensics; (3) understand security vulnerabilities and be able to describe threats and risks; (4) be able to explain best practices in giving access to systems and networks and implement proper authentication techniques; (5) be familiar with cryptographic techniques, asymmetric key algorithms, and create certificates; (6) describe the requirements for a cyber forensic investigation and demonstrate an understanding of tools, techniques and procedures; and (7) be conversant in current security related issues in the fields of cyber security and cyber forensics.

B. Course Topics

The course begins with an overview of the security problem followed by an introduction of fundamental tools and techniques for addressing security. After providing a broad introduction to security, the course focus shifts to forensics.

Course topics include:

- Confidentiality, integrity and access policies (policy and metapolicy)
- Information flow and content (encoding and entropy)
- Cryptography and ciphers
- Network security
- Malicious logic, vulnerability analysis
- Strategic planning for security
- Law and legal issues
- Volatile and persistent data
- First responder activities
- Hacking: ethical and not

The discussion on strategic planning for security includes a presentation of requirements to create a security organization. This discussion, intentionally placed two thirds of the way through the semester, presents a scaffolding that provides a real-world context and supports the creation of connections between security topics. This discussion illustrates the real world application of all that has been covered to date and creates an opportunity to shift the course focus from security to forensics.

C. Laboratory Component

The laboratory component of the course gives students practical experience with the concepts introduced in lecture and discussion. Each lab is designed so that students gain experience working with real world tools and real world problems. A broad array of commercial hardware and software, and open source tools are provided to develop solutions for problem based challenges involving confidentiality, integrity, access, and trust. Students identify and disable network attacks. They find hidden information, and they conduct forensic investigations using a systematic approach to evidence identification, preservation, analysis, documentation, and presentation following acceptable legal procedures and laws of evidence[6].

Lab exercises are completed by interdisciplinary teams to encourage transfer of understanding and perspective across the spectrum of divergent bodies of knowledge held by course students and to address varying levels of comfort and skill in using technology. Lab exercises are designed to be completed in real world settings on either personal computers or in the Computer Sciences Advanced Studies Lab. While connected to the campus network for internet access, the Advanced Studies Lab is reconfigurable as need be for this course and the networking courses that share the facilities.

Lab exercises assigned during the course include:

- Controlling access to files and folders with special access to network shared folders in Windows and Unix/Linux environments
- Mining cache, cookies, and history for traces of activity and hidden value
- Mining programs and files: Registry tracks
- Network security: Identifying and disabling network attacks with Security Onion, Squil, Sqert, and Snorby
- Securing networks with software and hardware firewalls
- Public faces – Social media and the flow of information
- Imaging and analyzing storage devices with EnCase
- Imaging and analyzing storage devices and capturing volatile data with open source tools
- Steganography

Two additional lab exercises are available for students that are interested in testing their programming abilities. The first exercise involves creating a covert channel to pass one bit of data. The second exercise involves implementing a robust queue. They are given Bishop and Elliott's 2011 paper on robust programming as a resource for this exercise [9].

D. AssessmentTechniques Used

Formative and summative evaluations are given to both make adjustments to content delivery and to assess student learning. Students are given weekly assignments that include a set of readings and at minimum one deliverable. Deliverables vary by week, but in general consist of one or more of the following: 1) short responses to issue specific questions used to measure understanding of the lecture and reading assignments, 2) lab results along with self-assessment of success, and suggestions on improving the lab, 3) short essays on how a reading relates to past, current, or future experiences in global information security, 4) contribution to a course glossary by adding terms and definitions to build a broad and common lexicon for security, 5) identification of a resource and explanation of its value, 6) a reaction paper on a particular assigned reading. Every class begins with a background knowledge probe to assess student familiarity with terms and concepts. Thought exercises introduced during lectures provide a means to gather input on how well students comprehend the content of discussion and lecture. These experiments require higher order thinking: analysis, synthesis, and evaluation, providing the instructor with information about students learning and a self-assessment tool for students. All laboratory exercises include a request for feedback on the activity and most include a required opinion either on the tools, process, or the lab's value add to the learning experience. A relatively casual atmosphere in lab leads to conversation and additional opportunities to gather feedback about content delivery and student learning.

Two larger learning exercises serve as exams. The first exercise serves as a midterm. Students are given three questions: two questions that require students to research specific security models not previously presented in lecture and discuss their application. A third question serves as a thought exercise requiring critical thinking and synthesis. The second large exercise serves as a final. Students choose one of two challenges. In the first challenge students must build a forensic tool kit from existing open source resources and write a comprehensive user's guide on when, why and how to use each tool in acquisition, analysis and presentation during a forensic investigation. In challenge two, students read Cliff Stoll's book "The Cuckoo's Egg" and write a 7 to 10 page response to one of three prompts. Each of the prompts requires analysis, synthesis, critical and creative thinking.

IV. Discussion

Computers, the Internet, e-mail, wireless technology toys, and social networks are pervasive and a ubiquitous part of everyday life. The growth in digital details that are created, captured, and stored in more places than most people realize is exponential as is the growth rate of crimes in which cyber technology is the instrument of, the target of, or by its nature, the location where evidence is stored or recorded. The number of security breaches and threats to personal, organizational, and national safety and the increasing costs of security breaches have create a focus on cyber security[10,11,12] and a demand for qualified security professionals in both the private and the public sector[2,3]. Academic institutions respond by offering new undergraduate and graduate courses in cyber security [13] and forensics [6].

A. Background

The course that was chosen for the GSSL MAIS technology sequence to address cybersecurity was originally designed for graduate students in a computer science master's program. Students were expected to be familiar with networks, operating systems, data structures, programming languages, software application programming and hardware. The course takes a breadth first approach to introducing the fundamentals of computer security and forensics. Balancing lecture content with hands-on laboratory exercises, students have the opportunity to experience theoretical concepts and their implementation. Reflective learning exercises are designed to empower students to link prior knowledge with new knowledge and develop a deep understanding of the complexity of cyber security and forensics theory and practice.

B. Challenges

It is a challenging task to offer this graduate level Computer Science Security and Forensics course to graduate students in programs outside of computer science. Traditionally at UTPA, the course is an elective in the Master's of Computer Science and the Master's of Science in Information Technology (MSIT) programs. The course is taken after students have completed an advanced networking course.

However, with the inclusion of this course in the GSSL MAIS, the demographic profile of students taking the course changes radically. Less than 3% of the students have undergraduate degrees in computer science and are pursuing a Master's degree in Computer Science. The remaining 97% of the students' program affiliations are split between the MSIT and the MAIS. Of this group, only 8% have formal undergraduate training in information technology.

The new demographic includes students who have undergraduate degrees in accounting, computer science, criminal justice, early childhood education, economics, graphic design, information technology, political science, psychology, and sociology. The majority of MAIS students move directly from their undergraduate education to the graduate program. The majority of MSIT students are currently working as professionals in information technology and have extensive experience in either networking or management information technology systems. On occasion the class includes a Chief Security Officer from a banking institution or local government agency.

A prerequisite course, Principles of Information Technology Systems, provides leveling preparation for the concepts introduced in the class. However, 40% of the class has either not taken the leveling course or are completing it concurrently.

Recognizing that the essential body of knowledge for the domains of security and forensics are broadly distributed and include deep subdomains, the first challenge is to modify the course. A set of topics are defined using the IC CAE documents, the five Primary Critical Skill Sets [3], and the UTPA GSSL program goals and curriculum. An approach to the topics is developed that recognizes that security issues do not rest solely in the domains of Computer Science and Information Technology[14].

Competency in mathematics presents a second challenge. Given the nontechnical nature of most students' backgrounds, competency in mathematics clusters at the level of college algebra. This means that when using theoretical constructs to introduce security concepts such as confidentiality, integrity, and information theory, additional techniques must be implemented to facilitate the learning or building up of the formal concepts. Metaphors provide excellent support in understanding concept proofs. For example, a love triangle is useful in explaining a trusted relationship. A coin is used to demonstrate encoding. Translating the concepts into examples from everyday life allows students to transfer existing knowledge.

The diversity in students' program of study demands the establishment of a common vocabulary in security and forensics to support effective communication and to facilitate sharing of perspectives and knowledge across the disciplines. To address this third challenge, students use a forum to provide profiles, including their backgrounds and expertise. They create a wiki, submitting terms and definitions, to build a common lexicon. A second wiki serves as a repository for students contributed resource materials. These wikis create a framework for growing the Essential Body of Knowledge (EBT) [15] and support peer to peer learning where knowledge is transferred and created in a learning community. The diversity of academic training, perspectives and experience means that students are exposed to the breadth of knowledge that professionals should know to be conversant in the field. Students, at minimum, know the key concepts and terms to perform their work functions in security and they gain, at least, a basic familiarity with all of the key terms and concepts in the EBT [15].

Thought exercises are used throughout the lectures to provide an opportunity for students to think independently, discuss their thoughts in pairs, and share their ideas with the class. This think-pair-share approach also serves as the basis for work outside of class. Students reflect on concepts and present their thoughts on forums or in the form of short essays. These reflections serve as the basis for conversation and the opportunity to elaborate on ideas. This approach increases personal communication that is necessary to process, organize and retain ideas[16]. The approach takes advantage of the students' diverse knowledge base to expand individual perspectives on security and forensics topics.

There is also a great diversity among the students' skill levels in the use and the understanding of computing environments. Labs, originally designed to expose students to the concepts introduced in lecture and discussion are found to be too complex. The labs are modified so that students with minimal background in computing are able to complete the exercises and gain conceptual insight. In addition, early in the semester students are intentionally directed into interdisciplinary teams. Each team has at least one individual with a strong background in information technology or networking. The multi-disciplinary nature of the lab teams is leveraged to assure exposure to alternative viewpoints and process design. Due to the lack of programming skills among students in the course, two additional labs are available for deeper investigation by those individuals that are interested: (1) programming a covert channel and (2) programming a non-robust queue [9].

Among other challenges include faculty competency across the breadth of the course topics. Fortunately, there is strong interest and investment in information security at the institutional level. Taking advantage of the human capital resources in Privacy and Security and in the UTPA Division of Information Technology, subdomain experts in network security and forensic investigation provide lectures and lab instruction and guidance. The University's Chief Security Officer, along with recognized security experts from the health industry and intelligence community, discuss strategic planning for security.

C. Observations and Course Outcomes

As a collective, the mix of learning activities complements the course learning objectives. Aside from the lectures, classroom and lab based activities are modified to reinforce collaborative learning. The intent in building a common lexicon and resource base is to allow students to discover the breadth and depth of issues related to cyber security and forensics. They have the opportunity to both review and build on each other's work. It is evident in the questions and comments in the forums and the contributions to the wikis that students are expanding their knowledge base. Periodically in lecture, thought exercises are used to gain a feeling for student understanding. These typically involve a specific problem to solve that requires the application of a new concept. Using the think-pair-share approach allows the students in the different programs another opportunity to learn how individuals with different backgrounds might approach the same problem. Essays on readings often contain not only reflections on course content, but also reflections on classroom think-pair-share and lab discussions. In addition, student essays on content and its projection on their lives often include commentary on how their views or knowledge have changed.

Labs that proved too difficult to complete without a prerequisite computer science background are reworked such that they are too difficult for one person to complete working alone, but are easily completed when individuals work in teams. The casual lab environment and multidisciplinary teams expose students to different approaches to solve problems and they are encouraged to investigate, compare and evaluate multiple approaches. On many occasions student teams define competitions for themselves to develop the most efficient or effective solutions or processes. Students often stay well past the end of the lab to do self-initiated benchmarking or complete peer reviews.

There are a number of times throughout the semester that discussions lead to one or more members of the class taking responsibility for peer teaching. For example, a student who served as a data analyst in a combat zone shared his direct experiences with encryption and ciphers. On another occasion, one GSSL student who serves as the Chief Security Officer for a bank explained security policies and processes for internet transactions, a second student in the MSIT program explained a possible underlying implementation, and a third student from Computer Science provided an alternative approach. And on yet another occasion a GSSL and a MSIT student worked outside of class to implement and subsequently demonstrate to the class a virus that would bypass the firewalls set up during a lab exercise.

The students in the MAIS program tend to be very high verbal, while the students in the MSIT and MSCS programs tend to be computationally stronger. It is apparent from essays, presentations and final challenge submissions that the writing and course discussions throughout the semester help to improve students' verbal and written communication skills as well as their awareness. While this is evidenced as the course progresses, this improvement is most apparent in the choices made for the final learning challenge. Even though the class is fairly evenly split between GSSL and technology based graduate students and the MSIT and MSCS students are focused on the forensics toolkit project, in the end, the majority of the students choose to complete the challenge in which they read a book and respond to a prompt. In all of the responses, students thoroughly address the technological issues discussed in the book as well as provide critical analysis of the strengths and failings of the human systems.

Finally, based on the responses collected from the university's standard Student Evaluation of Teaching Form, students appreciate the opportunity not only to take on responsibility for their own learning, but are more fully engaged when presented with the challenge. The opportunity for collaborative learning empowers students to learn. The exposure to multiple perspectives on the same concepts through active and meaningful interaction is received well. They indicate an appreciation of the exposure to a wide range of experts from the field and the juxtaposition of policy and implementation in theory and practice. Students indicate that they feel the information learned in the class is important, the mix of activities are beneficial to learning and the overall quality of the course is very good to excellent.

V. Conclusion

This paper describes a Computer Science course in Cyber Security and Cyber Forensics offered at UTPA. The challenges of offering this course to a multidisciplinary audience lead to changes that leverage the diverse student knowledge base. During the course students learn, practice and gain understanding of concepts and develop the technical and leadership skills required of cyber security professionals. Hands-on lab exercises facilitate understanding of difficult concepts and procedures. Using both commercial and open source tools provides a rich environment. Using interdisciplinary teams facilitates the exchange of knowledge and understanding. Students see how complex the issues in cyber security and forensics are. Students gain an appreciation for true multidisciplinary nature of the field.

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